

# ADVERSE HEALTH EFFECTS OF GLUTARALDEHYDE AND ITS RELATION TO WORKPLACE SAFETY MEASURES AND WORK PRACTICES OF HEALTH CARE WORKERS

By

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## Abstract

**Introduction:** Glutaraldehyde (GA) is a broad-spectrum biocidal agent for high level disinfection of heat sensitive equipments. It is widely used in hospitals especially in endoscopy units. **Aim of work:** This study aimed to identify adverse health effects of GA and to determine the impact of workplace safety measures and work practices on occurrence and severity of such health effects among health care workers (HCWs) at Ain Shams University hospitals. **Materials and methods:** A cross-sectional study was conducted including 160 HCWs from different departments of Ain Shams University hospitals divided into two groups according to exposure to GA, exposed group (No=80) and unexposed group (No =80). Both groups were interviewed using a structured questionnaire in addition to clinical examination and spirometry. An observational checklist was used to evaluate workplace safety measures where GA solution has been used and work practices of the exposed HCWs. **Results:** Exposed HCWs had a significantly higher frequency of nasal, lower respiratory tract, ocular, skin, headache and other symptoms than unexposed group. They also showed impairment of Pulmonary Function Tests (PFTs) which was significantly correlated to the years spent in the current occupation and the daily work hours. Regarding workplace safety measures in areas where GA was used, the availability of effective general ventilation system with Air Change per Hour (ACH) > 15, automatic washer and specific area for GA

disinfection had a significant effect in reduction of some adverse health effects. Unsafe work practices were associated with some adverse health effects of GA. **Conclusion:** Exposure to GA may lead to many adverse health effects and applying workplace safety measures together with adopting safe work practices can reduce such risks.

**Keywords:** Glutaraldehyde; Healthcare workers; Workplace safety; Work practices; Spirometry; Ventilation and Adverse health effects.

### Introduction

Glutaraldehyde (GA) is a biocide agent for high-level disinfection and cold sterilization to disinfect heat-sensitive equipments such as dialysis equipments, surgical instruments, suction bottles, bronchoscopes, endoscopes, ear, nose, and throat instruments. It is also used as a tissue fixative in histology and pathology labs and as a hardening substance in x-rays (NIOSH, 2001).

Hospital workers can be exposed to GA through inhalation or skin contact (OSHA, 2006). Its effect is mainly on the skin, eye and respiratory tract. Reported adverse health effects related to short term exposure to glutaraldehyde are due to its irritant effect (Cohen and Patton, 2006). They include irritation to the nose, eye and pharynx leading to sore throat, sneezing, cough, headache, nausea, rash and redness of skin (Takigawa and Endo, 2006; Nayebzadeh, 2007). Moreover, a sensitizing effect may occur due to long term exposure to glutaraldehyde (Waters

et al., 2003). It includes bronchitis, breathing difficulty, wheezing, cough, bronchial asthma, skin rash, staining, allergic and contact dermatitis (Kieć-Swierczyńska and Krecisz, 2000; Lipińska-Ojrzanowska et al., 2014). The most serious effect of glutaraldehyde is occupational asthma, a chronic condition characterized by bronchial hyper responsiveness reaction which can be either immediate or delayed (Sutton et al., 2007). Its severity depends on the duration of exposure. Once an individual becomes sensitized, he develops strong reaction with lower level of exposure (Takigawa and Endo, 2006).

Incidence of adverse health effects due to GA exposure have increased over the past few years (Vyas et al., 2000). Those adverse health effects are related to ineffective safety measures at the workplace (Waters et al., 2003; Takigawa and Endo, 2006).

Highest exposures and therefore highest health risks occur during spillage or during biocide changeover, thus safe

work practices have a significant effect on reducing GA exposure level and its adverse health effects (Nayebzadeh, 2007). Health studies of workers exposed to glutaraldehyde have shown that good work practices prevent allergic skin reactions (OSHA, 2006) and considered as a primary prevention to reduce occupational asthma (Heederik et al., 2012).

### **Aim of work**

This study aimed to identify adverse health effects of GA and to determine the impact of workplace safety measures and work practices on occurrence and severity of such health effects among health care workers (HCWs) at Ain Shams University hospitals.

### **Materials and methods**

- **Study design:** A comparative cross-sectional study was conducted.

- **Place and duration of the study:** The study was conducted at Ain Shams University hospitals from October 2015 to May 2016.

- **Study sample:** The study population included 2 groups; GA exposed group recruited from surgical operations units (general surgery and urology) and endoscopy units (GIT, gynecology and surgery), where GA solutions are used

to disinfect heat sensitive equipment, and unexposed group recruited from hospital units where GA solutions are not used. HCWs having a history of chronic respiratory or dermatological conditions due to any other causes were excluded from the study. The sample size was calculated according to the formula " $n = [t^2 \times p (1-p)] / m^2$ " (FluidSurveys, 2014) where "t" is the confidence level at 95% (standard value of 1.96), "p" is the prevalence of bronchial asthma due to GA exposure among HCWs (Mapp, 2001) and "m" is the margin of error at 5% (standard value of 0.05). The sample size is calculated for the exposed not the total sample studied, as you used the prevalence of asthma. Accordingly, a total sample of 160 HCWs were included in the study and divided into 2 groups matched for age and sex; a GA exposed group (80 HCWs) and an unexposed group (80 HCWs).

### **- Study methods:**

1- Data were collected through an **interview questionnaire** from all included HCWs (exposed and unexposed groups) including personal and occupational histories and symptoms of adverse health effects of GA as nasal, respiratory tract, ocular, skin, headache and other symptoms.

**2-Clinical examination** (nasal, chest, ocular and skin examination) were done for both groups.

**3-Pulmonary functions** were assessed by spirometry ( $FEV_1$ , FVC,  $FEV_1/FVC$ , PEF).

**4- Observational checklist** was used to evaluate workplace safety measures where GA solution has been used. It included evaluation of general ventilation, local exhaust ventilation (local exhaust hood and ductless fume hood), air change per hour (at least 10 per hour), automatic washers and closed transfer lines, use of safety nozzle, presence of mobile disinfecting station, warning signs, personal protective equipments (PPE), specific area for disinfection by GA with limiting access to only trained workers, good housekeeping of workplace, presence of emergency eye wash units which located near areas of GA usage and health education to HCWs about safe handling of GA (OSHA, 2006).

**5- Work Practice Checklist** was used to evaluate work practices of the exposed HCWs. It included the use of protective gloves, safety glasses and apron, running water in a sink before disposal of waste GA solution, pouring exhausted fresh GA solution gently

avoiding splash and spill or agitation of solution, and disposing all contaminated linen and towels properly (Nayebzadeh, 2007).

Nurses and maintenance workers had a major role while technicians had a minor role in disinfection process. Although surgeons and anesthesiologists (No=10) don't directly deal with GA; were also affected (by inhalation) as disinfection process was performed in the same area where they do their work duties. Accordingly, work practices were evaluated among nurses, maintenance workers and technicians (No=70).

Work practices were graded into 3 categories (appropriate, unsafe and poor) according to the following criteria:

**A- Appropriate work practices** include: Use of PPE, running water in a sink before disposal of GA waste solution, pouring exhausted fresh GA solution gently avoiding spill or agitation of solution, disposing all contaminated linen and towels properly.

**B- Poor work practices** include: Leaving container uncovered, inappropriate disposal of contaminated

linen and towels during disinfection process, excessive release of GA vapor and droplets during vigorous decanting and presence of droplets around the containers or on the surface.

### **C- Unsafe work practices include:**

Poor practice as defined above in addition to the presence of spills on surfaces (counters, surface, floors, etc.) during any part of handling with GA solution and leakage of solution from containers due to lose lids or cracks, etc... (Nayebzadeh, 2007).

### **Consent**

An informed consent was taken from each participant and confidentiality of

the obtained data was ensured

### **Ethical approval**

Approvals to conduct the study were obtained from Ain Shams University administration and Research Ethics Committee of Faculty of Medicine, Ain Shams University.

### **Data management**

The collected data were revised for completeness and consistency, coded and analysed by using the SPSS version 23 software. Data were analysed according to the type of variables. The level of significance adopted in this study was a two-sided P-value < 0.05 and the confidence level interval adopted for adjusted odds ratios was

## **Results**

The mean age of HCWs in the exposed and unexposed groups was  $34 \pm 10$  and  $37 \pm 9$  years old respectively. Male HCWs represented 36% of the exposed group and 24% of the unexposed group while female HCWs represented 64% of the exposed group and 76% of the unexposed group. There were no statistically significant differences between both groups regarding sociodemographic characteristics (age and gender), medical and family histories ( $p > 0.05$ ). Moreover, there was no statistically significant differences between both groups regarding their occupational history ( $p > 0.05$ ) where physicians represented 12% of the exposed group and 10% of the unexposed group, nurses represented 60% of the exposed group and 62% of the unexposed group, other workers represent 28% of the exposed group and 28% of the unexposed group. The mean duration of work of HCWs in the exposed and unexposed groups was  $10.4 \pm 8.9$  years and  $13.0 \pm 9.0$  years respectively, and the mean working hours per day of HCWs in the exposed and unexposed groups was  $8.7 \pm 4.2$  hours and  $8.9 \pm 5.0$  hours respectively (Results are not tabulated).

**Table 1: Comparison between both groups regarding GA adverse health effects.**

| Adverse health effects# | Exposed<br>No % | Unexposed<br>No % | X <sup>2</sup> | P               | Odds<br>ratio | CI        |
|-------------------------|-----------------|-------------------|----------------|-----------------|---------------|-----------|
| <b>Chest</b>            |                 |                   |                |                 |               |           |
| Nose irritation         | 79 (98.8%)      | 14 (17.5%)        | 108.49         | <b>0.0001**</b> | 6.54          | 4.03-10.6 |
| Rhinorrhea              | 60 (75%)        | 0 (0%)            | 96.000         | <b>0.0001**</b> | -             | -         |
| Throat irritation       | 48 (60%)        | 4 (5%)            | 55.176         | <b>0.0001**</b> | 9.14          | 3.5- 23.6 |
| Dry cough               | 48 (60.0%)      | 8 (10.0%)         | 43.956         | <b>0.0001**</b> | 4.8           | 2.5- 9.3  |
| Productive cough        | 17 (21.2%)      | 0 (0%)            | 19.021         | <b>0.0001**</b> | -             | -         |
| Dyspnea                 | 56 (70%)        | 2 (2.5%)          | 78.864         | <b>0.0001**</b> | 22.1          | 5.6- 86.9 |
| Wheezes                 | 25 (31.2%)      | 0 (0%)            | 29.630         | <b>0.0001**</b> | -             | -         |
| Asthmatic attack        | 7 (8.8%)        | 0 (0%)            | 7.320          | <b>0.014*</b>   | -             | -         |
| Chronic bronchitis      | 24 (30.0%)      | 2 (2.5%)          | 22.227         | <b>0.0001**</b> | 7.5           | 1.9- 28.8 |
| <b>Eye</b>              |                 |                   |                |                 |               |           |
| Eye sore                | 79 (98.8%)      | 0(0%)             | 156.04         | <b>0.0001**</b> | -             | -         |
| Eye irritation          | 80 (100%)       | 0(0%)             | 160.00         | <b>0.0001**</b> | -             | -         |
| <b>Skin</b>             |                 |                   |                |                 |               |           |
| Skin allergy            | 30 (40.0%)      | 5(6.2%)           | 25.222         | <b>0.0001**</b> | 4.3           | 1.9- 9.9  |
| Change of skin color    | 53 (70.7%)      | 0(0%)             | 85.9           | <b>0.0001**</b> |               |           |
| <b>Headache</b>         | 48 (60.0%)      | 19 (23.8%)        | 21.5           | <b>0.0001**</b> | 2.3           | 1.5- 3.47 |
| <b>Others##</b>         | 47 (58.8%)      | 6 (7.5%)          | 47.427         | <b>0.0001**</b> | 6.1           | 2.8- 13.1 |

# : Significant associations only are represented in this table.

##: "others" include nausea, frequent attack of common cold, nasal congestion (sinusitis), blurring vision, fatigue and abdominal pain collectively.

\*: Statistically significant (p<0.05)

\*\* : Highly statistically significant (p<0.01)

By comparing adverse health effects in both groups, it was found that GA exposed group had significantly higher frequencies of respiratory manifestations as nose irritation, rhinorrhea, throat irritation, dry cough, productive cough, dyspnea, wheezes, chronic bronchitis (which was diagnosed by productive cough for 3 months at 2 consecutive years) and asthmatic attack during exposure to GA than unexposed group. Results also showed significantly higher frequency of ocular manifestations as eye sore and eye irritation, skin manifestations as skin allergy and change of skin color, headache and other manifestations as nausea, frequent attack of common cold, nasal congestion (sinusitis), blurring in vision, fatigue and abdominal pain among GA exposed group than unexposed group (Table 1).

**Table 2: Comparison between both groups as regard post exposure pulmonary function.**

| PFTs                  | Exposed<br>Mean $\pm$ SD | Unexposed<br>Mean $\pm$ SD | t   | P               |
|-----------------------|--------------------------|----------------------------|-----|-----------------|
| FVC%                  | 7217 $\pm$               | 908 $\pm$                  | 8.5 | <b>0.0001**</b> |
| FEV <sub>1</sub> %    | 73.718 $\pm$             | 958 $\pm$                  | 9.4 | <b>0.0001**</b> |
| FEV <sub>1</sub> /FVC | 8713 $\pm$               | 916 $\pm$                  | 2.4 | <b>0.014*</b>   |
| PEF%                  | 5319 $\pm$               | 76 $\pm$ 16                | 7.8 | <b>0.0001**</b> |

PFTs: Pulmonary Function Tests

FVC%: Forced Vital Capacity.

FEV<sub>1</sub>%: Forced Expiratory Volume in the first second.

PEF%: Peak Expiratory Flow rate.

FEV<sub>1</sub>/FVC: Forced Expiratory Volume in the first second/Forced Vital Capacity.

\*: Statistically significant (p&lt;0.05)

\*\*: Highly statistically significant (p&lt;0.01)

Table 2 showed that there was a statistically significant differences between exposed and unexposed groups regarding FVC%, FEV<sub>1</sub>%, FEV<sub>1</sub>/FVC and PEF%.

It is worth noting that, among the exposed group, more impairment of Pulmonary Function Tests (PFTs) was significantly correlated to the years spent in the current occupation and the daily work hours ( $r = -0.467$ ,  $p < 0.01$ ) (results are not tabulated).

**Table 3: Relation between type of ventilation and GA adverse health effects.**

| Adverse health effects#                             | Types of ventilation <sup>###</sup> |                                   |                                |                         | p               |
|---|-------------------------------------|-----------------------------------|--------------------------------|-------------------------|-----------------|
|   | General<br>ventilation<br>No %      | Mechanical<br>ventilation<br>No % | Natural<br>ventilation<br>No % | Test of<br>significance |                 |
| <b>Chest</b><br>Dyspnea                             | 3 (5.4%)                            | 39 (69.6%)                        | 14 (25.0%)                     | X <sup>2</sup> =7.1     | <b>0.028*</b>   |
| <b>Eye</b><br>Eye sore                              | 8 (10.1%)                           | 54 (68.4%)                        | 17(21.5%)                      | X <sup>2</sup> =7.9     | <b>0.018*</b>   |
| Lacrimation   | 6 (8%)                              | 52 (69.3%)                        | 17(22.7%)                      | X <sup>2</sup> =12.9    | <b>0.020*</b>   |
| Redness eye   | 3 (5.2%)                            | 42 (72.4%)                        | 13(22.4%)                      | X <sup>2</sup> =7.8     | <b>0.002**</b>  |
| <b>Skin</b><br>Change of skin color                 | 6 (11.3%)                           | 42 (79.2%)                        | 5 (9.4%)                       | X <sup>2</sup> =19.3    | <b>0.0001**</b> |
| Dryness of skin                                     | 7 (12.7%)                           | 40 (72.7%)                        | 8 (14.5%)                      | X <sup>2</sup> =7.8     | <b>0.002**</b>  |
| <b>Others</b><br>Frequent attacks of<br>common cold | 1 (3.3%)                            | 25 (83.3%)                        | 4 (13.3%)                      | X <sup>2</sup> =7.9     | <b>0.019*</b>   |
| Fatigue   | 1 (3.1%)                            | 26 (81.2%)                        | 5 (15.6%)                      | X <sup>2</sup> =8.07    | <b>0.018*</b>   |
| Abdominal pain                                      | 1 (7.7%)                            | 12 (92.3%)                        | 0 (0%)                         | X <sup>2</sup> =7.4     | <b>0.040*</b>   |
| <b>Spirometry</b><br>FEV <sub>1</sub> /FVC          | Mean $\pm$<br>SD<br>94 $\pm$ 6      | Mean $\pm$ SD<br>84.6 $\pm$ 14    | Mean $\pm$ SD<br>92.7 $\pm$ 10 | F= 3.8 <sup>##</sup>    | <b>0.025*</b>   |

General ventilation: with air change per hour (ACH)&gt;15

Mechanical ventilation: split air conditioning

Natural ventilation: windows and doors.

FEV1/FVC: Forced Expiratory Volume in the first second/Forced Vital Capacity.

#: Significant associations only are represented in the table.

##: post hoc test revealed that FEV1/ FVC is significantly lower in the presence of mechanical ventilation with no ACH than in the presence of natural ventilation or general ventilation.

###: Risk Estimate statistics cannot be computed. They are only computed for a 2\*2 table.

\*: Statistically significant (p<0.05)

\*\* : Highly statistically significant (p<0.01)

Table 3 showed that exposed group revealed that there was a statistically significant association between the type of ventilation and health manifestations as dyspnea, change of skin color, skin dryness, eye sore, lacrimation, redness eye and other manifestations (frequent attack of common cold, fatigue, abdominal pain). These manifestations were more frequent in case of mechanical ventilation (split air conditioning) with no air change per hour (ACH) compared to natural ventilation through doors and windows and general ventilation with air change per hour (ACH) >15. Regarding pulmonary function tests of GA exposed group; there was a statistically significant difference in FEV<sub>1</sub>/ FVC among exposed HCWs in presence of different types of ventilation (p < 0.05), in which it was lowest in presence of mechanical ventilation (split air conditioning) with no ACH (84.6±14.0 L/sec) followed by natural ventilation (windows and doors) (92.7±10.0 L/sec) and general ventilation with air exchange (ACH) per hour>15 (94±6.0 L/sec).

**Table 4: Relation between use of automatic washer and specific area for disinfection by GA with limiting access and GA adverse health effects.**

| Automatic washer        |             |            |                 |               |                      |
|-------------------------|-------------|------------|-----------------|---------------|----------------------|
| Adverse health effects# | Yes<br>No % | NO<br>No % | p-value         | OR            | CI                   |
| <b>Skin</b>             |             |            |                 |               |                      |
| Change of color         | 5(9.4%)     | 48(90.6%)  | <b>0.0001**</b> | 5.7           | 2.3-                 |
| Dryness skin            | 10(16.1%)   | 52(83.9%)  | <b>0.038*</b>   | 2.4           | 14.4<br>1.04-<br>5.4 |
| <b>Others</b>           |             |            |                 |               |                      |
| Abdominal pain          | 0 (0%)      | 13(10%)    | <b>0.041*</b>   | -             | -                    |
| <b>Spirometry</b>       |             |            |                 |               |                      |
| PEF%                    | 62.1±22.7   | 51.5±18.3  |                 | <b>0.047*</b> |                      |



| Specific area for disinfection with limiting access |                  |                  |                |                |                     |
|---|------------------|------------------|----------------|----------------|---------------------|
| Adverse health effects#                             | Yes<br>No %      | NO<br>No %       | p-value        | OR             | CI                  |
| <b>Skin</b>   |                  |                  |                |                |                     |
| Change of color                                     | 21(39.6%)        | 32(60.4%)        | <b>0.003**</b> | 1.95           | 1.3-                |
| Skin allergy  | 11(37%)          | 19(6%)           | <b>0.048*</b>  | 1.6            | 2.9<br>0.9-<br>2.7  |
| <b>Others</b>                                       |                  |                  |                |                |                     |
| Frequent attack of common cold                      | 9 (30%)          | 21(70%)          | <b>0.004*</b>  | 1.93           | 1.06-               |
| Fatigue   | 10(31.2%)        | 22(68.8%)        | <b>0.007*</b>  | 1.8            | 3.5<br>1.05-<br>3.2 |
| <b>Spirometry</b>                                   | <b>Mean ± SD</b> | <b>Mean ± SD</b> |                |                |                     |
| FEV <sub>1</sub> /FVC                               | 929±             | 8215±            |                | <b>0.001**</b> |                     |
| PEF%  | 6016±            | 4720±            |                | <b>0.002**</b> |                     |

#Significant relations only are represented in the table.

FEV<sub>1</sub>/FVC: Forced Expiratory Volume in the first second/Forced Vital Capacity.

PEF%: Peak Expiratory Flow rate.

\*: Statistically significant (p<0.05)

\*\* : Highly statistically significant (p<0.01)

Table 4 showed that there was a statistically significant association between lack of use of automated washer and adverse health effects as change of skin color (90.6%, OR=5.7, 95% CI=2.3-14.4), dryness of the skin (83.9%, OR= 2.4, 95% CI=1.04-5.4) and other manifestations as abdominal pain (10%) (p < 0.05).

Regarding pulmonary function tests of GA exposed group; there was more deterioration in PEF% in absence of automated washer (51.5±18.3 versus 62±22.7) (p<0.05). In addition, there was a statistically significant association between absence of specific area for disinfection with limiting access and GA adverse health effects as skin allergy (63.3%, OR=1.6, 95% CI=0.9- 2.7), change of skin color (60.4%, OR=1.95, 95% CI=1.3- 2.9), frequent attack of common cold (70%, OR=1.93, 95% CI=1.06- 3.5) and fatigue (68.8%, OR=1.8, 95% CI=1.05- 3.2) by using chi-square test.

Moreover, there was more deterioration in FEV<sub>1</sub>/FVC and PEF% (82±15 versus 92±9 and 47±20 versus 60±16 respectively) in absence of specific area for disinfection with limiting access by using t-test (p<0.01).

**Table 5: Relation between work practices (WP) and its relation to GA adverse health effects.**

| Adverse health effects# | Poor WP          |                  | Unsafe WP |         | Test of significance   | P              | Odds ratio | 95% CI     |
|-------------------------|------------------|------------------|-----------|---------|------------------------|----------------|------------|------------|
|                         | No               | %                | No        | %       |                        |                |            |            |
| <b>Eye</b>              |                  |                  |           |         |                        |                |            |            |
| Lacrimation             | 23               | (34.3%)          | 44        | (65.7%) | Fischer Exact          | <b>0.047*</b>  | 2.9        | 2.09- 4.05 |
| Redness eye             | 16               | (29.6%)          | 38        | (70.4%) | X <sup>2</sup> =5.712  | <b>0.017*</b>  | 2.1        | 1.2-3.9    |
| <b>Skin</b>             |                  |                  |           |         |                        |                |            |            |
| Change of skin color    | 14               | (26.4%)          | 39        | (73.6%) | X <sup>2</sup> =10.758 | <b>0.001**</b> | 2.6        | 1.5- 4.6   |
| Dryness of skin         | 19               | (32.2%)          | 40        | (67.8%) | X <sup>2</sup> =3.924  | <b>0.048*</b>  | 1.9        | 1.1- 3.5   |
| <b>Others</b>           |                  |                  |           |         |                        |                |            |            |
| Frequent attack of cold | 5                | (16.7%)          | 25        | (83.3%) | X <sup>2</sup> =7.919  | <b>0.005**</b> | 3.1        | 1.3- 7.3   |
| Fatigue                 | 6                | (18.8%)          | 26        | (81.2%) | Fischer Exact          | <b>0.008**</b> | 2.8        | 1.2-6.1    |
| Abdominal pain          | 1                | (7.7%)           | 12        | (92.3%) | Fischer Exact          | <b>0.035*</b>  | 5.7        | 0.8-38.3   |
| <b>Spirometry</b>       | <b>Mean ± SD</b> | <b>Mean ± SD</b> |           |         |                        |                |            |            |
| FEV <sub>1</sub> /FVC   | 93±9             | 84±15            |           |         | t=2.7                  | <b>0.008**</b> | -          | -          |
| PEF%                    | 61±19            | 46±16            |           |         | t=3.4                  | <b>0.001**</b> | -          | -          |

# Significant relations only are represented in the table.

FEV<sub>1</sub>/FVC: Forced Expiratory Volume in the first second/Forced Vital Capacity.

PEF%: Peak Expiratory Flow rate.

\*: Statistically significant (p<0.05)

\*\* : Highly statistically significant (p<0.01)

According to work practices checklist, 26 (37.14 %) of work practices of GA exposed HCWs were poor and 44 (62.85 %) of them were unsafe. No one of the GA exposed HCWs adopt safe work practices (results are not tabulated).

Table 5 showed that there was a statistically significant association between HCWs work practices and their GA related adverse health effects (p<0.05). Unsafe work practice was significantly associated with lacrimation (OR=2.9, 95% CI=2.09-4.05), redness of the eye (OR=2.1, 95% CI=1.2-3.9), change of skin color (OR=2.6, 95% CI=1.5- 4.6), dryness of the skin (OR=1.9, 95% CI=1.1- 3.5), frequent attacks of common cold (Odds ratio=3.1, 95% CI=1.3-7.3), fatigue (OR=2.8, 95% CI=1.2-6.1) and abdominal pain (OR=5.73, 95% CI=0.8-38.3). Moreover, there was a statistically significant difference in pulmonary functions in relation to work practices (p<0.05), where FEV<sub>1</sub>/FVC and PEF% were significantly lower among HCWs with unsafe work practice compared to those with poor work practice (84±15 versus 93±9 L/sec and 46±16 versus 61±19 L/sec respectively).

.95%

### Discussion

Glutaraldehyde (GA) is a toxic substance which can cause irritation and sensitization effect on respiratory tract, eye and skin. Workplace safety measures and work practices are the cornerstone in its prevention and control. The current study aimed to identify adverse health effects of GA and its relation to workplace safety measures and work practices at Ain Shams University hospitals.

Exposed and unexposed groups were matched in socio-demographic data and occupational history as regard age, sex, marital status, residence, smoking habits, work unit, current occupation, years spent in the current occupation and the number of work hours per day, evidenced by the non-significant differences between both groups regarding such factors.

Exposed group had significantly higher frequency of upper respiratory tract (URT) manifestations (nasal and throat) in comparison to unexposed group (Table 1). This finding may be due to acute irritant effect of GA exposure during work and it agreed with the results of Takigawa and Endo (2006), who reported that the prevalence of

URT symptoms due to exposure to GA were nose irritation (64%), pharyngeal irritation (41%) and sore throat (16%) and were mainly due to the irritant effect of GA.

The higher frequency of nasal symptoms due to exposure to GA in the workplace reported in the present study (Table 1) compared to the work done by Takigawa and Endo (2006) (98% versus 64%) may be due to ineffective safety measures at the workplace and unsafe work practices.

The current study showed that the exposed group has a significantly higher frequency of lower respiratory tract (LRT) manifestations as dry cough, productive cough, dyspnea, wheezes, asthmatic attack and chronic bronchitis compared to unexposed group (Table 1). Those manifestations may be due to the irritant effect or the chronic allergic (sensitization) effect of GA. Wheezes and cough were the most frequent LRT symptoms. Vyas et al. (2000), in his study of the symptoms related to GA exposure among endoscopy nursing staff (current workers and ex-employees), found a high frequency of LRT symptoms among them. They also declared that LRT symptoms may be due to the irritant or the allergic effect of GA and

there was no dose response relationship except for chronic bronchitis. Chest tightness and persistent cough were the most prevalent symptoms in their study, which is consistent with the current study results. Moreover, the results were not far from what reported by Waters et al. (2003), in a study of symptoms in HCWs exposed to GA, who reported that the prevalence of asthma was (13.2%) and wheezes was (21%). The difference in the frequency of LRT symptoms between the current study and other studies (Vyas et al. 2000; Waters et al., 2003) may be due to different environmental conditions, duration of exposure and individual variations.

The exposed group had significantly higher frequency of ocular manifestations (eye sore and eye irritation) compared to unexposed group (Table 1). Nayebzadeh (2007), in his study among Indian healthcare workers using GA, detected high prevalence of ocular symptoms as eye irritation (64%), itching (42%), burning eyes (39%). Similarly, Pisaniello et al. (1997) found in their study among endoscopy nurses in South Australia, that nurses exposed to GA were significantly more likely to have ocular symptoms compared with

their control group.

The present study showed that the exposed group had significantly higher frequency of skin manifestations (skin allergy and change of skin color) compared to unexposed group (Table 1). Similar findings were reported by Waters et al. (2003), in a study of the symptoms of GA exposure among HCWs. The higher frequency of nasal, respiratory, ocular and skin symptoms and headache in the current study compared to other studies may be due to higher concentration of exposure due to bad environmental conditions or may be due to long duration of exposure, moreover stressful work in operating theatre and individual variations (Nayebzadeh, 2007).

Also the higher frequency of other symptoms as nausea, frequent attack of common cold, nasal congestion (sinusitis), blurring in vision, fatigue and abdominal pain among the exposed group may be contributed to GA exposure (Table 1). As an aldehyde, GA may cause indefinite complaints due to environmental exposure (Dimich-Ward et al., 2003).

Spirometry was performed for both groups. For the exposed group, it was performed before and after GA

exposure (after endoscopy session or after changeover of GA). GA exposed group was found to have significantly higher impairment in pulmonary functions, as indicated by lower FVC%, FEV<sub>1</sub>%, FEV<sub>1</sub>/FVC and PEF% (whether before or after the exposure), compare to unexposed group (Table 2). These results were similar of what reported by Vyas et al. (2000), in their study among endoscopy nursing staff, where they found that exposure to GA has been shown to reduce FVC and FEV<sub>1</sub> among current and ex-employees.

The current study showed that there was statistically significant association between type of ventilation in the workplace and GA adverse health effects (Table 3). HCWs in units having general ventilation system with air change per hour (ACH>15) had the least frequency of dyspnea, eye sore, redness eye, lacrimation, change of skin color, skin dryness, and other manifestations as frequent attack of common cold, fatigue, abdominal pain compared to natural ventilation (doors and windows) and mechanical ventilation (split air conditioning). Mechanical ventilation was significantly associated with the highest frequency of all mentioned adverse health effects (Table 3).

Moreover, there was more impairment in FEV<sub>1</sub>/FVC among exposed HCWs in the presence of mechanical ventilation with no air change per hour(ACH) than in the presence of natural ventilation and general ventilation with air change per hour(ACH) >15. The latter showed minimal or no impairment (Table 3). These results were in agreement with Weber and Rutala (2001), in their study about adverse health effects of GA.

The current study showed that areas where automatic washer was not used (only manual methods is present) have a significantly higher frequency of change of skin color, skin dryness, abdominal pain and impairment of PEF% with significant difference compared to other areas using automatic washer (Table 4). These results were consistent with the work done by Smith and Wang (2006), where they measure GA exposure level and its effect on HCWs. It revealed that increased use of automatic and semi-automatic washer/disinfection machines has reduced the potential for exposure to GA vapors, thus it decreases adverse health effects when compared with manual methods.

Moreover, results showed that workers in units which had specific area for GA disinfection process with

limiting access to only trained personnel had a lower frequency of skin allergy, change of skin color, frequent attack of common cold and fatigue. It also showed that workers in units without specific area for GA disinfection had significant higher impairment of pulmonary functions as  $FEV_1/FVC$ ,  $PEF\%$  than other areas (Table 4). Our results agreed with that of Cohen and Patton (2006), in their study on worker safety and its relation to GA exposure, where they reported that designing a safe place for GA disinfection process is very important in enhancing the safety when using toxic hazardous substance as GA.

HCWs with unsafe work practices had a higher frequency of lacrimation, redness eye, change of skin color, skin dryness, frequent attack of common cold, fatigue, abdominal pain, a significantly higher impairment in  $FEV_1/FVC$  ( $p < 0.05$ ) and  $PEF\%$  ( $p = 0.01$ ) than those with poor work practice (Table 5). The results of the current work were in agreement with Nayebzadeh (2007), in his study about the effect of work practices on personal exposure to GA among HCWs, in which he concluded that GA spills during any tasks especially changeover, is the main cause of exposure and that

areas with appropriate work practices had lower level of GA exposure than other areas with poor and unsafe work practices. Also, he found that workers in unsafe areas showed higher prevalence of symptoms of adverse health effects. Similarly, Jara and his coworkers (2013); in their study on health care workers in a primary health care unit, reported that safe and proper work practices in the workplace lead to decrease GA exposure and its adverse health effects.

### **Conclusion:**

This study documented a significant symptoms of adverse health effects and impairment of PFTs among exposed HCWs. Effective ventilation with  $ACH > 15$  cycle per hour and specific area for GA disinfection couldn't be dispensed in prevention and control of GA exposure. Manual method of GA disinfection lead to more adverse health effects than automatic washer. In addition, unsafe work practices can lead to more adverse health effects.

### **Recommendations:**

According to the results of the study, the following can be recommended:

- Pre-employment medical examination and periodic medical

examination of HCWs who handle GA should include PFTs to detect early deterioration in pulmonary functions.

- All workplace safety measures should be applied where glutaraldehyde is used especially local exhaust ventilation, air change per hour (more than 15 cycle per hour), facility design of workplace, presence of warning signs, using automatic washers and availability of personal protective equipments (PPE) (OSHA, 2006). The use of mechanical ventilation in the form of split air conditioning should be minimized.
- Health education for all workers who handle GA which should focus on proper work practices and its importance in reducing adverse health effects.
- The importance of proper and safe work practices in decreasing the exposure to GA and minimizing the adverse health effects of GA should be emphasized, as poor and unsafe work practices lead to spills and droplets leading to more exposure to GA vapor

and more adverse health effects.

### **Conflicts of interest**

The authors declared that they have no competing of interests

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