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OCCUPATIONAL EXPOSURE AND WORK PRACTICES AMONG ETHYLENE OXIDE STERILIZATION WORKERS

By

El-Helaly M[1,2], Balkhy H[1], Vallenius L[1] and Khan W[1]

[1] *Department of Infection, Prevention and Control, King Abdulaziz Medical City, Riyadh, Saudi Arabia,*

[2] *Department of Community Medicine, Faculty of Medicine, Mansoura University, Mansoura, Egypt.*

Abstract

Introduction: Ethylene Oxide (EtO) is a colorless flammable, gas or liquid. In the health care setting, EtO is commonly used for sterilizing heat- and moisture-sensitive medical equipment to prevent health-care associated infections. **Aim of work:** To assess the Ethylene Oxide (EtO) occupational exposure and work practices among the EtO sterilization workers. **Materials and methods:** This study included 28 hospital EtO sterilization workers and 32 controls, all of them filled self-administered questionnaire including questions on their demographic characteristics, work experience, and associated symptoms with special attention to pulmonary, digestive, neurologic, hematologic, reproductive, dermatologic and ophthalmologic symptoms. Liver, kidney and ventilatory function tests were carried out for all participants. Work practices of the EtO sterilization workers were assessed. Moreover, EtO 8-hour time weighted average (TWA) and short term 15 minutes personal monitoring were measured. **Results:** Both 8- hour TWA and short term 15 minutes personal monitoring of the EtO sterilization workers were below the OSHA recommended EtO levels and proper work practices were followed by the workers but 30% of them were not fit tested for respirators use. The study revealed insignificant difference between the EtO sterilization workers and the controls concerning clinical symptoms, liver, kidney and ventilatory function tests. However, the mean of the white blood cells and the lymphocytes absolute numbers were higher among EtO sterilization workers compared to that of the controls, but within the normal range. **Conclusion:** Routine monitoring of EtO sterilizers; training, proper work practices and periodic medical evaluation of the EtO sterilization workers

are important preventive measures to protect them from the harmful effects of EtO. Further research is recommended to study the health effects of EtO exposure at levels below the OSHA 8-hour TWA for EtO.

Keyword: Ethylene oxide, Sterilization, Work practice, Occupational, Exposure, Personal monitoring.

Introduction

Ethylene Oxide (EtO) is a colorless flammable, gas or liquid which has different industrial uses such as the manufacture of ethylene glycol (Kamela et al., 2011).

In the health care setting, EtO is commonly used for sterilizing heat- and moisture-sensitive medical equipment to prevent health-care associated infections caused by organisms transmitted to patients through these instruments used during their care (Occupational Safety and Health Administration (OSHA) 2015). EtO is one of the most widely used low temperature sterilizing agent because its effective bactericidal, sporicidal, and virucidal activity that will extend its future use in sterilizing heat-sensitive materials and devices that would be damaged by pure steam or liquid chemical sterilization (Landrigan et al., 1984, Mendes et al., 2007a). On the other side, EtO could be a potential hazard to the EtO sterilization workers, in addition it is a flammable gas.

The hospital EtO sterilization workers may be exposed to EtO during changing of pressurized ethylene oxide gas cylinders; from leaking valves, fittings, piping, and sterilizer door gaskets; from opening of the sterilizer door at the end of a cycle; from improper ventilation at the sterilizer door; from an improperly ventilated or unventilated air gap between the discharge line and the sewer drain; during removal of items from the sterilizer and transfer of the sterilized load to an aerator; from improper ventilation of aerators and aeration areas; from incomplete aeration of items; from inadequate general room ventilation; and from passing near sterilizers and aerators during operation. The EtO sterilization workers can be exposed to short, concentrated bursts of the gas when the door of a sterilizing machine is opened (Sun, 1986, Hori et al., 2002, Chien et al., 2007a and Dias et al., 2009).

EtO acute toxicity in humans may consist of irritation of the

eyes, respiratory tract and skin, headache, nausea, vomiting, diarrhea, neurological signs and symptoms such as seizures, peripheral neuropathy, gait disturbances, hypoesthesia and lymphocytosis (Currier et al., 1984, Sobaszek et al., 1999, and Yahata et al., 2001) . The effects of chronic exposure toxicity in humans are not well established; however the International Agency for Research on Cancer (IARC) has determined EtO as a definite human carcinogen (Grosse et al., 2007).

The Occupational Safety and Health Administration (OSHA)'s permissible exposure limit for ethylene oxide is an 8-hour time weighted average (8-hour TWA) of airborne concentration of EtO of 1 part EtO per million parts of air (1 ppm) with a short term exposure limit (STEL) of 5 ppm as averaged over a sampling period of any 15 minutes, and an action level of less than O.5 ppm 8-hour TWA (Occupational Safety and Health Administration (OSHA, 1984) and Daniel et al., 2004) . According to OSHA, employees exposed to EtO at and above its action level for at least thirty days a year are required to participate in a medical surveillance program (LaMontagne et al., 2004, OSHA, 2015).

Different studies were conducted to study the EtO exposure and its harmful effects in the industry (Currier et al., 1984,Yodaiken, 1997 ,Chien et al., 2007a and Valdez-Flores et al., 2011), however, as EtO is still commonly used as a sterilizing agent for thermal sensitive medical instruments and equipment (Landrigan et al., 1984), more research is needed to study its exposure among the EtO sterilization workers and the effectiveness of work practices to protect them from its harmful effects.

Aim of work

To assess the Ethylene Oxide (EtO) occupational exposure and work practices among the EtO sterilization workers.

Materials and methods

- **Study design:** This was a case-control study
- **Place and duration of study:** This study was carried out at the sterile processing department (SPD) of King Abdul Aziz Medical City (KAMC) - Saudi Arabia during

the period between January to May 2015.

- **Study Sample:** This study consisted of 60 participants, including EtO sterilization workers (28) and the controls (32). The 28 EtO sterilization workers were the total number of workers who were working in close proximity to 2 EtO sterilizers located at the SPD of KAMC, Saudi Arabia. The controls consisted of 32 employees who were randomly selected form the administration department at KAMC and they had not been exposed to EtO.

-Study methods

Description of the EtO sterilizers and the sterilization process:

Each of the two EtO sterilizers, is comprised of a sterilizing chamber with an air inlet (containing a bacteria-retentive filter); a steam inlet; gas conditioner; vacuum pump; EtO cylinder; and a vacuum system to vent the gas from the chamber to an exhaust drain to the outside. Both sterilizers used 100% pure EO (single-use cartridge) and the frequency of sterilization varied from 2 to 3 loads per day.

The medical equipment and devices to be sterilized were cleaned of contaminants and rinsed with distilled or demineralized water to remove any detergent or tap-water residues; then they were placed in packs and loaded by the EtO sterilization workers into baskets or carts to be placed inside the sterilizer chamber for the duration of the process that starts by heating of the sterilizing chambers by electrical resistance.

The sterilization cycle consists of four phases: conditioning, exposure (sterilizing), exhaust, and air purge. In the conditioning phase, a vacuum pump or water ejector withdraws air from the chamber and allows controlled amounts of moisture or steam to be released by a chamber heating system, thereby raising the relative humidity. Typically, after humidification, EtO is injected automatically into the chamber, initiating the exposure phase. In the exhaust phase, the vacuum system vents the gas from the chamber to an exhaust drain to the outside then the sterilizers purge the chamber with fresh, filtered air to prevent gas buildup from items degassing in the chamber.

The sterilized contents are then aerated to remove EtO residue within the sterilizer chamber. The EtO sterilization workers are responsible for loading and unloading products, in addition to controlling sterilizer parameters and ensuring that the EO supply was not disrupted.

EtO occupational exposure and work practices assessment:

The occupational exposure to EtO among the EtO sterilization workers as well as their work practices were assessed by an expert team consisted of an industrial hygienist and occupational health specialist.

Concerning the assessment of occupational exposure to EtO and work practices; all the EtO sterilization workers filled in a self-administered occupational exposure questionnaire according to OSHA (OSHA, 2015), including questions on: a) EtO work exposure duration in years; b) job task description; c) wearing the proper personal protective equipment (PPE) such as the respirators specially during loading, unloading and change of EtO cartidges and cylinders; d) the existence of the respiratory protection program and respiratory fit testing for the EtO sterilization workers; e) training on the hazards of EtO and how to protect themselves from its harmful effect as a part of hazard communication program.

EtO exposure assessment:

Exposure to EtO was assessed by personal monitoring. Based on OSHA (OSHA, 2015), four EtO sterilization workers were randomly selected from the EtO sterilization workers to represent their EtO exposure because all of EtO sterilization workers were doing the same work, sharing the same working condition, working in the same area, using the same EtO product for the same duration during their shift and working the same distance from the EtO source. They were monitored to determine their exposure for a full shift (8-hour TWA) working in close proximity to the EtO sterilizers.

EtO personal monitoring were done according to OSHA Sampling and analytical methods for ethylene oxide (OSHA, 2009) using passive dosimeters manufactured by the Minnesota Mining and Manufacturing Co. (3M). These dosimeters adsorb EtO vapors on chemically treated

activated charcoal. The contaminants are then desorbed and quantified by gas chromatography with a detection level of 0.012 ppm. Personal samples were taken in the "breathing zone" of the randomly selected four employees and each of them wore small badge clipped to their collar for the expected period of potential exposure (8-hour TWA) including operations with the highest potential for exposures such as changing EtO cylinders. The same selected workers wore another badges clipped to their collar for 15 minutes during unloading the sterilized items from the EtO sterilizers to monitor their STEL for EtO.

All monitors were kept in an ice box and shipped to an American Industrial Hygiene Association accredited laboratory that analyzed all samples and sent us the results. Samples were obtained during periods of maximum EtO concentration by using all available knowledge about the area, employees and process being sampled.

Medical history and laboratory assessment:

Both the EtO sterilization workers and the controls answered a self-administered questionnaire including questions on their personal history, smoking, education, work experience, and general body systems symptoms with special attention to pulmonary, digestive, neurologic, hematologic, reproductive, ophthalmologic and dermatologic symptoms. Also, a 5 ml. of venous blood was collected at a fixed time (8am) from all participants which was divided into 2 ml of blood on EDTA for CBC with differential; and 3 ml of blood which was centrifuged and the serum was stored in deep freezer (-20 C0) for biochemical investigations including: a) liver function tests such as ALP (alkaline phosphatase); AST (aspartate aminotransferase); ALT (alanine aminotransferase); serum albumin; serum bilirubin; b) kidney function tests such as serum creatinine; blood urea. All tests were analyzed by the KAMC main laboratory which is accredited by the College of American Pathologists (CAP).

Ventilatory function assessment:

Ventilatory function tests including forced expiratory volume in one second (FEV1), forced vital capacity (FVC), FEV1/FVC ratio and forced expiratory

flow at 25-75% (FEF25-75) were measured for all participants before the morning shift by two trained spirometry technicians using a MicroLoop portable spirometer (Micro Medical Ltd, Rochester, UK) according to the recommendations of the American Thoracic Society (Redlich et al., 2014). All variables were also converted into the percentage predicted value for each person with the equations integral in the spirometer.

Consent

The study protocol and its benefits and complications were explained to all participants, and all recruited subjects completed and signed an informed consent' form. The consent form developed according to the international ethical guidelines for biomedical research involving human subject, as prepared by the Council for International Organizations of Medical Sciences in collaboration with the World Health Organizations.

Ethical approval

The respective approvals of the review board and the ethics committee of the King Abdullah International Medical Research Center (KAIMRC) were obtained before commencing the study.

Data management

Data were entered into and analyzed by Statistical Package for the Social Science (SPSS) version 17.0. Qualitative data were presented as frequencies and percentages while quantitative data were presented as means and standard deviation (SD). Data were analyzed using Chi-square and Fisher's exact tests for qualitative data and student-t tests for quantitative data. Differences were considered significant when the p value was less than 0.05 and highly significant when the p value was less than 0.01.

Results

The assessment of occupational exposure to EtO and work practices among EtO sterilization workers showed that the mean work experience was 13.43±7.99 years. All exposed workers adopted good work practices including wearing proper PPE and respirators when required specially on dealing with EtO cartridges and cylinders; and all were trained on how

to operate the EtO sterilizers safely and had frequent hazard communication trainings concerning EtO. However, only 70% of them were fit tested for respirators use.

Regarding the EtO personal monitoring, both the 8-hour TWA and the short term 15 minutes of EtO personal exposure of the tested 4 EtO sterilization workers were below the detection level (0.012 ppm).

Table (1): Characteristics of the study population.

	EtO sterilization workers (No= 28)	**Controls (No= 32)**	**P-value**
	No (%)	**No (%)**	
Gender Female Male	 8(28.6%) 20(71.4%)	 13 (40.6%) 19(59.4%)	>0.05
Smoking Non-smoker Current smoker	 20(71.4%) 8(28.6%)	 25(78.1%) 7(21.9%)	>0.05
Education High school University degree Postgraduate	 13(46.4%) 14(50%) 1(3.6%)	 9(28.1%) 22(68.8%) 1(3.1%)	>0.05
	Mean ± SD[a]	**Mean ± SD**	
Age (years)	43.07±7.56	43.06±9.98	>0.05
Work experience (years)	13.43±7.99	11.31±6.64	>0.05

[a]SD: standard deviation P>0.05: Non significant

Table 1 showed that EtO sterilization workers had a mean age of 43.07±7.56 years, 13.43±7.99 mean years of work experience and most of them were males (71.4%) and non-smokers (71.4%). The controls matched the EtO sterilization workers concerning age, gender, smoking, education and work experience (Statistically non significant).

Table (2): Respiratory, dermatologic, ophthalmologic, gastrointestinal, peripheral and central nervous systems and reproductive symptoms among EtO sterilization workers compared to the controls.

Symptoms	EtO sterilization workers (No= 28) No (%)	Controls (No= 32) No (%)	P-value
-Respiratory symptoms.			
Cough	2(7.1%)	3(9.4%)	>0.05
Wheezes	2(7.1%)	0(0.0%)	>0.05
Shortness of breathing during work	0(0.0%)	0(0.0%)	-
Chest pain	0(0.0%)	0(0.0%)	-
Sore throat	0(0.0%)	0(0.0%)	-
-Dermatologic symptoms			
Hives or itchy eruption	2(7.1%)	1(3.1%)	>0.05
Urticarial during work	0(0.0%)	0(0.0%)	-
-Ophthalmologic symptoms.			
Eye irritation	5(17.9%)	6(18.8%)	>0.05
-Gastrointestinal symptoms.			
Nausea vomiting	1(3.6%)	0(0.0%)	>0.05
Diarrhea	3(10.7%)	3(9.4%)	>0.05
Constipation	1(3.6%)	2(6.3%)	>0.05
Heart burn	2(7.1%)	2(6.3%)	>0.05
-Peripheral nervous symptoms.			
Right hand numbness	1(3.6%)	2(6.3%)	>0.05
Left hand numbness	0(0.0%)	2(6.3%)	>0.05
Right leg numbness	0(0.0%)	1(3.1%)	>0.05
Left leg numbness	0(0.0%)	2(6.3%)	>0.05
Right arm weakness	1(3.6%)	2(6.3%)	>0.05
Left arm weakness	0(0.0%)	1(3.1%)	>0.05
Right leg weakness	0(0.0%)	1(3.1%)	>0.05
Left leg weakness	0(0.0%)	1(3.1%)	>0.05

-Central nervous system symptoms.			
Headache	8(28.6%)	5(15.6%)	>0.05
Vertigo	3(10.7%)	3(9.4%)	>0.05
Tremors	0(0.0%)	0(0.0%)	-
Diminished hearing	1(3.6%)	2(6.3%)	>0.05
Diminished vision	3(10.7%)	0(0.0%)	>0.05
Diminished smelling	1(3.6%)	1(3.1%)	>0.05
-Reproductive symptoms.			
Impotence	0(0.0%)	0(0.0%)	-
Loss of libido	0(0.0%)	0(0.0%)	-
History of abortion	0(0.0%)	0(0.0%)	-
History of having babies with congenital anomalies	0(0.0%)	0(0.0%)	-

P>0.05: Non significant

Table 2 showed that there was no statistical significant difference between the EtO sterilization workers and the controls regarding respiratory, dermatologic, ophthalmologic, gastrointestinal, neurologic and reproductive symptoms.

Table (3): Complete blood picture with differential among EtO sterilization workers compared to the controls.

Parameter	EtO sterilization workers (No = 28) (mean ± SD[a])	Controls (No = 32) (mean ± SD)	P-value
WBC[#] (10^9 /L)	8.407±2.098	7.359±1.614	<0.05*
Neutrophils (10^9/L)	4.010±1.459	4.087±1.168	>0.05
Neutrophils %	52.168±8.807	54.722±5.829	>0.05
Lymphocyte (10^9/L)	3.100±1.070	2.499±0.605	<0.05*
Lymphocyte %	37.11±8.39	34.16±6.25	>0.05
Monocytes (10^9/L)	0.55±0.17	0.514±0.169	>0.05
Monocytes %	6.69±1.62	6.95±1.66	>0.05
Basophils (10^9/L)	0.051±0.021	0.063±0.054	>0.05
Basophils %	0.61±0.23	0.88±0.56	<0.05*
Eosinophils (10^9/L)	0.279±0.178	0.241±0.12	>0.05
Eosinophils %	3.42±2.21	3.29±1.57	>0.05
RBC[c] (10^{12}/L)	5.277±0.573	5.205±0.587	>0.05
Hgb[d] (gram/L)	154.321±14.489	146.968±17.512	>0.05
HCT[e] (L/L)	0.448±0.090	0.443±0.046	>0.05
Platelets (10^9/L)	289.929±72.706	292.375±59.472	>0.05

a SD: Standard deviation; b WBC: white blood cell;

c RBC: red blood cell; d Hgb: hemoglobin;

e HCT: hematocrit p<0.05*: Significant P>0.05: Non significant

Table 3 showed statistical significant higher mean absolute numbers of WBC (8.407±2.098) and lymphocytes (3.100±1.070) among EtO sterilization workers compared to the controls (7.359±1.614 and 2.499±0.605 respectively). However, the increases in WBC and Lymphocytes among the EtO sterilization workers were not correlated significantly with their work experience (data not tabulated). In addition, the EtO sterilization workers showed statistical significant lower mean basophils percent (0.61±0.23) compared to that of the controls (0.88±0.56). Both the EtO sterilization workers and the controls did not differ significantly concerning all other CBC parameters.

Table (4): Liver, Kidney and Ventilatory function tests among EtO sterilization workers in comparison to the controls.

Test	EtO sterilization workers (No = 28) (mean ± SD[a])	Controls (No= 32) (mean ± SD)	P-value
Liver function tests			
Albumin (gram/L)	42.75±3.20	41.00±0.00	>0.05
Total Bilirubin (umol/L)	14.13±5.20	15.05±4.76	>0.05
ALP[b] (U/L)	76.71±16.03	75.38±16.88	>0.05
AST[c] (U/L)	25.43±9.21	28.47±15.74	>0.05
ALT[d] (U/L)	37.39±19.43	44.00±34.37	>0.05
Kidney function tests			
Blood urea nitrogen (mmol/L)	4.33±0.99	4.63±1.096	>0.05
Creatinine (umol/L)	76.09±13.18	76.69±13.14	>0.05
Ventilatory function tests			
FEV1[e] (L)	2.829±0.603	2.870±0.586	>0.05
FEV1 % of predict	91.379±9.620	94.306±9.236	>0.05
FVC [f] (L)	3.349±0.718	3.426±0.663	>0.05
FVC % of predict	90.688±9.019	94.431 ±8.956	>0.05
FEV1/FVC ratio	84.721±4.443	83.746 ±3.321	>0.05
FEF_{25-75} [g] (L s^{-1})	3.194±1.001	2.994±0.861	>0.05
FEF_{25-75} % of predict	82.619±23.595	80.744±20.714	>0.05

a SD: Standard deviation; b ALP: alkaline phosphatase; c AST: aspartate aminotransferase;

d ALT: alanine aminotransferase; eFEV1: forced expiratory volume in 1 second;

f FVC: forced vital capacity; gFEF25–75: forced expiratory flow at 25–75%.

P>0.05: Non significant

Table 4 showed that there was no significant difference between the EtO sterilization workers and the controls concerning liver or renal functions including albumin, total bilirubin, liver enzymes, blood urea nitrogen and creatinine levels. Also, both the EtO sterilization workers and the controls did not differ significantly regarding all ventilaltory function tests (Table 4).

Discussion

This study assessed the occupational exposure to EtO among the EtO sterilization workers who were operating 2 ETO sterilizers at SPD of KAMC; through personal monitoring, work practices assessment and medical evaluation.

To assess the occupational EtO exposure among the EtO sterilization workers, we conducted an 8-hour TWA and STEL EtO personal monitoring which showed that the EtO sterilization workers were exposed to very low EtO levels below the detection level (0.012 ppm) which is far below the OSHA permissible exposure limit (1ppm) (OSHA ,2015). This is in agreement with other studies that reported EtO personal exposure at hospital, lower than 1 ppm and even below the detection limit (Shaham et al., 2000, Hori et al., 2002 and Haufroid et al., 2007) which might be related to the recent technology that uses low EtO concentration less than 300 mg/L which shortens the aeration periods after sterilization and lowers the risk of exposure to high level of EtO; in addition to implementing OSHA EtO regulatory requirements (LaMontagne et al., 2004, Chien et al., 2007b and Mendes et al., 2007b).

On the other hand some studies reported increasing STEL which can lead to high EtO exposure in healthcare facilities that not comply with the OSHA EtO regulatory requirements (LaMontagne et al., 2004). Another study carried out in Taiwan, 2005 (Chien et al., 2007b) reported that the EtO sterilization workers in their study had 8-hours TWA EtO exposure of 7.35 ppm. They also found high EtO concentrations in the aeration area, near the sterilizer and in the warehouse (10.19, 5.75, and 8.78 ppm, respectively) and they recommended increasing post sterilization purge cycles, improving area ventilation and using respirators to decrease the worker exposures to EtO. Although our study did not show EtO personal and STE levels over OSHA recommended levels, we could not exclude worker exposure to ETO leak, in addition we did not measure the ambient EtO exposure at the area of the 2 ETO sterilizers.

Our study showed that the EtO sterilization workers, had proper work practices which supports other studies

concluded that proper work practices is an important control measure to protect the EtO sterilization workers from the harmful effects of EtO (LaMontagne et al., 2004, Chien et al., 2007b, Haufroid et al., 2007 and Moser and Reider , 2012).

Although there are numerous studies that reported symptoms among workers exposed to acute inhalation EtO, there are no data about EtO concentrations involved in these studies (Gardner et al., 1989, Sobaszek et al., 1999, Haufroid et al., 2007). The main symptoms were headaches, nausea and generally persistent periodic vomiting (Coggon et al., 2004 and Haufroid et al., 2007). Dyspnea, irritation of the eyes and upper respiratory mucosa, heart damage, excitation, stupor, vertigo and loss of consciousness were also observed (Gardner et al., 1989). Our study did not show any significant difference between the EtO sterilization workers and the controls concerning general body systems symptoms (Table 2), moreover no significant difference in comparison to the controls was reported regarding liver, kidney and ventilatory function tests (Table 4). On the other hand, the present study revealed statistical significant higher mean values of absolute number of the total WBC and Lymphocytes among the EtO sterilization workers compared to the controls (Table 3), however they were within the normal range and the increases in WBC and Lymphocytes among the EtO sterilization workers were not correlated significantly with their work experience (data were not tabulated). This can be considered as an early sign to the effect of EtO exposure among the studied EtO sterilization workers even the very low personal and STE levels below the recommended OSHA level. Also, this might be related to any EtO leak that might had occurred among the workers, but we could not assess. In addition, 30 % of the EtO sterilization workers were not fit tested to the respirators use, giving them false sense of security.

The results of the previous studies (LaMontagne et al., 1993 and Schulte et al., 1995) on hematological effects of low level EtO chronic exposure are contradictory and inconsistent. One of these studies (LaMontagne et al., 1993) reported relative lymphocytosis among

sterilization workers who were exposed to EtO levels below OSHA 8-hour TWA (1ppm), but this was not associated with ethylene oxide exposure and the authors suggested that lymphocytosis may occur only in very highly overexposed workers who simultaneously show severe acute neurotoxic and other symptoms (LaMontagne et al., 1993).

Other studies (Currier et al., 1984 and Shaham et al., 2000) reported no significant differences concerning the absolute mean number of the total WBC and a decrease ($P < 0.01$) in the absolute mean number of lymphocytes; between sterilizing workers exposed to < 0.01 to 0.06 ppm EtO and the controls. Shaham et al. 2000, reported significant elevation in the absolute mean number of monocytes, eosinophils, the percentage of hematocrit and the mean absolute number of the red blood cells among the exposed group compared with the control group, however our study did not find any significant difference concerning above hematological parameters, but we found a significant lower percentage of basophils in the EtO exposed group compared to the controls.

In addition to that, our study did not find significant difference between ETO exposed group and the controls regarding platelets mean value, however other studies (Shaham et al., 2000, Aydın et al., 2011) reported decrease ($P < 0.01$) in the mean absolute number of platelets among the exposed group compared with the control group and they reported that this decrease might be caused by the immunological sensitization to EtO in the bone marrow on long exposure period that can cause depression of platelets and lymphocytes.

Different studies reported acute respiratory symptoms and reduced ventilatory function tests among sterilizing workers exposed accidentally to high level of EtO (Castot et al., 1983, Deschamps et al., 1992, Coggon et al., 2004 and Haufroid et al., 2007) and other studies reported cases of occupational asthma as a result of acute exposure to ethylene oxide (Deschamps et al., 1992, Verraes and Michel, 1995). In the present study, we did not find any significant difference between EtO exposed group and the controls concerning respiratory, eye and skin symptoms; or the ventilatory function

test which might be because they were not exposed to acute or high levels of EtO.

The present study had some limitations such as relatively small sample size and using cross-section study design, collecting data through questionnaire that might be exposed to bias and we did not conduct EtO area monitoring which is important to assess any EtO leak. Moreover, we did not assess the engineering controls of the EtO sterilizers but this was not included in our objectives.

Conclusion

Routine monitoring of EtO sterilizers including area monitoring and leak test; training, proper engineering controls and work practices and periodic medical evaluation of the EtO sterilization works are important preventive measures to protect them from the harmful effects of EtO.

We recommend that using CBC with WBC differential in routine medical surveillance for EtO occupational exposure should be reassessed.

Further research is recommended to study the health effects of EtO exposure at levels below the OSHA 8-hour TWA for EtO.

Conflict of Interest

The authors declare that there is no conflict of interests.

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