RESEARCH

Evaluation of procedural modifications to reduce glutaraldehyde vapors during the disinfection of endoscopes using three sampling methods

Glutaraldehyde is the preferred disinfectant for fiberoptic endoscopes. A number of studies have reported adverse health effects in workers exposed to glutaraldehyde vapors. High exposures can occur during the pouring and disposal of glutaraldehyde solutions. This study has tested the effectiveness of three procedural modifications designed to reduce exposures during these activities. These procedures were: (1) the use of a splash-resistant safety nozzle during the pouring of glutaraldehyde solutions, (2) the use of neutralizers during the disposal of glutaraldehyde solutions, and (3) the pouring of 14-day versus 28-day glutaraldehyde solutions. This study also evaluated three sampling methods to monitor glutaraldehyde vapors. The three methods evaluated were: (1) the OSHA method 64 using filter cassettes impregnated with 2,4-dinitrophenylhydrazine (DNPH); (2) DNPH-coated passive diffusion badges; and (3) a direct reading glutaraldehyde meter. Results showed that when the safety nozzle was not used during disinfection procedures, geometric means for all sampling methods were above the ACGIH TLV of 0.05 ppm (filter cassettes = 0.105 ppm; passive badges = 0.191 ppm; meter = 0.082 ppm). Using the safety nozzle during the pour resulted in significant reductions in glutaraldehyde vapor concentrations (filter cassettes = 0.014 ppm; passive badges = 0.027 ppm; meter = 0.021 ppm). Disposal of non-neutralized glutaraldehyde solutions resulted in peak vapor concentrations of up to 0.10 ppm. Neutralization prior to disposal reduced glutaraldehyde vapor concentrations to less than 0.01 ppm. Conclusive differences were not found when the pouring of the 14-day glutaraldehyde solution was compared to the pouring of the 28-day glutaraldehyde solution. Both solution pours resulted in vapor concentration means exceeding the TLV. Comparison of sampling methods showed no statistically significant differences between each method pair or when all methods were compared simultaneously. For the detection of glutaraldehyde vapors, the meter was as sensitive and as accurate as the filter cassettes. In conclusion, employees can significantly reduce exposures to glutaraldehyde vapors by using these modified pouring and disposal procedures, and the meter examined in this study provides an optimal method to measure glutaraldehyde vapors.

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INTRODUCTION

Glutaraldehyde has successfully been used as a high level disinfectant for hospital devices that are not autoclavable. It is used to sterilize fiberoptic endoscopes at a concentration of approximately 2%, by weight. Numerous glutaraldehyde-based disinfection products are currently available and marketed under various brand names. These sterilants must be activated before use and are effective for up to 28 days. The use of these solutions has increased substantially over the last decade and there have been an increasing number of reports associated with skin, eye, and respiratory tract irritation in workers exposed to glutaraldehyde vapors during the disinfection process.[1–5] Exposure to glutaraldehyde is also implicated in causing asthma and allergic contact dermatitis.[6–9] Occupational exposure limits (OELs) to glutaraldehyde for various nations are listed in Table 1. In the United States, the American Conference of Governmental Industrial Hygienist's (ACGIH) threshold limit value (TLV) ceiling concentration for glutaraldehyde is 0.05 ppm.[4] In the United Kingdom, the 15-minute short-term exposure limit (STEL) was lowered from 0.2 to 0.05 ppm in 1999.[10] Other nations have higher OELs, but none allow for exposures above the most liberal standard, a ceiling value of 0.2 ppm.[11–13]

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Table 1. Occupational Exposure Limits for Glutaraldehyde Among Various Nations

Nation	Standard	Date	Reference
Australia NOHSC[a]	TWA[b]: 0.1 ppm (0.41 mg/m^3)	1995	NOHSC[a] (1999)
Germany FIOSH[c]	0.1 ppm MAK[d]; peak 0.2 ppm (5 minutes, 8 times/shift)	1996	NOHSC[a] (1999)
Sweden OSHA[e]	0.2 ppm (0.8 mg/m^3) ceiling limit	1996	OSHA[e] (1996)
United Kingdom HSE[f]	MEL[g] of 0.05 ppm (8-hour TWA[a]) and short-term exposure limit (STEL[h])	1999	HSE[f] (1999)
United States			
NIOSH[i]	REL[j]: ceiling 0.2 ppm (0.8 mg/m^3)	1997	NIOSH[i] (1997)
ACGIH[k]	TLV[l]: ceiling 0.05 ppm (0.2 mg/m^3)	1997	ACGIH[k] (1997)
OSHA[e]	PEL[m]: currently, no permissible exposure limit	2000	OSHA[e] (1997)

[a] NOHSC: National Occupational Health and Safety Commission.
[b] TWA: time-weighted average.
[c] FIOSH: Federal Institute of Occupational Safety and Health.
[d] MAK: maximum allowable concentration.
[e] OSHA: Occupational Safety and Health Administration.
[f] HSE: Health and Safety Executive.
[g] MEL: maximum exposure limit.
[h] STEL: short-term exposure limit.
[i] NIOSH: National Institute of Occupational Safety and Health.
[j] REL: recommended exposure limit.
[k] ACGIH: American Conference of Governmental Industrial Hygienists.
[l] TLV: threshold limit value.
[m] PEL: permissible exposure limit.

Hospital procedures that practice endoscopy cleaning involving the use of glutaraldehyde include radiation oncology, laser surgery, otolaryngology, gastroenterology, diagnostic radiology, surgical processing, and urology. Alternative disinfectants are available but the continual use of glutaraldehyde is primarily due to its efficacy, ease of use, cost effectiveness, lack of corrosivity, and speed of disinfection.[14]

Disinfection procedures that generate high glutaraldehyde air concentrations include the pouring, disposal, or disturbance of glutaraldehyde solutions. There is increasing use of automatic and semi-automatic disinfection machines intended to reduce exposures to glutaraldehyde vapors. However, the use of these machines has resulted in exposures due to a greater number of spills and leaks.[15] Other control recommendations to reduce glutaraldehyde exposures to hospital workers include the use of proper ventilation, personal protective equipment, substitution when possible, deactivation of solutions before disposal, and education on safe handling procedures.

In this study, three low cost, disinfection procedural modifications were tested for efficacy in reducing glutaraldehyde vapors. Three sampling methods used to monitor glutaraldehyde concentrations were also evaluated and compared. The glutaraldehyde meter used in this study has not been previously investigated.[14,15]

METHODS AND MATERIALS

Sampling Environment

Glutaraldehyde vapor sampling was carried out in a radiation oncology preparation room where routine tray disinfection of fiberoptic endoscopes is performed. The room measured 6 ft × 11 ft × 7.5 ft high and was ventilated by one interior supply and one interior return duct. Two doors, one on each end of the room lengthwise, were open during the investigation. An axial fan was used to clear the room atmosphere before each experiment and between test procedures. The glutaraldehyde meter was used to validate vapor removal to the 0.00 ppm level between each experiment. All persons involved in the experiments were protected from glutaraldehyde exposure with nitrile gloves, safety glasses, lab coats, and NIOSH approved half-faced air purifying respirators fitted with organic vapor cartridges.

Sampling Protocol

Glutaraldehyde sampling took place over 2 days. Room temperature, humidity, and pressure was recorded at the beginning of each sampling period. For accurate comparison to ACGIH TLVs, all sample results were corrected to normal temperature and pressure (25°C and 760 mmHg). For all experiments, triplicate DNPH (2,4-dinitrophenylhydrazine) impregnated passive badges (Assay Technology #571), triplicate DNPH impregnated filter cassettes (SKC #225-9003), and a glutaraldehyde meter (Environmental Sensors Co. #MVN-200) were used to measure glutaraldehyde vapors. Impregnated filter cassette samples were collected on glass fiber filters using a battery operated SKC personal sampling pump calibrated to a flow rate of 2 L/minute. One blank was provided for each set of triplicate passive badges and filter cassettes. The glutaraldehyde meter was factory calibrated prior to sampling. At the beginning of each sampling day, the meter was zeroed in a glutaraldehyde-free atmosphere. Personal breathing zone samples were acquired for each sampling device. Passive badges were placed in the breathing zone of the wearer, adjacent to cassettes and

Table 2. Tested Modified Procedures for the Manual Disinfection of Endoscopes

Solution Pouring[a]	Sink Disposal[b]
Pour of 14-day solutions	Disposal of soaking solutions
Pour of 28-day solutions	Disposal of soaking solutions neutralized for 5 minutes[c]
Pour of 14-day solutions using safety nozzle	Disposal of soaking solutions neutralized for 30 minutes

[a] Activated glutaraldehyde disinfection solution poured into soaking tray from product container.
[b] Activated glutaraldehyde disinfection solution discarded into sink from soaking tray.
[c] Solutions pre-incubated with sodium bisulfite for 5 or 30 minutes prior to sink disposal.

alternated. All samples were taken over 15-minute periods. Measurements taken with the glutaraldehyde meter were recorded every minute. Sampling began at the start of each pour or sink disposal procedure. A round Cidex sterilizing/disinfecting tray (#2032) 17 inches in diameter and 6 inches high, was used for all pouring and disposal procedures. Three solution pouring and three sink disposal procedures were monitored as indicated in Table 2.

Exposure Reduction Methods

Use of splash-resistant safety nozzle

To measure exposures using the splash-resistant safety nozzle, one gallon of activated 14-day Metricide (Metrex #10-1400) 2.6% glutaraldehyde solution, with a Glut-RX Safety Nozzle (Kem Medical Products #9180) attached, was poured into the soaking tray. For comparison, additional exposures were measured by pouring another bottle of activated Metricide without the safety nozzle attached.

14-Day solutions versus 28-day solutions

To measure exposures for the pouring of 14-day solutions versus 28-day solutions, one gallon of 28-day Metricide 28 (Metrex #10-2800) 2.5% glutaraldehyde solution was poured without the nozzle into the soaking tray. The 14-day solution pour was used for comparison.

Solution neutralization

To measure the effect of solution neutralization prior to sink disposal, 228 g of sodium bisulfite (Sigma #9000) were added to a tray containing one gallon of activated 14-day Metricide and incubated for either 5 or 30 minutes. As a control, sink disposal vapors were measured using non-neutralized 14-day solution.

At the completion of all experiments, filter cassettes and passive badges were submitted to an accredited laboratory for analysis by high performance liquid chromatography (HPLC).

Statistical Analysis

Differences between the original and modified disinfection procedures were compared using the Wilcoxon Rank-Sum test for filter cassette and passive badge samples and the Wilcoxon Sign-Rank test for meter readings. Non-parametric methods were used because sample sizes were too small to assume a normal distribution. Mean differences between sampling method pairs were compared using the Wilcoxon Rank-Sum test. The Kruskal–Wallis test was used to compare all sampling methods simultaneously. Filter cassette samples were plotted against passive badge samples using linear regression. Statistical calculations were performed using Intercooled STATA 6.0 for Windows 95/98/NT and Microsoft Excel 2000.

Table 3. Results of Glutaraldehyde Monitoring During the Pouring of Disinfection Solutions With or Without the Use of a Splash-Resistant Safety Nozzle

Sampling Method	No. Samples	No Nozzle[a]			Safety Nozzle[b]			p-Value[c]
		AM ± SD[d] (ppm)	GM (GSD)[e] (ppm)	Range (ppm)	AM ± SD[d] (ppm)	GM (GSD)[e] (ppm)	Range (ppm)	
Filter cassette[f]	3	0.109 ± 0.033	0.105 (1.338)	0.085–0.147	0.016 ± 0.009	0.014 (1.963)	0.007–0.025	0.050
Passive badge[f]	3	0.194 ± 0.040	0.191 (1.223)	0.162–0.239	0.028 ± 0.008	0.027 (1.308)	0.023–0.037	0.046
Meter[g]	15	0.096 ± 0.053	0.082 (0.269)	0.026–0.197	0.022 ± 0.016	0.021 (0.394)	BDL[h]–0.060	0.001

[a] Pour without safety nozzle.
[b] Pour with safety nozzle.
[c] p-Value is the probability that there is no difference between the means of the two pouring procedures. A level of significance of $p = 0.05$ was used. Analysis was determined using the Wilcoxon Rank-Sum test for filter cassette and badge samples, and the Wilcoxon Signed-Rank test for meter samples.
[d] AM: arithmetic mean; SD: standard deviation.
[e] GM: geometric mean; GSD: geometric standard deviation.
[f] Filter cassette and passive badge sampling was performed in triplicate ($n = 3$) and averaged over 15 minutes.
[g] Meter readings were recorded every minute over 15 minutes ($n = 15$).
[h] BDL: below detection limit of 0.01 ppm.

Table 4. Results of Glutaraldehyde Monitoring for the Pouring of Disinfection Solutions Made Effective for 14 or for 28 Days of Reuse

Sampling Method	No. Samples	14 Days[a]			28 Days[b]			p-Value[c]
		AM ± SD[d] (ppm)	GM (GSD)[e] (ppm)	Range (ppm)	AM ± SD[d] (ppm)	GM (GSD)[e] (ppm)	Range (ppm)	
Filter cassette[f]	3	0.109 ± 0.033	0.105 (1.338)	0.085–0.147	0.081 ± 0.021	0.079 (1.299)	0.062–0.104	0.275
Passive badge[f]	3	0.194 ± 0.040	0.191 (1.223)	0.162–0.239	0.089 ± 0.054	0.077 (1.308)	0.037–0.145	0.050
Meter[g]	15	0.096 ± 0.053	0.082 (0.269)	0.026–0.197	0.051 ± 0.041	0.038 (0.415)	BDL[h]–0.111	0.001

[a] Solutions made effective for 4 days after activation.
[b] Solutions made effective for 28 days after activation.
[c] *p*-Value is the probability that there is no difference between the means for the pouring of the two different solutions. A level of significance of $p = 0.05$ was used. Analysis was determined using the Wilcoxon Rank-Sum test for filter cassette and badge samples, and the Wilcoxon Signed-Rank test for meter samples.
[d] AM: arithmetic mean; SD: standard deviation.
[e] GM: geometric mean; GSD: geometric standard deviation.
[f] Filter cassette and passive badge sampling was performed in triplicate ($n = 3$) and averaged over 15 minutes.
[g] Meter readings were recorded every minute for 15 minutes ($n = 15$).
[h] BDL: below detection limit of 0.01 ppm.

RESULTS

Exposure Reduction Methods

Use of splash-resistant safety nozzle

Results of glutaraldehyde monitoring during the pouring of disinfection solutions with and without the use of a splash-resistant safety nozzle are shown in Table 3. Use of the safety nozzle reduced geometric mean concentrations by 87% for the filter cassettes, 86% for the passive badges, and 74% for the meter. When the safety nozzle was not used, geometric means for all sampling methods were above the ACGIH TLV of 0.05 ppm. When the nozzle was used, geometric means dropped below this OEL. In addition, use of the safety nozzle reduced highest range concentrations for the pour of 14-day solution by 82% for the filter cassettes, 85% for the passive badges, and 70% for the meter. Mean concentrations for the two pouring procedures were significantly different ($\alpha = 0.05$) among all sampling methods.

14-Day solutions versus 28-day solutions

Results of glutaraldehyde monitoring for the pouring of 14-day solutions versus the pouring of 28-day solutions are shown in Table 4. The 28-day solution pour resulted in geometric mean reductions of 25% for the filter cassettes, 60% for the passive badges, and 54% for the meter. Even with these reductions, geometric means for both solution pours were above the ACGIH TLV for both the filter cassette and passive badge methods. Highest range concentrations for all methods were above the ACGIH TLV for both the 14- and 28-day solution pours. The probability that mean concentrations were different for the two pouring procedures were below the 0.05 significance level for the passive badges ($p = 0.049$) and meter ($p = 0.008$), but above the significance level for the filter cassette method ($p = 0.275$). Figure 1 shows a comparison of glutaraldehyde exposure trends over time for all pouring procedures using the meter. Pours without the nozzle lasted 25–30 seconds, while pours with the nozzle lasted 80 seconds. For both 28- and 14-day solution pours, peaks occurred at minute four of the 15-minute sampling period. Glutaraldehyde vapor concentrations for the 14-day solution pour remained above the ACGIH TLV until minute 13. Concentrations for the 28-day solution pour exceeded the ACGIH TLV at minute 3 and remained above it until minute 10. Although geometric means for meter readings were below the ACGIH TLV when the nozzle was used, one peak concentration slightly exceeded it. This peak, with a value of 0.060 ppm, occurred at minute 1. All subsequent meter readings were below the TLV.

Solution Neutralization

Table 5 shows results of glutaraldehyde neutralization procedures. Neutralization with sodium bisulfite using a pre-incubation period of 5 or 30 minutes resulted in reducing all filter cassette and passive badge samples to below detectable levels. Neutralized solutions liberated a compound that interfered with meter readings resulting in no detection. All geometric mean concentrations were below the TLV for the sink disposal of non-neutralized solutions. Highest range concentrations for the filter cassette and passive badge samples were below the TLV at 0.023 and 0.048 ppm, respectively. The highest range concentration for the meter was above the TLV at 0.103 ppm. *p*-Value for the disposal of neutralized solutions could not be determined for filter cassette and passive badge samples because values were below detection limits. *p*-Value for the disposal of neutralized solutions could not be determined for meter readings due to the aforementioned compound interference.

Figure 2 shows the glutaraldehyde exposure trend over time for sink disposal of the 14-day non-neutralized solution. Monitoring of glutaraldehyde vapor concentrations with the meter began at the start of the disposal pour. Although each disposal pour lasted 25–30 seconds, monitoring continued throughout the 15-minute sampling period with vapor concentrations

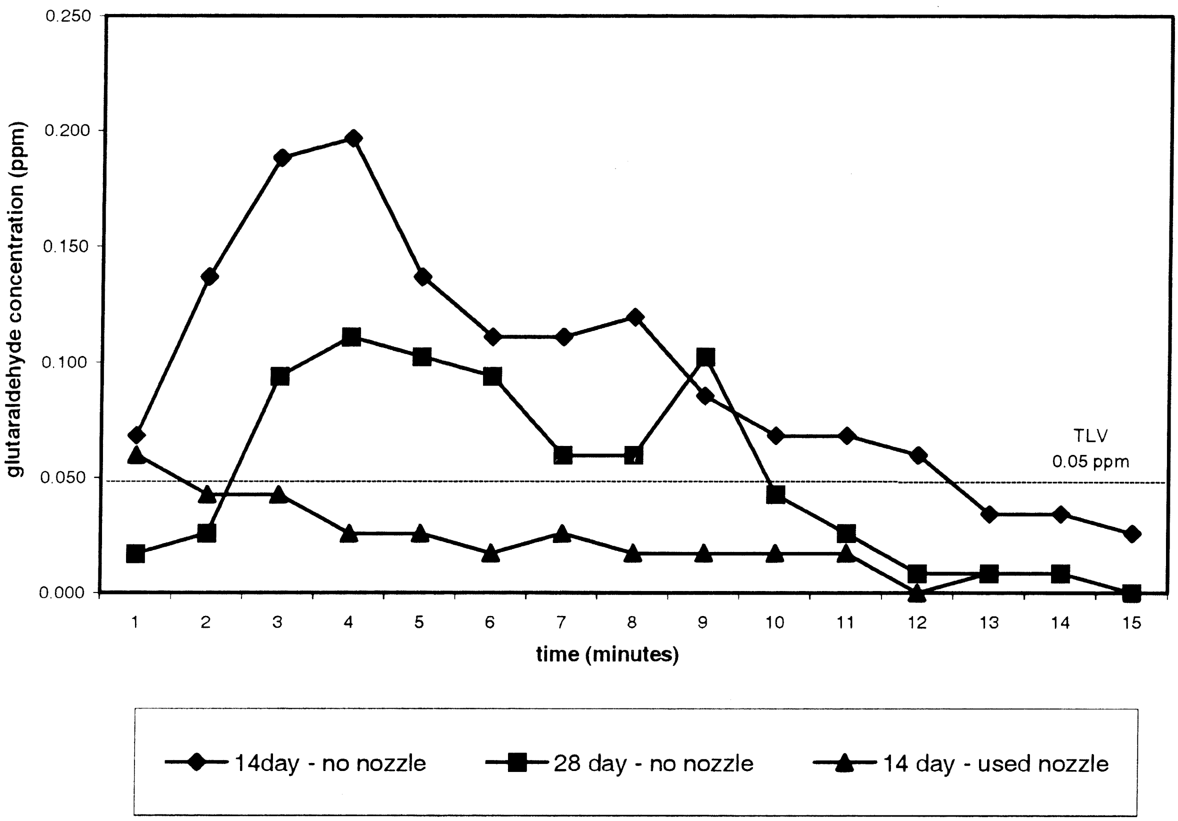

Figure 1. Glutaraldehyde exposure trends over time for the pouring procedures using the glutaraldehyde meter (pours without the nozzle lasted 25–30 seconds, pours with the nozzle lasted 80 seconds).

recorded at 1-minute intervals ($n = 15$). A peak glutaraldehyde concentration of 0.103 ppm occurred at minutes 1 and 2 and concentrations remained above the ACGIH TLV until minute 5. A small secondary peak of 0.017 ppm occurred at minute 10. All recorded concentrations remained below the TLV after minute 5.

Monitoring Methods

Results of the filter cassette and passive badge monitoring methods were plotted by regression as shown in Figure 3. Only values above detection limits for each method were used ($n = 12$). The slope of the regression line was significantly greater than zero at $p < 0.001$. The correlation coefficient square was 0.79. Regression correlation between the meter and the other methods could

Table 5. Results of Glutaraldehyde Monitoring for Disinfection Solutions Neutralized or Not Neutralized With Sodium Bisulfite Prior to Sink Disposal

Sampling Method	No. Samples	Non-neutralized[a]			Neutralized 5 Minutes[b]	Neutralized 30 Minutes[b]
		AM ± SD[c] (ppm)	GM (GSD)[d] (ppm)	Range (ppm)	All Measurements	All Measurements
Filter cassette[e]	3	0.021 ± 0.002	0.021 (1.299)	0.019–0.023	BDL[f]	BDL[f]
Passive badge[e]	3	0.036 ± 0.014	0.034 (1.570)	0.021–0.048	BDL[f]	BDL[f]
Meter[g]	15	0.030 ± 0.042	0.032 (0.314)	BDL[f]–0.103	ND[h]	ND[h]

[a] Sodium bisulfite not added prior to disposal.
[b] Sodium bisulfate added to the tray of activated solution and pre-incubated for 5 or 30 minutes prior to disposal.
[c] AM: arithmetic mean; SD: standard deviation.
[d] GM: geometric mean; GSD: geometric standard deviation.
[e] Filter cassette and passive badge sampling was performed in triplicate ($n = 3$) and averaged over 15 minutes.
[f] BDL: below detection limit of 0.01 ppm for filter cassettes and 0.02 ppm for passive badges.
[g] Meter readings were recorded every minute for 15 minutes ($n = 15$).
[h] ND: not able to detect due to interfering compounds from the neutralization reaction.

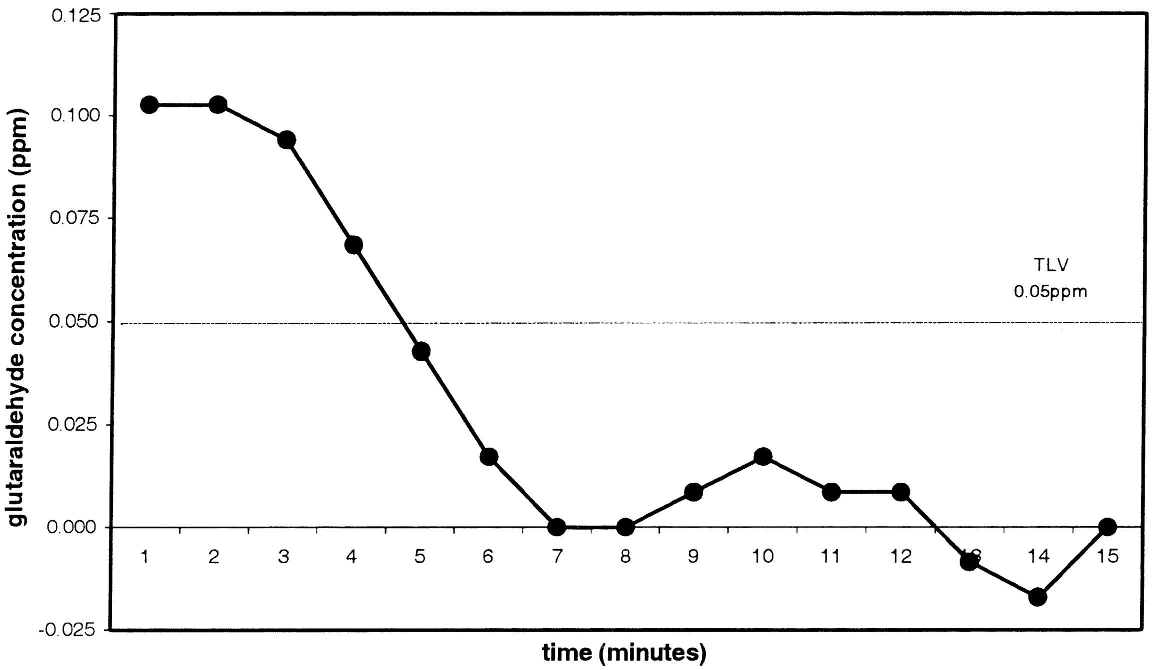

Figure 2. Glutaraldehyde exposure trend over time for the sink disposal of non-neutralized 14-day solution using the glutaraldehyde meter.

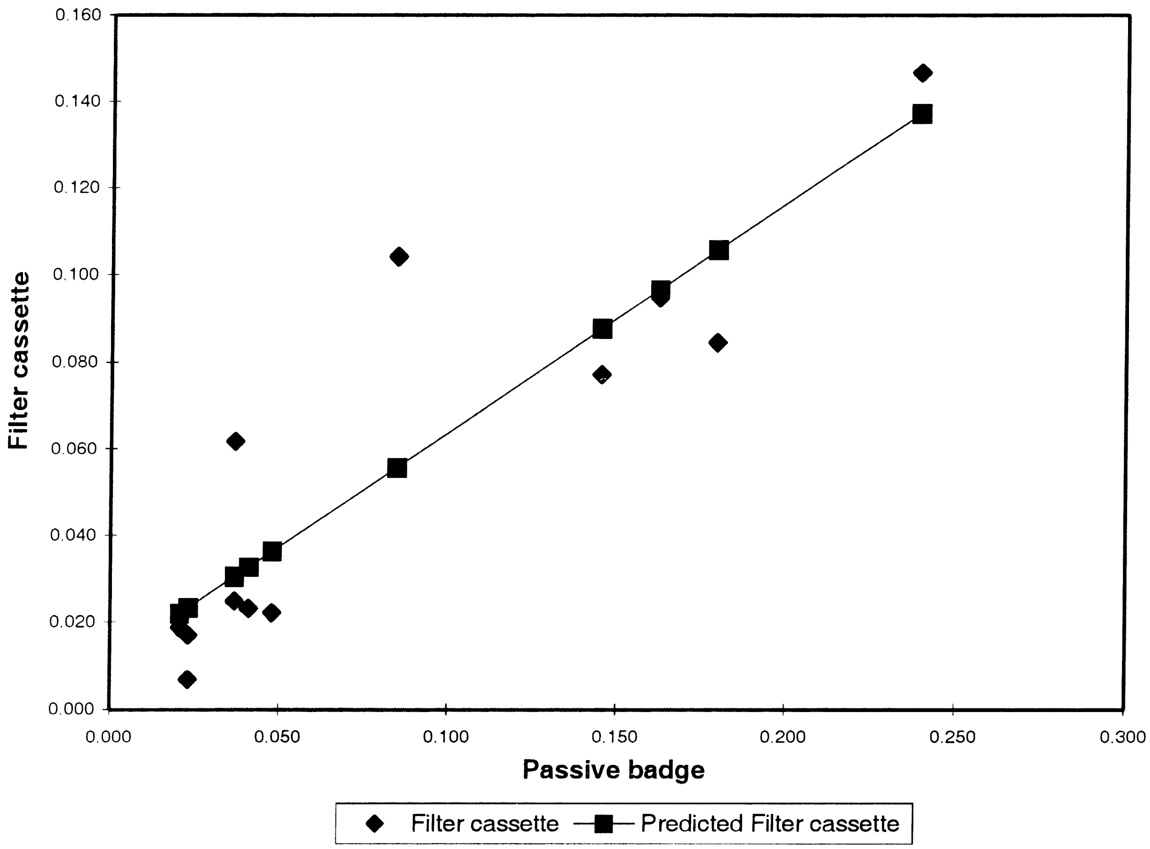

Figure 3. Comparison of filter cassette and passive badge glutaraldehyde monitoring methods. Linear fit: filter cassette = 0.526 (passive badge) + 0.011 ($R^2 = 0.79$, $p = 0.0001$).

not be determined since sampling was performed differently. For filter cassette and passive badge methods, sampling occurred in triplicates ($n = 3$) averaged over 15 minutes. Geometric means for passive badges were higher than all but one of the detectable measurements. Sampling methods were compared using only detectable measurements.

Non-parametric statistical analysis showed no significant differences between filter cassette and passive badges ($p = 0.260$). Differences were not statistically significant when the meter was compared to the filter cassettes ($p = 0.449$) or when the meter was compared to passive badges ($p = 0.065$). Means compared simultaneously for all methods did not show significance ($p = 0.133$). The largest mean differences occurred between the passive badge and meter samples, and the smallest mean differences occurred between the filter cassette and meter samples.

DISCUSSION

Exposure Reduction Methods

This study tested the effectiveness of three procedural modifications designed to reduce worker exposures during endoscope disinfection. These methods were: (1) the use of a splash-resistant nozzle to minimize glutaraldehyde exposures; (2) the use of neutralizers during glutaraldehyde solution disposal; and (3) the pouring of 14-day versus 28-day glutaraldehyde solutions. When the safety nozzle was used during the pour, mean glutaraldehyde concentrations were significantly reduced and below the ACGIH TLV of 0.05 ppm. Without the nozzle, mean concentrations were considerably above the ACGIH TLV. The nozzle efficiently reduced vapor generation and splashing likely by allowing full flow control. During the pour, flow was carefully regulated via the nozzle's central control valve.

Published research by Jordon et al. showed that glutaraldehyde disinfection solutions could be deactivated by the addition of sodium bisulfite at a 3:1 molar ratio.[17] This study shows that deactivation with sodium bisulfite can reduce glutaraldehyde concentration levels to below a 0.01 ppm limit of detection. Although non-neutralized solution means were below the ACGIH TLV, peaks were as high as 0.103 ppm at the start of the disposal and remained above the TLV until minute 5. Thus, neutralization should be performed prior to all disposal procedures to reduce glutaraldehyde exposures. The results of this study show that as little as 5 minutes is required to neutralize solutions to 0.01 ppm or below.

Significant mean differences in glutaraldehyde vapors generated during the 14-day versus 28-day solution pours were not found among all sampling methods. Although glutaraldehyde concentrations differed slightly for the two solutions, this did not likely cause the observed differences in vapor concentrations. It is more likely that variations in pouring methods accounted for these differences. More importantly, peak concentrations were above the TLV during the pour for both solutions. Thus, control measures are needed regardless of which solution variety is used.

Monitoring Methods

When sampling methods were compared, means for passive badges were generally higher than filter cassette and meter measurements, and the meter gave the lowest means. There was a significant, positive correlation between the passive badge and filter cassette samples as shown by the regression model. When passive badge measurements were compared to filter cassettes, Wellons et al.[16] found a linear fit regression model (filter cassette $= 0.47$ (passive badge) $+ 0.00$) similar to our model (filter cassette $= 0.526$ (passive badge) $+ 0.011$). Both models suggest passive badges are estimating exposure levels approximately two-fold higher than filter cassettes. Higher detection limits for passive badges (0.02 ppm) limit their use for measurements near the TLV. Methods that are more sensitive would be preferable. Both the meter and filter cassette have lower detection limits of 0.01 ppm. Either could be used to accurately determine glutaraldehyde vapors near the TLV. The filter cassette or passive badge methods do not provide instantaneous readings as given by a meter. The use of filter cassettes require more equipment, longer times to assemble, more discomfort for the wearer, and costly, time consuming lab analysis than does a meter.

Sampling using filter cassettes or passive badges should be performed in a shorter time frame than 15 minutes for pouring and disposal procedures. Results of time exposure trends illustrate that sampling should occur no longer than 6 minutes for the pour and no longer than 5 minutes for the disposal. This would ensure peak exposures are detected and not lowered by averaging over longer periods.

The previous studies by Niven et al. and Wellons et al. did not investigate the specific glutaraldehyde meter used in this study.[15,16] Both studies found their instrumentation ineffective when compared to other methods. In our experiments, the meter provided a sensitive and accurate method, comparable to the filter cassettes. It also responded quickly to varying glutaraldehyde concentrations. Interferences may cause problems, however. In this investigation, sodium bisulfite neutralized solutions released an interfering compound. Sulfur dioxide can be liberated during sodium bisulfite neutralization and may interfere with meter readings (Eugene Luksha, Environmental Sensors Co.). More advanced instruments using the same principal of detection are available from this manufacturer that prevent interferences through the use of filters. Sampling with the meter also provides a complete exposure profile. By using the meter, employees could monitor and prevent exposures to hazardous glutaraldehyde vapors.

CONCLUSION

Reports of adverse health effects suggest that control strategies are needed to eliminate or reduce glutaraldehyde exposures to acceptable levels. This study has examined three simple, low-cost procedural modifications designed to reduce glutaraldehyde vapors during the disinfection of endoscopes. The results of this investigation have shown the use of a safety nozzle can significantly reduce the potential for inhalation exposures. The splashing of disinfection solutions can be minimized to enough to reduce the risk for skin or eye contact. Neutralization of solutions before disposal can also significantly reduce inhalation exposures.

Both the filter cassette and meter methods are sensitive enough to measure glutaraldehyde levels near the ACGIH TLV. Passive badges offer a less sensitive and less precise method of measurement. The meter is comparatively as accurate to the filter cassettes, offers instantaneous results, and is easier to use. In conclusion, employees can significantly reduce exposures to glutaraldehyde vapors by using these modified pouring and disposal procedures, and the meter provides an optimal method to measure glutaraldehyde vapors.

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References

1. Newman, M.A.; Kachuba, J.B. Glutaraldehyde: a potential health risk to nurses. *Gastroenterol. Nurs.*, **1992**, *14*(6), 296–300.
2. Pisaniello, D.L.; Gun, R.T.; Tkaczuk, M.N.; Nitscke, M.; Crea, J. Glutaraldehyde exposures and symptoms among endoscopy nurses in South Australia. *Appl. Occup. Environ. Hyg.*, **1997**, *12*(3), 171–7.
3. Rastogi, S.K.; Pangtey, B.S. Occupational health risks of glutaraldehyde—a review. *Inhal. Toxicol.*, **1998**, *10*(1), 27–31.
4. ACGIH. *Documentation of the Threshold Limit Values and Biological Exposure Indices*. ACGIH: Cincinnati, OH, 2001.
5. Byrns, G.E.; Palatianos, K.H.; Shands, L.A.; Fennelley, K.P.; McCammon, C.S.; Boudreau, A.Y.; Breysse, P.N.; Mitchell, C.S. Chemical hazards in radiology. *Appl. Occup. Environ. Hyg.*, **2000**, *15*(2), 203–8.
6. Fowler, J.F. Allergic contact dermatitis from glutaraldehyde exposure. *J. Occup. Med.*, **1989**, *31*(10), 852–6.
7. Gannon, P.G.; Bright, P.; Cambell, M.; O'Hickey, S.P.; Burge, P.S. Occupational asthma due to glutaraldehyde and formaldehyde in endoscopy and X-ray departments. *Thorax*, **1995**, *50*, 156–9.
8. Stefano, F.D.; Siriruttanapruk, S.; McCoach, J.; Burge, S.P. Glutaraldehyde: an occupational hazard in the hospital setting. *Allergy*, **1999**, *54*, 1105–9.
9. Shaffer, M.P.; Belsito, D.V. Allergic contact dermatitis from glutaraldehyde in health-care workers. *Contact Dermatitis*, **2000**, *43*(3), 150–6.
10. Health and Safety Executive, United Kingdom. *Press Release*, HSE updates list of occupational exposure limits, 1999; Health and Safety Executive, United Kingdom. *Press Release*, E065:99.
11. National Occupational Health and Safety Commission, Commonwealth of Australia. *Exposure Standard Glutaraldehyde*, 1999.
12. The Occupational Safety and Health Administration of Sweden. *Occupational Exposure Limit Values*, 1996.
13. Occupational Safety and Health Administration, United States. Regulations (*Standards–29 CFR*) *Table Z-1 Limits for Air Contaminants*, 1997.
14. British Society of Gastroenterology Working Party. Cleaning and disinfection of equipment for gastrointestinal endoscopy. *Gut*, **1998**, *42*(1), 585–93.
15. Niven, K.M.; Cherrie, J.W.; Spencer, J. Estimation of exposure from spilled glutaraldehyde solutions in a hospital setting. *Ann. Occup. Hyg.*, **1997**, *41*(6), 691–8.
16. Wellons, L.S.; Trawick, E.G.; Stowers, M.F.; Jordon, S.P.; Wass, T.L. Laboratory and hospital evaluation of four personal monitoring methods for glutaraldehyde in ambient air. *AIHA J.*, **1998**, *59*, 96–103.
17. Jordon, S.P.; Russu, M.R.; Blessing, R.L.; Theis, A.B. Inactivation of glutaraldehyde by reaction with sodium bisulfite. *J. Toxicol. Environ. Health*, **1996**, *47*, 299–309.

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