

REVIEW ARTICLE

The systemic nature of mustard lung: Comparison with COPD patients

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ABSTRACT

Sulphur mustard (SM) is a powerful blister-causing alkylating chemical warfare agent used by Iraqi forces against Iran. One of the known complications of mustard gas inhalation is mustard lung which is discussed as a phenotype of chronic obstructive pulmonary disease (COPD). In this complication, there are clinical symptoms close to COPD with common etiologies, such as in smokers. Based on information gradually obtained by conducting the studies on mustard lung patients, systemic symptoms along with pulmonary disorders have attracted the attention of researchers. Changes in serum levels of inflammatory markers, such as C-reactive protein (CRP), tumor necrosis factor alpha (TNF- α), nuclear factor κ B (NF- κ B), matrix metalloproteinases (MMPs), interleukin (IL), chemokines, selectins, immunoglobulins, and signs of imbalance in oxidant-antioxidant system at serum level, present the systemic changes in these patients. In addition to these, reports of extra-pulmonary complications, such as osteoporosis and cardiovascular disease are also presented. In this study, the chance of developing the systemic nature of this lung disease have been followed on using the comparative study of changes in the mentioned markers in mustard lung and COPD patients at stable phases and the mechanisms of pathogenesis and phenomena, such as airway remodeling in these patients.

KEY WORDS: sulphur mustard; mustard lung; COPD; systemic inflammations; chronic respiratory disease

Introduction

The sulphur mustard (SM) or mustard gas is a strong alkylating and vesicant chemical warfare agent that has been deployed by Iraqi troops against Iran (Evison *et al.*, 2002; Paromov *et al.*, 2007; Moin *et al.*, 2009). The former toxicity with this vesicant agent has caused serious disability in more than 34 000 Iranian veterans whose various organs have been affected by this agent (Khateri *et al.*, 2003). The toxicity with SM is followed by short-term and long-term side effects in different tissues (Heidari *et al.*, 2016; Rahmani *et al.*, 2016; Sheikhi & Rahmani, 2016). The humid tissues, such as eye and respiratory system, can be further affected by SM (Ghasemi *et al.*, 2008; Pourfarzam *et al.*, 2009a) and several side effects are involved. Previous studies showed that the respiratory deficiencies are the most prevalent long-term disorders among persons poisoned with SM (Khateri *et al.*, 2003; Pourfarzam *et al.*, 2009a). The victims are complaining

from several respiratory symptoms, including coughing, sputum, bloody sputum, and chest pain (Weinberger *et al.*, 2011). The prevalent disorders in the lower part of the respiratory system in SM-exposed patients are as follows: airway obstructive disease, bronchiectasis, and pulmonary fibrosis (Balali-Mood *et al.*, 2011). In humans, inhaling SM causes acute and chronic pulmonary impairment (Emad & Rezaian, 1999; Hefazi *et al.*, 2005; Ghanei *et al.*, 2008; Ekstrand-Hammarstrom *et al.*, 2011). Mustard lung (ML) is a unique form of chronic obstructive pulmonary disease (COPD) that has been proposed as one of the foremost long-term expressions for SM and it is implied that systemic inflammation may involve the pathogenesis of this form of COPD (Lari *et al.*, 2012). Cellular and molecular structural changes in the airway wall under the concept of airway remodeling are one of the major pathological consequences in ML-patients and the clinical picture is similar to what is seen in COPD patients. The remodeling process in ML patients with three signs of bronchial epithelial damage, subepithelial fibrosis, and angiogenesis and thus aberrant repair in airways in response to the damage and inflammation is reported (Figure 1). In chronic conditions, the inflammatory cells are infiltrated and along with epithelial damaged cells of the airways leading to the secretion of different

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inflammatory mediators, including inflammatory, fibrogenic, and angiogenic factors and after remodeling of the induction, they present severe inflammatory conditions (Firoozabadi *et al.*, 2017). It has been mentioned in review studies that inflammatory responses and structural changes in the airways may be due to epigenetic changes caused by SM, so that the epigenetic codes to express the pro-inflammatory proteins in the immune and epithelial cells are changed. These changes may include increasing or decreasing methylation of CpG islands, histone

modifications, long noncoding RNA expression, and chromosome remodeling (Ghasemi *et al.*, 2008; Imani *et al.*, 2015).

Both cellular and hormonal disorders have been reported following poisoning with mustard gas (Krumbhaar & Krumbhaar, 1919; Dayhimi *et al.*, 1988; Zandieh *et al.*, 1990; Ghotbi & Hassan, 2002). There is also the possibility for the presence of systemic effects caused by mustard gas in ML-patients. Studies of these patients have shown that immunity and inflammatory

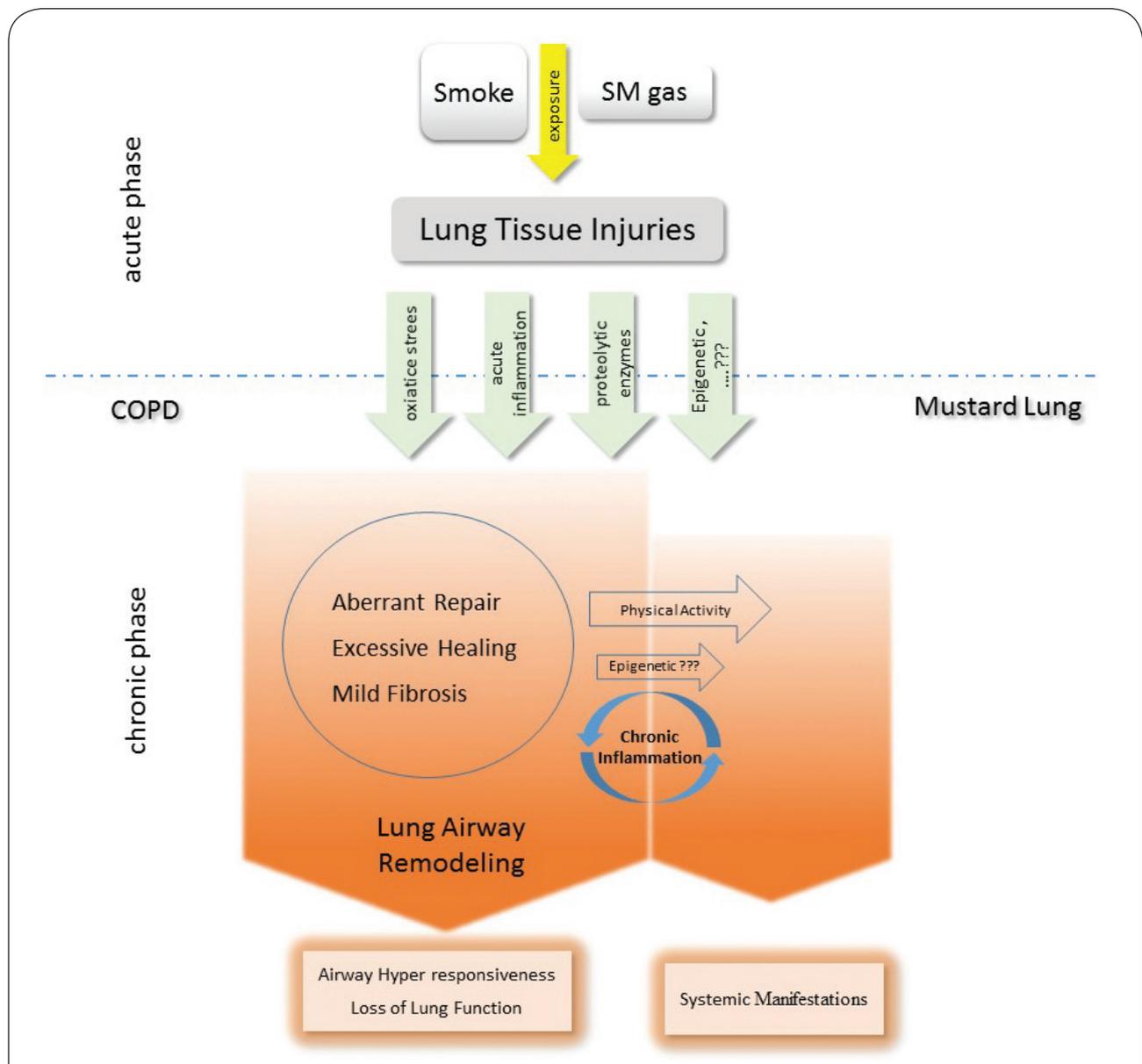


Figure 1. Old SM inhalation in ML patients as exposure to smoking in COPD patients regardless the length of exposure time is followed by acute lung epithelial tissue damage and activates pathogenesis pathways of patients. The prevalence of oxidant, proteolytic, and inflammatory conditions deteriorates the airway and gradually chronic phase conditions develop over the years. However, SM potential in creating epigenetic changes or its other unknown mechanisms can exacerbate this trend. In the course of time, aberrant repair of the airway and the lack of proper repair of epithelial cover, the creation of fibrosis and vascularity with varying degrees form the remodeling phenomenon in the airway of these patients and could also lead to the excessive airway response and the loss of lung function. By making this change, the formed airways and complications are converted into severe chronic inflammation and along with the reduced physical activity in these patients, the area presents systemic responses and extra-pulmonary complications develop.

reactions might have been involved in the morbidity of longterm effects caused by mustard gas at systemic level (Imani *et al.*, 2015). The inflammatory mechanisms form the major part of the pathogenesis of topical processes in pulmonary disorders due to SM (Mahmoudi *et al.*, 2005; Ghanei & Harandi, 2007). At the same time, studies of these patients showed systemic pathogenetic processes, such as rising function of hemocytes (neutrophils, etc.) (Shahriary *et al.*, 2015) and variation at serum level of proinflammatory mediators, including interleukins (ILs), tumor necrosis factor (TNF), chemokines, C-reactive protein (CRP), fibrinogen, etc., as well as other important markers in systemic variations distorting oxidant and antioxidant balance, with this finding visible also in ML-patients (Naghii, 2002). Similarly, emerging extra pulmonary complications (e.g. osteoporosis and cardiovascular diseases), implied in similar chronic pulmonary diseases, such as COPD as systemic effects of disease may be assumed as a further reason for the presence of important systemic variations in ML-patients (Bayat & Aslani, 2010; Karbasi-Afshar *et al.*, 2013). This evidence (Figure 1) draws the attention of researchers to the systemic nature of disease and with respect to similar manifestations in these patients to the pathology of COPD (Ekstrand-Hammarstrom *et al.*, 2011). The multitude of reports about the subject of systemic inflammation and other systemic variations in COPD-patients (Schunemann *et al.*, 2000; Biskobing, 2002; Schols, 2002), are motivating evidence to follow the theory of the presence of systemic manifestation in ML-patients (Shahriary *et al.*, 2017; Shahriary & Rahmani, 2017).

According to the definition proposed by the European Respiration Society (ERS), COPD is a disease that is characterized by restriction of airflow and narrowing of airways and it is an irreversible process (Geddes *et al.*, 2005). Based on the report of the World Health Organization (WHO), there are 80 million patients with (COPD) in the world (Voll-Aanerud *et al.*, 2008). The environmental and genetic factors involved in the morbidity of COPD include smoking and inhalation of the resulting smoke, air pollution, old age, occupational agents, and antitrypsin alpha-1 deficiency (Zakerimoghdam *et al.*, 2011). Patients with COPD suffer from much impairment of which one can refer to asthma, intolerance of physical activity, coughing, sputum, and depression (Mirbagher Ajorpaz & Rezaei, 2009). This disease is a complex inflammatory condition with parenchymal and airway impairment. Emphysema and airway inflammation and impairment, the impairment that leads to enlargement of alveolar airway, fibrosis of pathways, elastic irreversibility, and over-enlargement of smooth muscle, goblet cell hyperplasia and mucus plugging are some of the manifestations and side-effects in these patients (Littner, 2011). The widely conducted studies on COPD patients show noticeable cellular and hormonal variations as well as extreme variations in proinflammatory mediators (ILs, TNF, CRP, fibrinogen, etc.), the presence of wide extra pulmonary complications (cardiovascular and osteoporosis), and variations in oxidant- antioxidant system. Many researchers have not only

introduced it as a disease with pulmonary symptoms, but also as a pulmonary disease with extensive systemic manifestation (Agusti & Soriano, 2008; Barnes & Celli, 2009).

With view and exploration of various complications caused by mustard gas in ML-patients and on comparing them with what occurs systematically in COPD disease, we attempt to present noticeable documentation on the systemic nature of this disease. In this study, we review the systemic aspects in patients with stable ML, stable COPD, and pay attention to similarities in variation of systemic inflammatory factors for these two chronic pulmonary diseases.

Systemic inflammation and inflammatory factors in pulmonary patients

Many markers are positioned in systemic inflammation among stable COPD-patients and this refers to a remarkable relationship among variations of these markers and complication of the disease in review of various studies (Karadag *et al.*, 2008a). Most of the reports show that inflammatory cytokines play an important role in the pathogenesis of various pulmonary diseases (Vaillant *et al.*, 1996; Chung, 2005; Laskin *et al.*, 2007). Similarly, it has been observed that some of the cytokines may also play a role in primary pulmonary impairments after being exposed to mustard gas, where this important point has been reported *in vitro* and in animal-sample model (Tsuruta *et al.*, 1996; Sabourin *et al.*, 2002). The resulting pulmonary toxicity mechanism from SM is not transparent (Mishra *et al.*, 2012) and typically the precise role of cytokines has not been clearly defined in short-term and long-term effects of mustard gas (Yaraee *et al.*, 2013). Despite the fact that no accurate role of mediators has been properly identified in COPD patients, most of the documentation have shown that systemic inflammation may directly be related to some complications, such as cachexia, disordered function of skeletal muscles, depression, osteoporosis, etc. (Nussbaumer-Ochsner & Rabe, 2011). To examine systemic inflammation in patients with COPD, it is necessary to identify inflammatory factors. Some of these factors have been further noticed in the following, along with expression of variations which are introduced in patients with stable ML and stable COPD (Figure 1, Tables 1 and 2).

CRP

One of the important factors in systemic inflammation studied and assessed in stable COPD patients is CRP. CRP is a plasma protein sensitive to inflammation in humans (Kony *et al.*, 2004) that is included in the group of pentraxin molecules and its gene is located in chromosome No. I (Anderson, 2006). CRP has been used only as an inflammatory marker in infections and inflammatory diseases, but recently it has been identified to be followed with the risk of cardiac infarction, angina pectoris, and

coronary sudden death, and it even plays a role in systemic hypertension (Pinto-Plata *et al.*, 2006; Kraus *et al.*, 2007). One of the foremost characteristics of this protein is, unlike other reactants of the inflammatory phase, that CRP serum level remains high for a long time even in the absence of stimulants (Shrivastava *et al.*, 2015). Many studies have been carried out on CRP serum level in patients with COPD during recent years. They show the relationship between CRP serum level as a marker with functional potential of the patient and respiratory distress (Pinto-Plata *et al.*, 2006; Man *et al.*, 2008) as well as a predictor factor in clinical consequence and primary awareness of COPD (Wu *et al.*, 2005; Dahl *et al.*, 2007; Dahl & Nordestgaard, 2009), along with repeated exacerbation of clinical symptoms (Hurst *et al.*, 2006). Widely conducted studies on COPD patients have reported that CRP serum level is significantly higher in COPD patients and it is related to rale and whizzing sounds as well as to the severity of the disease (Higashimoto *et al.*, 2009). Many researchers including Karadag *et al.* (Karadag *et al.*, 2008b) have shown that the CRP serum level is increased not only in exacerbated patients but also in patients with stable COPD. The researcher has also analyzed this protein in ML-patients and the results have shown that the serum level of this inflammatory factor has been increased even in stable patients. Purfarzam declared that the CRP

serum level is noticeably high in ML-patients and it is significantly related to rale and whizzing sounds. In his investigation, he divided ML-patient into hospitalized and non-hospitalized groups and showed that the CRP level was high in stable patients rather than the hospitalized patients (Pourfarzam *et al.*, 2009b). Similarly, Attaran *et al.* (Attaran *et al.*, 2009) found a significant difference in high-sensitivity C-reactive protein (HS-CRP) serum level in ML-patients and implied that it is related to exacerbation of the disease in these patients and thus the level of this factor might act as a suitable primary awareness for disease exacerbation. Also in this study the CRP serum level was significantly higher in ML-stable patients than in healthy persons (Attaran *et al.*, 2009). In a new study done by Rahmani *et al.* (Rahmani *et al.*, 2017), CRP serum level was significantly higher in ML-stable patients than in healthy subjects.

There was only a non-compliant report with the aforementioned studies in a paper by Ghasemi *et al.* (Ghasemi *et al.*, 2009), since non-hospitalized ML-patients have also been compared separately from healthy controls, but the CRP level had no significant variation in their study. Certainly, sampling details for analysis of samples and sensitivity of kits in this study have not been identical with the above mentioned studies and the authors have not implied any reason to explain the lack of variation in

Table 1. Serum inflammatory markers in COPD patient.

Authors	Year	Marker	Design/population	Method	Outcome
Karadag	2008	CRP	Case: patients with stable COPD Control: age- and sex-matched subjects with normal pulmonary function	Case control	Serum CRP was significantly higher in stable COPD patients than in control
Moermans	2011	TNF-alpha	Case: COPD patients, encompassing the whole severity spectrum of the disease Control: matched subjects with normal pulmonary function	Case Control	TNF-alpha was increased significantly in patients with stable - COPD
Lee	2012	NFkb	Case: patients with stable COPD nonsmoker control smoker control;	Case control	Demonstrated that in patients with stable COPD there is increased activity of NFKB
Aldonyte	2004	MMP	The studied group consisted of 20 controls with PiMM AAT, 10 asymptomatic PiZZ AAT individuals and 20 patients with COPD: 10 PiZZ and 10 PiMM AAT cases.	Case control	Serum level of MMP-9 was increased in stable COPD patients
Montaño	2014	MMP	Case: 1- biomass exposure; 2- tobacco smoking Control: Healthy matched subject	Case control	Indicated rising serum level of MMP-9, MMP-7, and MMP-1 in these patients compared to healthy controls
Moraes	2014	IL	Case: patients with stable COPD Control: with normal lung function and no history of smoking	cross-sectional	Serum levels of IL-8 and IL-6 have been reported higher than in healthy controls
Yanbaeva	2009	IL	Case: COPD patients Control: healthy smokers	Case control	Raised plasma levels of IL-6 were demonstrated in COPD patients.
Hammad	2015	IL-1b	Case: COPD patients Control: healthy subject	Case-control	Serum level in IL-1b was also increased in stable- COPD patients
Pinto-Plata	2007	chemokines	Case: COPD patients Control: matched healthy subject	Case-control	Serum levels of chemokines in these patients are higher than in healthy controls
Spruit,	2003	CXCL8	Case: 1-Hospitalized COPD patients 2-Clinically stable COPD patients Control: Healthy elderly subjects	Case Control	Rather than in exacerbated patients, CXCL8 level was increased in stable patients
Schumacher	2005	PSGL-1	COPD patients Smoking volunteers Non-smoking volunteers	Case Control	Level of P-selectin glycoprotein ligand-1was higher in all COPD stable patients than in healthy controls

Table 2. Serum inflammatory markers in Mustard Lung Patient.

Study	Year	Marker	Design/population	Method	Outcome
Attaran <i>et al.</i>	2009	CRP	Case: Fifty consecutive SM patients with stable COPD Control: Thirty healthy men	Case control	CRP Increased with significant statistical differences
Ghasemi <i>et al.</i>	2009	CRP	Hospitalized Group: severity of problems at the exposure time, victims who had moderate to severe problems at exposure time and were hospitalized Not hospitalized Group: patients who had mild and sub-clinical problems at exposure time Control Group: included men who were matched with the study group by age	Case Control	There was no significant difference in CRP level
Pourfarzam <i>et al.</i>	2009	CRP	Hospitalized Group: based on severity of problems at the time of exposure. Not hospitalized Control : based on severity of problems at the time of exposure. Control Control: unexposed	Case control	CRP Increased with significant statistical differences
Shohrati <i>et al.</i>	2013	MMP	Case Group: patients exposed to sulfur mustard gas Control Group: healthy participants	Case control	Serum MMPs in chemically injured showed no significant difference from normal people except for the MMP-9.
Kiani <i>et al.</i>		MMP	Normal Group: SM exposed but without lung complications Mild Group: SM-exposed with mild lung complications Severe Group: exposed to SM with severe lung complications	Case control	They don't compare not hospitalized patient with healthy people but MMP-9 in Not Hospitalized group was higher than normal range
Pourfarzam <i>et al.</i>		MMP	Hospitalized Group: based on severity of problems at the time of exposure. Not hospitalized Control : based on severity of problems at the time of exposure. Control Control: unexposed	Case control	They do not compare not hospitalized patient with healthy people but MMP-9 in Not Hospitalized group was higher than normal range
Attaran <i>et al.</i>	2006	IL	Case Control: chemical warfare veterans with stable COPD. All subjects were nonsmoking males who had validated documentation of sulfur mustard gas exposure and experienced symptoms after sulfur mustard poisoning. Control Group: nonsmoking healthy men with no history of pulmonary or inflammatory diseases.	Case control	serum IL-6 is increased in patients with sulfur mustard
Yaraee <i>et al.</i>	2009	IL	Case Control: SM-exposed individuals Control Group: unexposed participants	Case-control	TNF, IL-1 α , IL-1 β and IL-1Ra levels were significantly lower in the exposed group than in controls
Pourfarzam <i>et al.</i>	2009	IL	Hospitalized Group: based on severity of problems at the time of exposure. Not hospitalized Control : based on severity of problems at the time of exposure. Control Control: unexposed	Case-control	IL-8 and IL-6 significantly decreased in the SM exposed
Shohrati <i>et al.</i>	2014	IL	First Group: SM-exposed patients with mild to moderate pulmonary symptoms Second Group: SM-exposed patients with moderate to severe pulmonary symptoms Control: individuals without any history of lung diseases but with matched age and gender	Case Control	IL 6 was significantly higher than the control group's
Ghazanfari <i>et al.</i>	2013	IG	Case Group: male participants from Sardasht who were exposed to SM Control Group: unexposed age matched controls from the unexposed town of Rabat	Case Control	IgM and IgG4 were significantly decreased in the peripheral blood
Mahmudi <i>et al.</i>	2005	IG	Case Group: All SM-poisoned veterans in the province of Khorasan, Iran, who had severe clinical complications Control Group: 35 healthy age-matched	Case Control	IgM levels were significantly higher in patients
Hassan <i>et al.</i>	2002	IG	Review of old report of SM exposed Patient	Comparison SM patient with normal range reference	IgM, IgG and IgE were significantly higher in patients
Ghazanfari <i>et al.</i>	2009	Chemokine	Case: SM exposed Patient Control: non SM exposed Patient	Case Control	Elevated levels of MCP-1/CCL2, decreased levels of IL-8/CXCL8 and RANTES/CCL5
Yaraee <i>et al.</i>	2009	Selectin	Case Group: exposed Control Group: non exposed	Case Control	sL-selectin and sP Selectin were significantly lower in SM exposed group, sE-selectin was significantly increased
Parvizpour <i>et al.</i>	2011	NF κ B	Case: 189 people of Sardasht sulfur mustard victims Control: 32 people of Rabat civil.	Case Control	NF κ B expression level in exposure group was upregulated

CRP level. What was however reported in most of these studies on stable COPD was that stable ML patients showed an increase in this inflammatory factor.

Tumor necrosis factor- α (TNF α)

TNF- α has been proposed as one of the reaction cytokines at acute phase. It is involved in systemic inflammation (Strieter *et al.*, 1993) and it is also important in the study of systemic inflammation in stable COPD patients (Moermans *et al.*, 2011). The active macrophages are the paramount sources for TNF- α and the primary role of TNF- α is the regulation of immunity cells (Rohani *et al.*, 2010). TNF- α activates neutrophils, macrophages, and epithelial cells and releases matrix metalloproteinase (MMP) from macrophages. It further prevents the synthesis of protein in skeletal muscle and thus plays a role in reducing body mass index (BMI) (Reid *et al.*, 2002; Lehmann *et al.*, 2005). The variations at serum level of this factor are important in stable COPD patients. It was found to be increased significantly in comparison with healthy subjects in many studies, such as the study of Moermans *et al.* (Moermans *et al.*, 2011) who have implied that this factor was significantly increased in patients with stable-COPD. Likewise, Karadag *et al.* (Karadag *et al.*, 2008b) have also shown a rising serum level of TNF- α in stable-COPD patients. But studies on ML-patients signified noticeable reduction in this factor. This factor was thus noticeably decreased even in stable ML patients compared to healthy subjects in the study of Yaraee *et al.* (Yaraee *et al.*, 2009a). In the study of Riahi-Zanjani *et al.* (Riahi-Zanjani *et al.*, 2014), the serum level of this factor was also significantly lower than in the control group. The rising serum level of TNF- α may be logically justified in the trend of occurrence of systemic inflammation in COPD patients since in most of the studies this factor was noticeably increased. It should be mentioned that TNF- α is produced in macrophages and activation of NF- κ B transcription factor may induce emerging of the TNF- α gene (Blackwell & Christman, 1997). Thus since variations in NF- κ B may show variations in secretion of TNF- α , NF- κ B should be explored in these patients.

NF- κ B

NF- κ B is a connecting protein to DNA and is proposed as a transcription factor. NF- κ B is one of the factors studied in systemic inflammation and it has also been noticed in COPD patients (Imanifooladi *et al.*, 2010). This factor remains non-active in the cytoplasm of cells till they receive the suitable signal for activation. In fact, NF- κ B is stimulated and activated in response to cellular stimuli (Fooladi *et al.*, 2012). NF- κ B involves various cellular functions and plays an essential role in various biological activities. Among the known functions of NF- κ B are regulation of immunity and inflammatory responses, cell division, and apoptosis. It is also necessary

in hematopoiesis and in increasing T-, B-, and NK-cells, dendritic cells, macrophages, and neutrophils (Denk *et al.*, 2000; Siebenlist *et al.*, 2005). Similarly, NF- κ B plays the role of proinflammatory genes of cytokines, chemokines, immunity receptors, enzymes, and other proinflammatory molecules. Inappropriate function of NF- κ B is one of the mechanisms involved in inflammatory diseases (Hayden & Ghosh, 2008; Batra *et al.*, 2011). NF- κ B is also important as the basic element in pathologic mechanisms of asthma and other chronic respiratory diseases (Wright & Christman, 2003). NF- κ B also induces the production of some of the immunoreceptors, acute phase proteins, Cox-2, INOs, etc. (Blackwell & Christman, 1997). Lee *et al.* (Lee *et al.*, 2012) demonstrated increased activity of NF- κ B in patients with stable COPD. This factor has also been evaluated in ML-patients and in a study that was conducted by Parvizpour *et al.* (PARVIZPOUR *et al.*, 2011) on SM exposed patients NF- κ B was significantly increased. Parvizpour mentioned that the respiratory symptoms caused by SM and variations of spirometry parameters would lead to deficiency in oxygen delivery to tissues and he assumed hypoxia to be one of the reasons for the probable increase of NF- κ B. Likewise, there is a positive feedback system between hemocytes and stromal cells, regulated by NF- κ B. Since hemocytes are reduced in these patients, this factor may be increased to compensate for shortage of hemocytes (PARVIZPOUR *et al.*, 2011).

Matrix metalloproteinase (MMP)

The studies conducted on stable COPD patients have shown that MMPs might be one of the other important systemic inflammatory mediators in these patients (Aldonyte *et al.*, 2004). MMPs are families of proteolytic enzymes that play a role in digestion of most extracellular matrix compounds and basal membrane tissue and for this reason they are important in physiologic and pathologic processes. MMP-2 and MMP-9 as collagenase enzymes type 4, due to possession of fibronectin triple structure, were able to connect and digest collagen, the most important composition of the basement membrane (Egeblad & Werb, 2002; Visse & Nagase, 2003). The level of MMP-9 is low in normal lungs, but this level has been reported to be high in some diseases, including asthma, idiopathic pulmonary fibrosis, and COPD. MMP-1 is also a type of MMPs that can lead to loss of fibril collagens. In general, the expression of MMP1 is very low under normal conditions, but its cab is overexpressed in alveolar epithelial cells (Fukuda *et al.*, 1998; Foronjy *et al.*, 2003; Kim *et al.*, 2004).

In a study conducted by Aldonyte *et al.* (Aldonyte *et al.*, 2004) on stable COPD patients, the serum level of MMP-9 was increased. Similarly, the study of Montano (Montano *et al.*, 2014) showed a rising serum level of MMP-9, MMP-7, and MMP-1 in these patients as compared to healthy controls. The conducted researches on ML, such as the study of Shohrati, have shown that the level of MMP-9 was significantly higher in these patients (Shohrati *et*

al., 2014b). Similarly, Kiani reported that serum level of MMP-1 was higher in SM exposed-patients, while the level of activity of MMP-2 was reduced and it was concluded that these variations might play a role in the pathogenesis and viability of pulmonary symptoms in these patients (Kiani *et al.*, 2013). However, these findings are mainly aligned with the recurrence phase of disease and no comparison was done under stable conditions. In another study, Pourfarzam compared hospitalized and non-hospitalized patients and showed that the level of MMP-9 was higher in hospitalized patients (Pourfarzam *et al.*, 2013). In this study, a healthy control group has not been involved for comparison and similarly to the study of Kiani, the severity of the disease (Lung Complications) in exacerbation phase was related to MMP variations.

Regarding the studies of Pourfarzam and Kiani, the mean level of MMP-9 was expressed for stable patients (949 and 1139 ng/ml, respectively) and these values are much higher than the normal range of MMP-9 (Sheu, 2008) (85–332 ng/ml) in healthy persons. These findings comply with the results of studies on COPD patients in such a way that the serum level of MMP-9 in these patients was higher than in other patients under stable conditions.

Interleukins (ILs)

ILs are also important and measurable markers in systemic inflammation analyzed in various pulmonary diseases, including studies on systemic inflammation; these markers have been noticed in stable COPD patients (de Moraes *et al.*, 2014). Of course, concerning ILs in COPD and ML diseases, most of the studies have been carried out on ILs 1, 6, and 8. ILs are cytokines, which are released from leukocytes and other cells (Ishii *et al.*, 2000). The relationship among ILs-1 with variations has been shown at the beginning of some clinical conditions, chronic inflammatory conditions, and also responses in the acute phase. ILs-1 α and β are two relevant structural forms to IL-1 attached to 2 types of existing receptors on target cells. IL-1, often along with other cytokines or other mediators, plays a role in developing disease and normal homeostasis. Although IL-1 and TNF are structurally separated from each other and attach to various receptors, they have some relevant functions (Ishii *et al.*, 2000; Sapey *et al.*, 2009). ILs-6 and 8 are produced from mononucleus phagocytic cells, endothelial cells, and fibroblasts and they act in both innate and adaptive immunity. IL-8 is well known for the induction of lipolysis, suppression of TNF α , and stimulation for producing cortisol (Irwin *et al.*, 2002; Lai *et al.*, 2012). IL-6 has been proposed as a primary main mediator in inflammatory response of the host to infection and its concentration reaches the maximum level immediately after bacteremia. Under such conditions, CRP concentration is increased within a few hours. IL-6 plays an essential role in induction of CRP production in the liver (Procanoy & Silveira, 2004; Barnes *et al.*, 2011).

A review on conducted studies in stable-COPD patients shows that serum level of these cytokines is increased; for example, in a study by Moraes *et al.* (de Moraes *et al.*, 2014), serum levels of IL-8 and IL-6 were reported to be higher than in healthy controls. Hammad *et al.* (Hammad *et al.*, 2015) have also shown that in IL-1b the serum level was also increased in stable-COPD patients. The review of studies on stable ML patients has shown different variations of levels of these ILs. In a study by Attaran *et al.* (Attaran *et al.*, 2010), serum level of IL-6 in ML patients was significantly higher than in the control group and it was significantly related to the severity of the disease. Similarly, Shohrati (Shohrati *et al.*, 2014a) reported the serum level of IL-6 to be significantly higher in ML patients and assumed this to be relevant to exacerbation of pulmonary symptoms. Also Yaraee *et al.* (Yaraee *et al.*, 2009a) found that the serum level of IL-1Ra in ML patients was significantly higher than in the control group and even in stable-ML patients. Of course, serum levels of IL-1 α and IL-1 β were significantly lower than in the control group in their study (Yaraee *et al.*, 2009a); thus these variations signify systemic variations in these patients. These are unexpected and the reason for their reduction is questionable. Yaraee (Yaraee *et al.*, 2009a) expressed disagreement of his findings with other studies. The difference in the conditions of the patients studied in each of the researches and the exclusive focus of Yaraee (Yaraee *et al.*, 2009a) on the history of exposure to SM, while the focus point of other authors was on the presence of pulmonary symptoms along with exposure history, might be a reason for these variations. Similarly, it should be noted that in the studies conducted by Attaran (Attaran *et al.*, 2010) and Shohrati (Shohrati *et al.*, 2014a), ML patients were not separated in terms of hospitalization or not. Also, Shohrati (Shohrati *et al.*, 2014a) considers the difference between his findings and the study of Pourfarzam (Pourfarzam *et al.*, 2009b) to be in the existing different conditions of patients, including exacerbation and stable state, as well as types of diseases (BO or COPD). Variations of ILs in the study of Pourfarzam *et al.* (Pourfarzam *et al.*, 2009b) is exposed to the same conflict compared to the studies of Shohrati and Attaran (Attaran *et al.*, 2010) since the findings resulting from their studies have shown that serum level of ILs-6 and -8 were significantly lower than in the control group, even in non-hospitalized patients, yet similar to the study of Yaraee *et al.* (Yaraee *et al.*, 2009a). In this study, the patients were compared with healthy persons separately based on hospitalization and non-hospitalization. Concerning IL-8, in addition to the study of Pourfarzam (Pourfarzam *et al.*, 2009b), in another study by Riahi-Zanjani (Riahi-Zanjani *et al.*, 2014) reduced serum level was observed where these variations have taken place, unlike what is seen in COPD patients. Finally, a new study done by Rahmani *et al.* (Rahmani *et al.*, 2017) reported the serum level of IL-6 to be significantly higher in ML patients and they designed this study in valuable inclusion and exclusion criteria to reach better results.

Immunoglobulins

Immunoglobulins also play a role in the pathogenesis of several inflammatory pulmonary diseases, including emphysema, asthma, and bronchitis (Chauhan *et al.*, 1990; O’Keeffe *et al.*, 1991; Groot Kormelink *et al.*, 2011) and are considered to be a biomarker in exacerbation of pulmonary diseases. Shalaby *et al.* (Samaha *et al.*, 2015) showed that IgE level was higher in stable-COPD patients than in healthy controls. Also, among the types of immunoglobulins, IgE, IgG, and IgM were studied in SM-exposed patients and it has been shown that their levels were significantly increased in these patients. Of course, newer clinical findings signify the reversed variations in some factors within different time intervals after exposure. In the study conducted by Ghazanfari *et al.* (Ghazanfari *et al.*, 2013), ML patients were studied regardless their stable or exacerbate conditions and it was indicated that the levels of IgM and IgG4 were reduced in these patients. However, it has been reflected in the Ghasemi (Ghasemi *et al.*, 2013) study that IgM was increased in ophthalmic, pulmonary, and/or dermal patients exposed to SM. Also, similarly to Ghazanfari (Ghazanfari *et al.*, 2013), in this investigation the stable and exacerbate patients were not separated. Likewise, in a reviewing research to analyze the effects of mustard gas which Hassan (Hassan *et al.*, 2006) conducted during the first year of exposure, it was shown that immunoglobulin IgE, IgG, and IgM levels were increased significantly in these patients. Of course, only percentage and frequency were mentioned in this study, while statistical and significance tests were not conducted. These variations in stable patients were considered to be a very important clue of systemic variations and this is required in conducting similar studies on ML patients with more reliable documented discussion.

Chemokines

Chemokines are a great family related structurally to chemotoxic cytokines and play an important role in the regulation of inflammation and immunity responses (Calderon & Berman, 2005). Some chemokines in COPD and ML patients were noticed in studies on systemic inflammation. Pinto-Plata *et al.* (Pinto-Plata *et al.*, 2007) showed that serum levels of chemokines in these patients were higher than in healthy controls. Similarly, Spruit *et al.* (Spruit *et al.*, 2003) also showed that before exacerbation, CXCL8 level was increased in stable patients. Also the results from studies of Ghazanfari (Ghazanfari *et al.*, 2009) on Iranian veterans and stable ML patients indicated that four chemokines (MCP-1/CCL2, RANTES/CCL5, IL-8/CXCL8, and Fractalkines/CX3CL1) were subjected to variation in serum level in these patients so that the level of MCP-1/CCL2 was significantly increased and levels of IL-8/CXCL8 and RANTES/CCL5 were significantly decreased. Ghazanfari (Ghazanfari *et al.*, 2009) implied that the rising level of MCP-1/CCL2 might be due to anti-inflammatory response and the lower level of

IL-8/CXCL8 and RANTES/CCL5 might show differences in pathophysiology and molecular mechanism involved in SM long-term clinical manifestation. In COPD patients, chemokines were lower than other mediators and there were different variations at serum level of the types of chemokines similar to ML patients. Altogether, variations in chemokines show systemic variations; it is thus clear that further research of these factors will open more windows for the researchers of systemic signs and symptoms in pulmonary patients, particularly ML patients.

Soluble L, P and E selectin

Selectins are membrane glycoproteins attached to carbohydrates that are introduced as cell adhesion molecules involved in developing various inflammatory reactions (Ley, 2003). These markers have also been found in COPD and ML. Selectin L, E and P are related to lymphocytes, endothelial and platelets cells, respectively (Yaraee *et al.*, 2009b). The study of Schumacher *et al.* (Schumacher *et al.*, 2005) reported that the level of P-selectin glycoprotein ligand-1 was higher in all COPD stable patients than in healthy controls. Increased E-selectin was also reported in COPD patients in the study of Aldonyte *et al.* (Aldonyte *et al.*, 2004). Selectins have been investigated in ML-patients as well. The studies conducted by Yaraee (Yaraee *et al.*, 2009b) reported increased serum levels of E-selectin in patients with SM complications and the level of L&P-selectin was decreased in these patients. Similarly to the variation in other cytokines, selectin expression patterns may show suppression of acute inflammation in SM-exposed patients as compared to healthy controls. This different pattern may play a vital role in regulation of the immunity system in these patients. Of course, these studies were conducted on COPD patients though they should be carried out on ML-patients more widely with more documentation and the involved cells should be identified more accurately.

Oxidant-antioxidant variations in ML and COPD patients

Many studies have shown the relationship among anti-oxidants, pulmonary function, and progress of COPD (Schwartz & WEISS, 1990,1994) and some other studies have also shown that consuming vitamins and fruits may be accompanied with forced expiratory volume in 1 second (FEV1) and reduced COPD symptoms (Strachan *et al.*, 1991; Miedema *et al.*, 1993; Tabak *et al.*, 1998). A review of conducted studies on COPD patients shows that similar mechanisms involving oxidative stress and pulmonary inflammation may be considered as reasons for many COPD systemic effects (Wouters *et al.*, 2002; Langen *et al.*, 2003).

There is homeostasis between oxidants and antioxidants in healthy persons with normal respiratory system (Sies & Stahl, 1995). Increase in the concentration of

oxidants or reduction in antioxidants may distort this homeostasis and lead to a condition called oxidative stress. It seems that oxidative stress plays an important role in the pathogenesis of pulmonary diseases through direct impairment or involvement of efficient molecular mechanisms in pulmonary inflammation (Adamson & Bowden, 1974). Some of these studies have shown rising oxidant loading that was followed by increase in oxidative stress markers in alveoli, blood, and urine of smokers and patients with pulmonary diseases (Adamson & Bowden, 1974; Sies & Stahl, 1995; MacNee, 2005). The antioxidant system against free radicals may be divided into enzymatic and non-enzymatic parts. Metallo-enzyme of superoxide dismutase is the first natural antioxidant against toxicity of free radicals. There is an extracellular type of superoxide dismutase where the major activity of this enzyme occurs in plasma, lymph, and synovial fluid (Comhair *et al.*, 2000). Some studies reported that extracellular superoxide dismutase enzyme was increased in response to oxidative stresses in various pulmonary diseases (Levitt *et al.*, 2003). Although the pathological basis of acute and chronic effects of mustard gas is still unknown on pulmonary tissue, studies on animals *in vitro* have shown that mechanism of injury by mustard gas, activation of proteases, and production of free radicals may lead to oxidative stress in the given tissues (Kopff *et al.*, 1993; Husain *et al.*, 1996). With respect to these studies, it has been proved that the released free radicals by neutrophils and macrophages are important mediators in injury of lung tissue (Comhair & Erzurum, 2002). In a study carried out by Shohrati *et al.* (Shohrati *et al.*, 2009), it was implied that a significant difference was observed in catalase enzyme between two control groups and chemically-injured veterans and this enzyme was at a higher level among ML-patients. Of course, no significant difference was observed between the two groups in superoxide dismutase activity. Similarly, Shohrati (Shohrati *et al.*, 2009) reported in his study that the mean value of extracellular superoxide dismutase varied also in the control group, but it was higher in severe ML-patients and this difference was statistically significant. Yet there was no significant difference between the two groups in terms of mean activity of extracellular superoxidase dismutase. With respect to the findings of Shohrati (Shohrati *et al.*, 2009), extracellular superoxide dismutase may play a role in the progress of inflammation and pulmonary impairments caused by mustard gas.

Extrapulmonary complications in ML and COPD patients

Osteoporosis

Osteoporosis is characterized with decreased density in bone mass and increase in risk of fractures. The main signs of osteoporosis include reduced construction of minerals and bone matrix that contains collagen and non-collagen proteins, while the matrix-mineral ratio remains fixed (Kelley *et al.*, 1997). The relative risk of

osteoporosis in patients with COPD is higher than in the general population (Iqbal *et al.*, 1999) and this issue is proposed as an important problem in COPD. In patients with progressive COPD, osteoporosis is prevalent with some symptoms, such as pain, rising dependency, and it is also followed by increase in mortality. The etiology of osteoporosis varies in these patients, including smoking, vitamin D deficiency, and lower body mass index (BMI), hypogonadism sedentary lifestyle, and glucocorticoid drug use (Biskobing, 2002). Some studies have shown that low bone mineral (BMD) in COPD-patients is highly prevalent even in milder stages (Jorgensen & Schwarz, 2008). Likewise, a wide investigation in which 6000 patients with COPD were studied reported that more than half of the patients suffered from osteopenia and/or osteoporosis (Calverley *et al.*, 2007). Similarly, vertebral compression fractures are relatively prevalent in COPD patients and furthermore kyphosis is also observed in these patients, in relation to reduced pulmonary function (Carter *et al.*, 2008). The probability of morbidity of these impairments is very high in COPD patients since it includes many similar backgrounds with etiology of osteoporosis in COPD patients, such as sedentary lifestyle and intake of glucocorticoids. Few studies have been conducted on osteoporosis in these patients. The report presented by Agin *et al.* (Agin, 2004) shows that osteoporosis in SM-exposed patients cause severe disability in which significant difference was observed in two ML and the control group (with osteoporosis and osteopenia ranges) and most variations (65%) were seen in spine vertebrae. The intensity of involvement was higher in the hipbone (5%) in the ML group. Further studies with reliance on a wider population in stable patients may contribute further to perception of variations in ML patients at systemic level in the morbidity of osteoporosis. Yet despite wide studies in COPD patients, this finding has not come to a single result in systemic mechanisms in these patients. A review of studies has shown that morbidity of this impairment keeps still increasing in COPD patients (Graat-Verboom *et al.*, 2009).

Cardiovascular signs and symptoms

Based on epidemiologic findings, reducing FEV1 is solely important as one of the morbidity and mortality markers in cardiovascular diseases (Sin & Man, 2005). It should also be noted that the relevant cardiac failure secondary to coronary vessel atherosclerosis is seen in 20% of COPD patients (Rutten *et al.*, 2005). Similarly, Lahousse *et al.* (Lahousse *et al.*, 2013) have shown that the main causes of mortality in their COPD patients studied was cardiovascular impairment and heart failure, stroke, sudden (cardiac) death, cardiac arrest, acute myocardial infarction, and chronic ischemic heart disease as mortality causes for 38.3% of their patients. Although the conducted studies on ML-patients have been focused mainly on intrapulmonary complications and also sometimes on some cellular and hormonal factors, based on a few reports about extrapulmonary impairments, cardiovascular complications are considered a noticeable factor

in deterioration of the status of ML patients and of their rising morbidities and even mortalities (Rohani *et al.*, 2010). In a control case study, Rohani *et al.* (Rohani *et al.*, 2010) reported that exercise stress test has been positively significant in SM-patients since the group of patients were categorized in coronary arteries diseases. Similarly, there was left ventricular (VV) diastolic abnormality in 23% of patients and generally the conclusion resulting from the study signifies that cardiovascular complications are assumed to be one of the other long-term impairments in SM-patients (Rohani *et al.*, 2010). Likewise, in a study that was carried out on ML patients as candidates for coronary artery bypass graft (CABG) surgery by Fakhraddin *et al.* (Fakhraddin *et al.*, 1999), it was implied that physical activity was significantly lower in ML-patients and hypercholesterolemia and sedentary lifestyle were followed by coronary vessel complications in ML-patients. Similarly, Rezaian (Rezaian *et al.*, 2008) also expressed in a study on ML-patients that SM caused exercise capacity constraint in these patients. Karbasi and Afshar (Karbasi-Afshar *et al.*, 2013) also expressed that angiographic variations and cardiovascular diseases are exacerbated in these patients. As mentioned, such studies in COPD patients may also signify the presence of cardiovascular impairment in these patients; this refers to the reduced exercise capacity and ability of patients as well as to increase in cardiovascular diseases within a wider range.

Conclusion

The presented study was carried out to explore the systemic expressions in chemically-injured and pulmonary veterans exposed to mustard gas with inhaling toxicity by single dosage of mustard gas for several years and their comparison with systemic manifestation in COPD patients. As implied in the introduction and other sections of this article, the main objective was systemic variations in stable-phase in these patients where these goals caused many studies to be excluded from the range of this paper since many studies relating to systemic factors have been examined in exacerbate-phase and studies that dealt with these patients at stable-phase play a lesser role among the published articles. Similarly, variations of inflammatory factors have been explored at serum level in this essay, while most of the studies have reviewed these factors and explored the level of these variables in pulmonary fluid. As it has been reviewed in various parts of this article, it was witnessed in stable ML-patients that CRP increases, TNF α decreases, NF- κ B raises, MMP-9 and MMP-1 increase, MMP-2 decreases, serum level reduces in IL-1 α , and IL-1 β , while IL-6 usually increases and IL-8 decreases, IgE, IgG, and IgM increase (and reduction was also seen in IgM and IgG4), MCP-1/CCL2 increases and IL-8/CXCL8 and RANTES/CCL5 reduce, E-selectin increases, and L&P-selectin decreases and deactivation of extracellular superoxidase dismutase enzyme occurs. Exacerbation of disability and skeletal failure along with cardiovascular complications are observed. Systemic variations of these

factors have a regular and routine trend in stable COPD patients in various studies where CRP was increased, TNF α increased, NF- κ B increased, MMP-1, MMP-7, and MMP-9 increased, IL-6 and IL-6 increased, and IgE IL-1b increased. An increase is seen in chemokines including CXCL8 and selectins, including P-selectin glycoprotein ligand-1. Similarly, increased rates of cardiovascular diseases and osteoporosis were also seen in these patients. In general, all the aforementioned factors presented noticeable variations in this group; however, these variations were accompanied with a more regular and routine trend in COPD patients than in ML-patients, where according to the viewpoint of researchers, such a difference may show different pathophysiology and molecular mechanism involving SM-long term clinical expressions and/or it might be due to different conditions of patients and type of disease (BO or COPD) and/or the fact that variations in factors tend to compensate less the number of hemocytes since it has been reduced with exposure to mustard gas. This difference in results may be due to the difference in samplings and methods.

Conclusively, it is to be noted that with respect to the review of various studies in this article and observation of results regarding various extrapulmonary complications in ML-patients, it seems that the resulting complications from SM gas may create a wider range of disorders in which the involvement of various systems signifies the presence of systemic effects in ML-patients. Considering the fact that the volume of information on the subject is small, more studies should be designed and if the findings of this article are confirmed, then they show the start of a new phase of SM-gas side-effects in ML patients. This phase makes it necessary to apply wider and multifactor therapeutic strategies in these patients. It is therefore suggested to give more transparent answers to systemic ambiguities in ML-patients by conducting extensive studies on the factors reviewed in this investigation.

REFERENCES

- Adamson IY, Bowden DH. (1974). The pathogenesis of bleomycin-induced pulmonary fibrosis in mice. *Am J Pathol* **77**: 185–197.
- Agin K. (2004). Comparison of prevalence of osteoporosis in patients with asthma following chemical injury in patients with asthma Sulfur-mustard non chemical victims. *Mil Res J* **4**: 419–422.
- Agusti A, Soriano JB. (2008). COPD as a systemic disease. *COPD: Journal of Chronic Obstructive Pulmonary Disease* **5**: 133–138.
- Aldonyte R, Eriksson S, Piitulainen E, Wallmark A, Janciauskiene S. (2004). Analysis of systemic biomarkers in COPD patients. *Copd* **1**: 155–164.
- Anderson GP. (2006). COPD, asthma and C-reactive protein. *Eur Respir J* **27**: 874–876.
- Attaran D, Lari SM, Khajehdaluae M, Ayatollahi H, Towhidi M, Asnaashari A, Marallu HG, Mazloomi M, Balali-Mood M. (2009). Highly sensitive C-reactive protein levels in Iranian patients with pulmonary complication of sulfur mustard poisoning and its correlation with severity of airway diseases. *Hum Exp Toxicol* **28**: 739–745.
- Attaran D, Lari SM, Towhidi M, Marallu HG, Ayatollahi H, Khajehdaluae M, Ghanei M, Basiri R. (2010). Interleukin-6 and airflow limitation in chemical warfare patients with chronic obstructive pulmonary disease. *Int J Chron Obstruct Pulmon Dis* **5**: 335–340.

- Balali-Mood M, Afshari R, Zojaji R, Kahrom H, Kamrani M, Attaran D, Mousavi SR, Zare GA. (2011). Delayed toxic effects of sulfur mustard on respiratory tract of Iranian veterans. *Hum Exp Toxicol* **30**(9): 1141–1149.
- Barnes PJ, Celli BR. (2009). Systemic manifestations and comorbidities of COPD. *Eur Respir J* **33**: 1165–1185.
- Barnes TC, Anderson ME, Moots RJ. (2011). The many faces of interleukin-6: the role of IL-6 in inflammation, vasculopathy, and fibrosis in systemic sclerosis. *Int J Rheumatol* **2011**: 721608.
- Batra S, Balamayooran G, Sahoo MK. (2011). Nuclear factor-kappaB: a key regulator in health and disease of lungs. *Arch Immunol Ther Exp (Warsz)* **59**: 335–351.
- Bayat N, Aslani J. (2010). Comparing the bone mineral density in chemical injures and non-chemical asmatic patients. *Trauma Monthly* **2011**: 105–110.
- Biskobing DM. (2002). COPD and osteoporosis. *Chest* **121**: 609–620.
- Blackwell TS, Christman JW. (1997). The role of nuclear factor-kappa B in cytokine gene regulation. *Am J Respir Cell Mol Biol* **17**: 3–9.
- Calderon TM, Berman JW. (2005). Overview and history of chemokines and their receptors. *Current Topics in Membranes* **55**: 1–47.
- Calverley PM, Anderson JA, Celli B, Ferguson GT, Jenkins C, Jones PW, Yates JC, Vestbo J, investigators T. (2007). Salmeterol and fluticasone propionate and survival in chronic obstructive pulmonary disease. *N Engl J Med* **356**: 775–789.
- Carter JD, Patel S, Sultan FL, Thompson ZJ, Margaux H, Sterrett A, Carney G, Murphy N, Huang Y, Valeriano J, Vasey FB. (2008). The recognition and treatment of vertebral fractures in males with chronic obstructive pulmonary disease. *Respir Med* **102**: 1165–1172.
- Comhair SA, Bhathena PR, Dweik RA, Kavuru M, Erzurum SC. (2000). Rapid loss of superoxide dismutase activity during antigen-induced asthmatic response. *Lancet* **355**: 624.
- Comhair SA, Erzurum SC. (2002). Antioxidant responses to oxidant-mediated lung diseases. *Am J Physiol Lung Cell Mol Physiol* **283**: L246–255.
- Dahl M, Nordestgaard BG. (2009). Markers of early disease and prognosis in COPD. *Int J Chron Obstruct Pulmon Dis* **4**: 157–167.
- Dahl M, Vestbo J, Lange P, Bojesen SE, Tybjaerg-Hansen A, Nordestgaard BG. (2007). C-reactive protein as a predictor of prognosis in chronic obstructive pulmonary disease. *American journal of respiratory and critical care medicine* **175**: 250–255.
- Dayhimi I, Bahar K, Eliasy H. (1988). The effect of sulfur mustard gas (SMG) on the immune system. In: The First International Medical Congress on Chemical Warfare Agents in Iran Mashhad, Iran: Mashhad University of Medical Sciences.
- de Moraes MR, da Costa AC, Correa Kde S, Junqueira-Kipnis AP, Rabahi MF. (2014). Interleukin-6 and interleukin-8 blood levels' poor association with the severity and clinical profile of ex-smokers with COPD. *Int J Chron Obstruct Pulmon Dis* **9**: 735–743.
- Denk A, Wirth T, Baumann B. (2000). NF-kappaB transcription factors: critical regulators of hematopoiesis and neuronal survival. *Cytokine Growth Factor Rev* **11**: 303–320.
- Egeblad M, Werb Z. (2002). New functions for the matrix metalloproteinases in cancer progression. *Nat Rev Cancer* **2**: 161–174.
- Ekstrand-Hammarstrom B, Wigenstam E, Bucht A. (2011). Inhalation of alkylating mustard causes long-term T cell-dependent inflammation in airways and growth of connective tissue. *Toxicology* **280**: 88–97.
- Emad A, Rezaian GR. (1999). Immunoglobulins and cellular constituents of the BAL fluid of patients with sulfur mustard gas-induced pulmonary fibrosis. *Chest* **115**: 1346–1351.
- Evison D, Hinsley D, Rice P. (2002). Regular review: chemical weapons. *BMJ: British Medical Journal* **324**: 332.
- Fakhraddin F, Reza SA, Yahya D, Akbar KZA, Mahdi C. (1999). Does Sulfur Mustard (HD) have an accelerating effect on CABG in HD-exposed people? Is it a link? *Medical Science and Technology* **48**: RA11–RA13.
- Firoozabadi MD, Shahriary A, Rahmani H. (2017). Mustard lung anesthesia; general anesthesia for patients with chronic obstructive pulmonary disease due to sulphur mustard exposure. *Minerva Pneumol* **56**: 254–257.
- Fooladi AAI, Nourani MR, Yazdani S. (2012). *Lung and Systemic Inflammation in COPD*: INTECH Open Access Publisher.
- Foronjy RF, Okada Y, Cole R, D'Armiento J. (2003). Progressive adult-onset emphysema in transgenic mice expressing human MMP-1 in the lung. *Am J Physiol Lung Cell Mol Physiol* **284**: L727–737.
- Fukuda Y, Ishizaki M, Kudoh S, Kitaichi M, Yamanaka N. (1998). Localization of matrix metalloproteinases-1, -2, and -9 and tissue inhibitor of metalloproteinase-2 in interstitial lung diseases. *Lab Invest* **78**: 687–698.
- Geddes EL, Reid WD, Crowe J, O'Brien K, Brooks D. (2005). Inspiratory muscle training in adults with chronic obstructive pulmonary disease: a systematic review. *Respir Med* **99**: 1440–1458.
- Ghanei M, Adibi I, Farhat F, Aslani J. (2008). Late respiratory effects of sulfur mustard: how is the early symptoms severity involved? *Chronic respiratory disease* **5**: 95–100.
- Ghanei M, Harandi AA. (2007). Long term consequences from exposure to sulfur mustard: a review. *Inhal Toxicol* **19**: 451–456.
- Ghasemi H, Ghazanfari T, Babaei M, Soroush MR, Yaraee R, Ghassemi-Broumand M, Javadi MA, Foroutan A, Mahdavi MR, Shams J, Pourfarzam S, Moaiedmohseni S, Nadoushan MR, Owlia P, Panahi Y, Hassan ZM, Faghihzadeh S. (2008). Long-term ocular complications of sulfur mustard in the civilian victims of Sardasht, Iran. *Cutan Ocul Toxicol* **27**: 317–326.
- Ghasemi H, Ghazanfari T, Yaraee R, Ghassemi-Broumand M, Soroush MR, Pourfarzam S, Masdari Z, Faghihzadeh S, Babaei M, Javadi MA. (2009). Evaluation of relationship between the serum levels of inflammatory mediators and ocular injuries induced by sulfur mustard: Sardasht-Iran Cohort Study. *Int Immunopharmacol* **9**(13–14): 1494–1498.
- Ghasemi H, Mostafaie A, Yaraee R, Hassan ZM, Rezaei A, Mahmoudi M, Faghihzadeh S, Soroush MR, Ardestani SK, Babaei M, Jalali-Nadoushan M, Khamesipour A, Ghassemi-Broumand M, Ghazanfari T. (2013). Association of serum immunoglobulins levels and eye injuries in sulfur mustard exposed: Sardasht-Iran Cohort Study. *Int Immunopharmacol* **17**: 944–951.
- Ghazanfari T, Mostafaie A, Yaraee R, Pourfarzam S, Faghihzadeh S, Rezaei A, Mahmoudi M, Vaez-Mahdavi MR, Moaiedmohseni S, Soroush MR, Naghizadeh MM, Faghihzadeh E, Hassan ZM. (2013). Are serum levels of immunoglobulin classes and IgG subclasses involved in delayed pulmonary complications induced by sulfur mustard? Sardasht-Iran Cohort Study. *Int Immunopharmacol* **17**: 936–943.
- Ghazanfari T, Yaraee R, Kariminia A, Ebtekar M, Faghihzadeh S, Vaez-Mahdavi MR, Rezaei A, Vojgani M, Soroush MR, Kermani-Jalilvand A. (2009). Alterations in the serum levels of chemokines 20years after sulfur mustard exposure: Sardasht-Iran Cohort Study. *Int Immunopharmacol* **9**(13–14): 1471–6.
- Ghotbi L, Hassan Z. (2002). The immunostatus of natural killer cells in people exposed to sulfur mustard. *Int Immunopharmacol* **2**: 981–985.
- Graat-Verboom L, Wouters EF, Smeenk FW, van den Borne BE, Lunde R, Spruit MA. (2009). Current status of research on osteoporosis in COPD: a systematic review. *Eur Respir J* **34**: 209–218.
- Groot Kormelink T, Pardo A, Knipping K, Buendia-Roldan I, Garcia-de-Alba C, Blokhuis BR, Selman M, Redegeld FA. (2011). Immunoglobulin free light chains are increased in hypersensitivity pneumonitis and idiopathic pulmonary fibrosis. *PLoS One* **6**: e25392.
- Hammad DR, Elgazzar AG, Essawy TS, El Sameie SAA. (2015). Evaluation of serum interleukin-1 beta as an inflammatory marker in COPD patients. *Egyptian Journal of Chest Diseases and Tuberculosis* **64**: 347–352.
- Hassan ZM, Ebtekar M, Ghanei M, Taghikhani M, Noori Daloui MR, Ghazanfari T. (2006). Immunobiological consequences of sulfur mustard contamination. *Iran J Allergy Asthma Immunol* **5**: 101–108.
- Hayden MS, Ghosh S. (2008). Shared principles in NF-kappaB signaling. *Cell* **132**: 344–362.
- Hefazi M, Attaran D, Mahmoudi M, Balali-Mood M. (2005). Late respiratory complications of mustard gas poisoning in Iranian veterans. *Inhal Toxicol* **17**: 587–592.
- Heidari A, Sheikhi MA, Rahmani H. (2016). Inflammatory status of Non-Smoker Sulphur Mustard exposed Patient with Cancer candidate for Coronary artery bypass grafting Surgery. *Int J Pharm Res Allied Sci* **5**: 196–198.
- Higashimoto Y, Iwata T, Okada M, Satoh H, Fukuda K, Tohda Y. (2009). Serum biomarkers as predictors of lung function decline in chronic obstructive pulmonary disease. *Respir Med* **103**(8): 1231–1238.
- Hurst JR, Donaldson GC, Perera WR, Wilkinson TM, Bilello JA, Hagan GW, Vessey RS, Wedzicha JA. (2006). Use of plasma biomarkers at exacerbation of chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* **174**(8): 867–874.
- Husain K, Dube SN, Sugendran K, Singh R, Das Gupta S, Somani SM. (1996). Effect of topically applied sulphur mustard on antioxidant enzymes in blood cells and body tissues of rats. *J Appl Toxicol* **16**: 245–248.
- Chauhan S, Gupta MK, Goyal A, Dasgupta DJ. (1990). Alterations in immunoglobulin & complement levels in chronic obstructive pulmonary disease. *Indian J Med Res* **92**: 241–245.

- Chung KF. (2005). Inflammatory mediators in chronic obstructive pulmonary disease. *Curr Drug Targets Inflamm Allergy* **4**: 619–625.
- Imani S, Panahi Y, Salimian J, Fu J, Ghanei M. (2015). Epigenetic: A missing paradigm in cellular and molecular pathways of sulfur mustard lung: a prospective and comparative study. *Iran J Basic Med Sci* **18**: 723–736.
- Imanifooladi AA, Yazdani S, Nourani MR. (2010). The role of nuclear factor-kappaB in inflammatory lung disease. *Inflamm Allergy Drug Targets* **9**(3): 197–205.
- Iqbal F, Michaelson J, Thaler L, Rubin J, Roman J, Nanes MS. (1999). Declining bone mass in men with chronic pulmonary disease: contribution of glucocorticoid treatment, body mass index, and gonadal function. *Chest* **116**: 1616–1624.
- Irwin CR, Myrillas TT, Traynor P, Leadbetter N, Cawston TE. (2002). The role of soluble interleukin (IL)-6 receptor in mediating the effects of IL-6 on matrix metalloproteinase-1 and tissue inhibitor of metalloproteinase-1 expression by gingival fibroblasts. *J Periodontol* **73**: 741–747.
- Ishii T, Matsuse T, Teramoto S, Matsui H, Miyao M, Hosoi T, Takahashi H, Fukuchi Y, Ouchi Y. (2000). Neither IL-1 β , IL-1 receptor antagonist, nor TNF- α polymorphisms are associated with susceptibility to COPD. *Respir Med* **94**: 847–851.
- Jorgensen NR, Schwarz P. (2008). Osteoporosis in chronic obstructive pulmonary disease patients. *Curr Opin Pulm Med* **14**: 122–127.
- Karadag F, Karul AB, Cildag O, Yilmaz M, Ozcan H. (2008a). Biomarkers of systemic inflammation in stable and exacerbation phases of COPD. *Lung* **186**: 403–409.
- Karadag F, Kirdar S, Karul AB, Ceylan E. (2008b). The value of C-reactive protein as a marker of systemic inflammation in stable chronic obstructive pulmonary disease. *Eur J Intern Med* **19**(2): 104–108.
- Karbasi-Afshar R, Shahmari A, Madadi M, Poursaleh Z, Saburi A. (2013). Coronary angiography findings in lung injured patients with sulfur mustard compared to a control group. *Ann Card Anaesth* **16**: 188–192.
- Kelley WN, Harris ED, Ruddy S, Sledge CB. (1997). *Textbook of rheumatology*: WB Saunders Philadelphia.
- Khateri S, Ghanei M, Keshavarz S, Soroush M, Haines D. (2003). Incidence of lung, eye, and skin lesions as late complications in 34,000 Iranians with wartime exposure to mustard agent. *J Occup Environ Med* **45**(11): 1136–1143.
- Kiani A, Mostafaie A, Shirazi FH, Ghazanfari T. (2013). Serum profiles of matrix metalloproteinases and their tissue inhibitors in long-term pulmonary complication induced by sulfur mustard: Sardasht-Iran Cohort Study (SICS). *Int Immunopharmacol* **17**(3): 964–967.
- Kim H, Liu X, Kohyama T, Kobayashi T, Conner H, Abe S, Fang Q, Wen F-Q, Rennard SI. (2004). Cigarette smoke stimulates MMP-1 production by human lung fibroblasts through the ERK1/2 pathway. *COPD* **1**(1): 13–23.
- Kony S, Zureik M, Driss F, Neukirch C, Leynaert B, Neukirch F. (2004). Association of bronchial hyperresponsiveness and lung function with C-reactive protein (CRP): a population based study. *Thorax* **59**: 892–896.
- Kopff M, Zakrzewska I, Strzelczyk M, Klem J, Dubiecki W. (1993). Superoxide dismutase and catalase activity in psoriatic patients treated topically with ointment containing 2-chloroethyl-3-chloropropyl sulfide. *Pol J Pharmacol* **46**(5): 439–444.
- Kraus VB, Stabler TV, Luta G, Renner JB, Dragomir AD, Jordan JM. (2007). Interpretation of serum C-reactive protein (CRP) levels for cardiovascular disease risk is complicated by race, pulmonary disease, body mass index, gender, and osteoarthritis. *Osteoarthritis Cartilage* **15**(8): 966–971.
- Krumbhaar EB, Krumbhaar HD. (1919). The Blood and Bone Marrow in Yellow Cross Gas (Mustard Gas) Poisoning: Changes produced in the Bone Marrow of Fatal Cases. *J Med Res* **40**: 497–508.
- Lahousse L, Loth DW, Joos GF, Hofman A, Leufkens HG, Brusselle GG, Stricker BH. (2013). Statins, systemic inflammation and risk of death in COPD: the Rotterdam study. *Pulm Pharmacol Ther* **26**: 212–217.
- Lai Y, Liu X, Zeng Y, Zhang Y, Shen Y, Liu Y. (2012). Interleukin-8 induces the endothelial cell migration through the Rac1/RhoA-p38MAPK pathway. *Cell* **51**: 38MAPK.
- Langen RC, Korn SH, Wouters EF. (2003). ROS in the local and systemic pathogenesis of COPD. *Free Radic Biol Med* **35**: 226–235.
- Lari SM, Attaran D, Towhidi M. (2012). *COPD Due to Sulfur Mustard (Mustard Lung)*: INTECH Open Access Publisher.
- Laskin DL, Sunil VR, Laumbach RJ, Kipen HM. (2007). Inflammatory cytokines and lung toxicity. In: *Cytokines in Human Health*, pp 83–112: Springer.
- Lee KY, Ho SC, Chan YF, Wang CH, Huang CD, Liu WT, Lin SM, Lo YL, Chang YL, Kuo LW, Kuo HP. (2012). Reduced nuclear factor-kappaB repressing factor: a link toward systemic inflammation in COPD. *Eur Respir J* **40**: 863–873.
- Lehmann W, Edgar CM, Wang K, Cho TJ, Barnes GL, Kakar S, Graves DT, Rueger JM, Gerstenfeld LC, Einhorn TA. (2005). Tumor necrosis factor alpha (TNF-alpha) coordinately regulates the expression of specific matrix metalloproteinases (MMPs) and angiogenic factors during fracture healing. *Bone* **36**: 300–310.
- Levitt JM, Lodhi IJ, Nguyen PK, Ngo V, Clift R, Hinshaw DB, Sweeney JF. (2003). Low-dose sulfur mustard primes oxidative function and induces apoptosis in human polymorphonuclearleukocytes. *Int Immunopharmacol* **3**: 747–756.
- Ley K. (2003). The role of selectins in inflammation and disease. *Trends Mol Med* **9**: 263–268.
- Littner MR. (2011). In the clinic. Chronic obstructive pulmonary disease. *Ann Intern Med* **154**: ITC4-1-ITC4-15; quiz ITC4-16.
- MacNee W. (2005). Pulmonary and systemic oxidant/antioxidant imbalance in chronic obstructive pulmonary disease. *Proc Am Thorac Soc* **2**: 50–60.
- Mahmoudi M, Hefazi M, Rastin M, Balali-Mood M. (2005). Long-term hematological and immunological complications of sulfur mustard poisoning in Iranian veterans. *Int Immunopharmacol* **5**: 1479–1485.
- Man SF, Xing L, Connett JE, Anthonisen NR, Wise RA, Tashkin DP, Zhang X, Vessey R, Walker TG, Celli BR, Sin DD. (2008). Circulating fibronectin to C-reactive protein ratio and mortality: a biomarker in COPD? *Eur Respir J* **32**: 1451–1457.
- Miedema I, Feskens EJ, Heederik D, Kromhout D. (1993). Dietary determinants of long-term incidence of chronic nonspecific lung diseases. The Zutphen Study. *Am J Epidemiol* **138**: 37–45.
- Mirbagher Ajorpaz N, Rezaei M. (2009). The Effects of pulmonary rehabilitation techniques on the clinical status of patients with moderate severity chronic obstructive pulmonary diseases (COPD) at University Hospitals of Isfahan in 2006–7. *ZUMS Journal* **17**: 1–12.
- Mishra NC, Rir-sima-ah J, Grotendorst GR, Langley RJ, Singh SP, Gundavarapu S, Weber WM, Pena-Philippides JC, Duncan MR, Sopori ML. (2012). Inhalation of sulfur mustard causes long-term T cell-dependent inflammation: possible role of Th17 cells in chronic lung pathology. *Int Immunopharmacol* **13**: 101–108.
- Moermans C, Heinen V, Nguyen M, Henket M, Sele J, Manise M, Corhay JL, Louis R. (2011). Local and systemic cellular inflammation and cytokine release in chronic obstructive pulmonary disease. *Cytokine* **56**: 298–304.
- Moin A, Ghazanfari T, Davoudi SM, Emadi N, Panahi Y, Hassan ZM, Soroush MR, Khateri S, Amini R, Naghizadeh MM. (2009). Long-term skin findings of sulfur mustard exposure on the civilians of Sardasht, Iran. *Toxin Reviews* **28**: 24–29.
- Montano M, Sansores RH, Becerril C, Cisneros J, Gonzalez-Avila G, Sommer B, Ochoa L, Herrera I, Ramirez-Venegas A, Ramos C. (2014). FEV1 inversely correlates with metalloproteinases 1, 7, 9 and CRP in COPD by biomass smoke exposure. *Respir Res* **15**: 74.
- Naghii MR. (2002). Sulfur mustard intoxication, oxidative stress, and antioxidants. *Mil Med* **167**: 573–575.
- Nussbaumer-Ochsner Y, Rabe KF. (2011). Systemic manifestations of COPD. *Chest* **139**: 165–173.
- O’Keeffe S, Gzel A, Drury R, Cullina M, Grealley J, Finnegan P. (1991). Immunoglobulin G subclasses and spirometry in patients with chronic obstructive pulmonary disease. *Eur Respir J* **4**: 932–936.
- Paromov V, Surrentes Z, Smith M, Stone WL. (2007). Sulfur mustard toxicity following dermal exposure: role of oxidative stress, and antioxidant therapy. *J Burns Wounds* **7**: e7.
- Parvizpour F, Ghazanfari T, Salimi H, Faghihzadeh S, Yaraee R, Sharifnia Z, Soroush MR, Naghizadeh MM. (2011). NF κ B gene expression survey in peripheral blood cell of sardasht warfare agent victims 20 years after exposure to sulfur mustard. *Tebe-E-Janbaz* **3**(12): 38–47.
- Pinto-Plata V, Toso J, Lee K, Park D, Bilello J, Mullerova H, De Souza MM, Vessey R, Celli B. (2007). Profiling serum biomarkers in patients with COPD: associations with clinical parameters. *Thorax* **62**: 595–601.
- Pinto-Plata VM, Mullerova H, Toso JF, Feudjo-Tepie M, Soriano JB, Vessey RS, Celli BR. (2006). C-reactive protein in patients with COPD, control smokers and non-smokers. *Thorax* **61**: 23–28.
- Pourfarzam S, Ghazanfari T, Merasizadeh J, Ghanei M, Azimi G, Araghizadeh H, Foroutan A, Shams J, Ghasemi H, Yaraee R. (2009a). Long-term pulmonary complications in sulfur mustard victims of Sardasht, Iran. *Toxin Reviews* **28**: 8–13.

- Pourfarzam S, Ghazanfari T, Yaraee R, Ghasemi H, Hassan ZM, Faghihzadeh S, Ardestani SK, Kariminia A, Fallahi F, Soroush MR, Merasizadeh J, Mahlojirad M, Naghizadeh MM, Ghanei M. (2009b). Serum levels of IL-8 and IL-6 in the long term pulmonary complications induced by sulfur mustard: Sardasht-Iran Cohort Study. *Int Immunopharmacol* **9**: 1482–1488.
- Pourfarzam S, Yaraee R, Hassan ZM, Yarmohammadi ME, Faghihzadeh S, Soroush MR, Fallahi F, Ardestani SK, Ebtekar M, Moaiedmohseni S, Naghizadeh MM, Ghasemi H, Shams J, Ghazanfari T. (2013). Chemokines, MMP-9 and PMN elastase in spontaneous sputum of sulfur mustard exposed civilians: Sardasht-Iran Cohort Study. *Int Immunopharmacol* **17**: 958–963.
- Procianny RS, Silveira RC. (2004). The role of sample collection timing on interleukin-6 levels in early-onset neonatal sepsis. *J Pediatr (Rio J)* **80**: 407–410.
- Rahmani H, Javadi I, Shirali S. (2016). Respiratory complications due to sulfur mustard exposure. *Int J Curr Res Acad Rev* **4**(6): 143–149.
- Rahmani H, Javadi I, Shirali S. (2017). Evaluation of serum levels of interleukin-6 and C-reactive protein in mustard lung patients and its relationship with pulmonary complications. *Minerva Pneumologica* **56**: 84–89.
- Reid MB, Lannergren J, Westerblad H. (2002). Respiratory and limb muscle weakness induced by tumor necrosis factor-alpha: involvement of muscle myofibrils. *Am J Respir Crit Care Med* **166**: 479–484.
- Rezaian GR, Emad A, Ghayumi MA, Rezaian S, Zare N. (2008). Exercise intolerance and chronotropic impairment-The long-term cardiovascular sequelae of mustard gas exposure: A paired-comparative study. *Environ Toxicol Pharmacol* **26**: 212–215.
- Riahi-Zanjani B, Balali-Mood M, Mousavi SR, Karimi G, Sadeghi M, Shirmast E, Mahmoudi M. (2014). Serum cytokine profiles of Khorasan veterans 23 years after sulfur mustard exposure. *Cytokine* **70**: 161–164.
- Rohani A, Akbari V, Moghadam FT. (2010). A case control study of cardiovascular health in chemical war disabled Iranian victims. *Indian J Crit Care Med* **14**: 109–112.
- Rutten FH, Moons KG, Cramer MJ, Grobbee DE, Zuithoff NP, Lammers JW, Hoes AW. (2005). Recognising heart failure in elderly patients with stable chronic obstructive pulmonary disease in primary care: cross sectional diagnostic study. *BMJ* **331**: 1379.
- Sabourin CL, Danne MM, Buxton KL, Casillas RP, Schlager JJ. (2002). Cytokine, chemokine, and matrix metalloproteinase response after sulfur mustard injury to weanling pig skin. *J Biochem Mol Toxicol* **16**: 263–272.
- Samaha HMS, Elsaid AR, NasrEldin E. (2015). Total serum IgE level in COPD patients. *Egypt J Chest Dis Tuberc* **64**(3): 573–577.
- Sapey E, Ahmad A, Bayley D, Newbold P, Snell N, Rugman P, Stockley RA. (2009). Imbalances between interleukin-1 and tumor necrosis factor agonists and antagonists in stable COPD. *J Clin Immunol* **29**(4): 508–516.
- Shahriary A, Mehrani H, Ghanei M, Parvin S. (2015). Comparative proteome analysis of peripheral neutrophils from sulfur mustard-exposed and COPD patients. *J Immunotoxicol* **12**: 132–139.
- Shahriary A, Panahi Y, Shirali S, Rahmani H. (2017). Relationship of serum levels of interleukin 6, interleukin 8, and C-reactive protein with forced expiratory volume in first second in patients with mustard lung and chronic obstructive pulmonary diseases: systematic review and meta-analysis. *Postepy Dermatol Alergol*. **34**(3): 192–198.
- Shahriary A, Rahmani H. (2017). Need to study of systemic markers changes in acute phase of respiratory complication due to sulfur mustard. *Toxin Reviews* **36**(3): 261–263.
- Sheikhi MA, Rahmani H. (2016). Inflammatory statuses of non-smoker mustard lung patient candidate for coronary artery bypass grafting surgery. *Int J Pharm Res Allied Sci* **5**: 194–195.
- Sheu B. (2008). *Levels of neutrophils stimulation and matrix Metalloprotease in plasma of individuals with elevated blood pressure and acute/long-term exercise*: ProQuest.
- Shohrati M, Amini-Harandi A, Najafian B, Saburi A, Ghanei M. (2014a). The role of serum level of interleukin-6 in severity of pulmonary complications of sulfur mustard injuries. *Iran J Med Sci* **39**: 382–386.
- Shohrati M, Ghanei M, Shamspour N, Jafari M, Khasmaki MNA. (2009). Extra cellular Superoxide Dismutase activity in lung injuries due to Sulfur Mustard. *J Qazvin Uni Med Sci* **12**: 5–11.
- Shohrati M, Haji Hosseini R, Esfandiari MA, Najafian N, Najafian B, Golbedagh A. (2014b). Serum matrix metalloproteinase levels in patients exposed to sulfur mustard. *Iran Red Crescent Med J* **16**: e15129.
- Shrivastava AK, Singh HV, Raizada A, Singh SK. (2015). C-reactive protein, inflammation and coronary heart disease. *The Egyptian Heart Journal* **67**(2): 89–97.
- Schols AM. (2002). Pulmonary cachexia. *Int J Cardiol* **85**: 101–110.
- Schumacher A, Liebers U, John M, Gerl V, Meyer M, Witt C, Wolff G. (2005). P-selectin glycoprotein ligand-1 (PSGL-1) is up-regulated on leucocytes from patients with chronic obstructive pulmonary disease. *Clin Exp Immunol* **142**(2): 370–376.
- Schunemann HJ, Dorn J, Grant BJ, Winkelstein W, Trevisan M. (2000). Pulmonary function is a long-term predictor of mortality in the general population: 29-year follow-up of the Buffalo Health Study. *CHEST Journal* **118**: 656–664.
- Schwartz J, Weiss ST. (1990). Dietary factors and their relation to respiratory symptoms the second national health and nutrition examination survey. *Am J Epidemiol* **132**(1): 67–76.
- Schwartz J, Weiss ST. (1994). Relationship between dietary vitamin C intake and pulmonary function in the First National Health and Nutrition Examination Survey (NHANES I). *Am J Clin Nutr* **59**(1): 110–114.
- Siebenlist U, Brown K, Claudio E. (2005). Control of lymphocyte development by nuclear factor-kappaB. *Nat Rev Immunol* **5**: 435–445.
- Sies H, Stahl W. (1995). Vitamins E and C, beta-carotene, and other carotenoids as antioxidants. *Am J Clin Nutr* **62**(6 Suppl): 1315S–1321S.
- Sin DD, Man SF. (2005). Chronic obstructive pulmonary disease: a novel risk factor for cardiovascular disease. *Can J Physiol Pharmacol* **83**: 8–13.
- Spruit MA, Gosselink R, Troosters T, Kasran A, Gayan-Ramirez G, Bogaerts P, Bouillon R, Decramer M. (2003). Muscle force during an acute exacerbation in hospitalised patients with COPD and its relationship with CXCL8 and IGF-I. *Thorax* **58**: 752–756.
- Strachan DP, Cox BD, Erzinclioğlu SW, Walters DE, Whiclow MJ. (1991). Ventilatory function and winter fresh fruit consumption in a random sample of British adults. *Thorax* **46**: 624–629.
- Strieter RM, Kunkel SL, Bone RC. (1993). Role of tumor necrosis factor-alpha in disease states and inflammation. *Crit Care Med* **21**: S447–463.
- Tabak C, Feskens EJ, Heederik D, Kromhout D, Menotti A, Blackburn HW. (1998). Fruit and fish consumption: a possible explanation for population differences in COPD mortality (The Seven Countries Study). *Eur J Clin Nutr* **52**: 819–825.
- Tsuruta J, Sugisaki K, Dannenberg AM, Jr., Yoshimura T, Abe Y, Mounts P. (1996). The cytokines NAP-1 (IL-8), MCP-1, IL-1 beta, and GRO in rabbit inflammatory skin lesions produced by the chemical irritant sulfur mustard. *Inflammation* **20**: 293–318.
- Vaillant P, Menard O, Vignaud JM, Martinet N, Martinet Y. (1996). The role of cytokines in human lung fibrosis. *Monaldi Arch Chest Dis* **51**: 145–152.
- Visse R, Nagase H. (2003). Matrix metalloproteinases and tissue inhibitors of metalloproteinases: structure, function, and biochemistry. *Circ Res* **92**: 827–839.
- Voll-Aanerud M, Eagan TM, Wentzel-Larsen T, Gulsvik A, Bakke PS. (2008). Respiratory symptoms, COPD severity, and health related quality of life in a general population sample. *Respir Med* **102**: 399–406.
- Weinberger B, Laskin JD, Sunil VR, Sinko PJ, Heck DE, Laskin DL. (2011). Sulfur mustard-induced pulmonary injury: therapeutic approaches to mitigating toxicity. *Pulm Pharmacol Ther* **24**: 92–99.
- Wouters EF, Creutzberg EC, Schols AM. (2002). Systemic effects in COPD. *CHEST Journal* **121**: 1275–1305.
- Wright JG, Christman JW. (2003). The role of nuclear factor kappa B in the pathogenesis of pulmonary diseases: implications for therapy. *Am J Respir Med* **2**: 211–219.
- Wu S, Chen P, Jiang X, Liu Z. (2005). C-reactive protein level and the correlation between lung function and CRP levels in patients with chronic obstructive pulmonary diseases. *Zhong Nan Da Xue Xue Bao Yi Xue Ban* **30**(4): 444–446. [in Chinese]
- Yaraee R, Ghazanfari T, Ebtekar M, Ardestani SK, Rezaei A, Kariminia A, Faghihzadeh S, Mostafaie A, Vaez-Mahdavi MR, Mahmoudi M. (2009a). Alterations in serum levels of inflammatory cytokines (TNF, IL-1alpha, IL-1beta and IL-1Ra) 20years after sulfur mustard exposure: Sardasht-Iran cohort study. *Int Immunopharmacol* **9**(13–14): 1466–1470.
- Yaraee R, Ghazanfari T, Faghihzadeh S, Mostafaie A, Soroush MR, Inai K, Foroutan A, Shams J, Naghizadeh MM, Hassan ZM. (2009b). Alterations in the serum levels of soluble L, P and E-selectin 20years after sulfur mustard exposure: Sardasht-Iran Cohort Study. *Int Immunopharmacol*. **9**(13–14): 1477–1481.

Yaraee R, Hassan ZM, Pourfarzam S, Rezaei A, Faghihzadeh S, Ebtekar M, Soroush M-R, Ardestani SK, Kazemi H, Mahmoudi M. (2013). Fibrinogen and inflammatory cytokines in spontaneous sputum of sulfur-mustard-exposed civilians—Sardasht-Iran Cohort Study. *Int Immunopharmacol* **17**(3): 968–973.

Zakerimoghadam M, Tavasoli K, Nejad AK, Khoshkesht S. (2011). The effect of breathing exercises on the fatigue levels of patients with chronic obstructive pulmonary disease. *Acta Med Indones* **43**: 29–33.

Zandieh T, Marzban S, Tarabadi F, Ansari H. (1990). Defects of cell-mediated-immunity in mustard gas injury after years. *Scand J Immunol* **32**(4): 423.