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1970

Hood, Joyce L., Evaluation of a Hospital Decontamination Protocol for Mass Casualty Patient Surge. Master of Public Health (Occupational Health Practice), May 2007, 43 pp., 3 tables, 10 illustrations, references, 25 titles.

Recent studies have expressed concern about hospitals' ability to decontaminate casualties who have been contaminated with chemical, biological or radioactive agents. Since September 11, 2001, more attention has focused on hospital preparedness, but prior to 9/11, most of the focus was on decontamination in the field rather than pre-hospital. The objective of this study was to evaluate the effectiveness of two urban hospitals' decontamination teams using quantitative methods. Subjects were contaminated with equal amounts of visible and invisible simulants in six locations. Residual contamination was measured and the team was debriefed regarding opportunities for improvement. Considerable improvements were noted after de-briefing, but initially the surface area of contamination was not appreciably affected before briefing was done. The effect of shower time and residual contamination was also examined. Hospital decontamination preparedness is minimal at best, even in large urban hospitals, increasing the risk of secondary contamination within the emergency departments.

EVALUATION OF A HOSPITAL DECONTAMINATION

PROTOCOL FOR MASS CASUALTY

PATIENT SURGE

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EVALUATION OF A HOSPITAL DECONTAMINATION PROTOCOL FOR MASS CASUALTY PATIENT SURGE

THESIS

Presented to the School of Public Health

University of North Texas
Health Science Center at Fort Worth

In Partial Fulfillment of the Requirements

for the Degree of

Master of Public Health

By

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Fort Worth, Texas
May 2007

ACKNOWLEDGMENTS

I want to express my gratitude to my husband Brad and to my sons Nathan, Micah and Ben for being patient with me and wholeheartedly supporting me while I pursued my graduate degree. I also want to thank Dr. Terry Gratton, Dr. Lilly Ramphal, and Dr. Michael Larrañaga for being such wonderful, supportive professors during my graduate studies and for believing in me and my pledge to continue to make a difference in improving the occupational health of healthcare workers: I promise to incorporate everything I have learned into my practice. Special thanks go to the University of North Texas Health Science Center, Wendy Cotten at Cook Children's Health Care System, Gaylene Stengel at Harris Methodist Fort Worth Hospital, and Fred Bolton and Dave Volz of Hazmat Science Applications for making this study possible. I hope this study will make a difference in the ever-changing world in which we live.

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CHAPTER 1

INTRODUCTION TO RESEARCH

1.1 Rationale

Hospital-based emergency decontamination (decon) teams are relatively new additions to the overall disaster preparedness of hospitals. Historically, traditional disaster preparedness training in hospitals has revolved around mass trauma casualties from events such as air crashes, multiple vehicle accidents, industrial accidents, and mass shootings. One model for disaster preparedness training involved "table-top" exercises where scenarios were worked through in a classroom setting. Another model involved the use of simulated "patients" who arrived at the hospital for triage and medical care in the emergency department. These "patients" typically arrived through the emergency medical services (EMS) from the local municipality. Since September 11, 2001 and the ensuing false alarms associated with terrorism, there has been a broader focus to prepare hospitals for the possibility of receiving victims who have been contaminated with biological, chemical, or radioactive substances; the development and training of hospital-based decon teams has been one of the by-products of this national disaster. Secondary exposure of hospital workers due to inadequate or no decontamination has become a greater concern. Since 9/11, the Joint Commission on Accreditation of Healthcare

Organizations (JCAHO) and the Occupational Safety and Health Administration (OSHA) have developed standards to guide hospitals in preparing for such disasters. Even most federal regulations have focused mainly on response and decontamination at the scene rather than hospital decontamination procedures (Hick et al., 2003). In the last 2-3 years, Health Resources and Service Administration (HRSA) funding has been made available to hospitals to assist in preparation for mass casualty "surge" in response to potential terrorist use of Weapons of Mass Destruction (WMD).

The hospital-based decon team's primary objective is to quickly decontaminate victims, preventing secondary exposures in the emergency department and in other hospital personnel. They may also be dealing with medical or trauma emergencies simultaneously while decontaminating the victims, which can complicate an already difficult task. There has been some attempt to standardize decontamination procedures for hospital-based decon teams, but the general consensus is that most hospitals are not well prepared to handle a large number of mass casualties needing decontamination (Macintyre et al., 2000; Hick & Penn et al., 2003; Edgell & James, 1994; Bennett, 2006; Wetter, Daniell, & Treser, 2001). According to the United States General Accounting Office (GAO) survey, hospitals in the US are not prepared to manage this "surge" in response to any mass casualty event, whether intentional or accidental (GAO, 2003). As late as December, 2006, it was concluded that five years after 9/11, the preparedness of public health to meet emergencies is still not at an acceptable level (Trust for America's Health, 2006). Most hospitals in the United States have not made this a priority in part due to the limited monetary resources (Hick et al., 2003), increasing the concern for the

overall effectiveness and preparedness of hospital-based decon teams. The Occupational Safety and Health Administration's "Best Practices for Hospital-Based Receivers of Victims of Mass Casualty Incidences Involving the Release of Hazardous Substances" was published in 2005 and provided some clearer guidelines specific to hospitals; however it was based on the assumption that most self-directed casualties will have little or no contamination (OSHA, 2005). One of the critical benchmarks that the Health Resources and Services Administration (HRSA) uses to measure the ability to rapidly meet an increased demand in emergencies is the ability to decontaminate effectively (Trust for America's Health, 2006). A report was published in December, 2006 that showed we are still behind in preparedness, and some HRSA funds allocated to states specifically for disaster preparedness were reduced in 2006 as compared to 2005 (Trust for America's Health, 2006).

1.2 Statement of Purpose

The purpose of this study was to review the literature and conduct a research project to determine whether current hospital decontamination teams can effectively decontaminate victims of chemical, biological, or radioactive agent contamination, thus preventing secondary contamination in hospital emergency departments (EDs).

1.3 Research Questions

One question that remains unanswered in the literature is: are hospital-based decon teams trained to provide adequate decontamination? Are there more effective ways of decontaminating victims of chemical or biological events that will prevent secondary contamination of ED staff? Adequate and effective decontamination impacts both employee safety and the ability to handle mass casualties that need decontamination.

1.3.1 First Sub Problem

Traditionally, hospital-based decon team members have received some type of "standardized" initial training and annual re-training as required by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) or the Occupational Safety and Health Administration (OSHA). This annual re-training usually consists of table-top drills that go through the decon sequence or by viewing videos. Are hospital-based decon teams trained to provide the most adequate decontamination possible and do they decontaminate their victims adequately enough to prevent secondary exposure to ED staff receiving the victims post-decon?

1.3.2 Second Sub Problem

There is much concern regarding the ability of hospital decontamination teams to deal with mass casualties requiring decontamination and the effectiveness of current methods used for decontamination. Are there more effective ways of decontaminating victims of chemical or biological events that will prevent secondary contamination of ED staff and allow them to process them more quickly through the decon line?

1.4 Delimitations

Only peer reviewed journal articles were used as the foundation in this research project, predominantly from the emergency medicine, public health, and occupational and environmental health disciplines. The research project involved two hospital decon teams who performed the exercise according to their current approved protocol, and with only their current knowledge, training, and experience. Both teams received initial training from the same source, although annual re-training may vary slightly.

1.5 Limitations

There is much debate in the literature regarding the preparedness of hospitals to handle mass casualty surge in general, but there seems to be many questions in the literature regarding the effectiveness of hospital based decon teams in handling cases of chemical and/or biological mass casualty contamination, whether intentional or

accidental. Even though this study is limited to two hospital decon teams, the outcomes may serve to spur further research to quantify residual contaminants post-decon. There were no exercises such as this found in the literature that simulated contamination and measured post-decon residual contaminants.

1.6 Assumptions

For the purposes of this study, it was assumed that most hospital-based decon teams conduct decontamination procedures in a similar fashion, since most hospitals fall under the oversight of the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) or the Occupational Safety and Health Administration (OSHA).

1.7 Definition of Terms

Decontamination (Decon): The process of cleaning a victim that has been contaminated with chemicals or other substances of concern that allows that victim to be handled without the caregiver wearing specialized equipment (Keim & Kaufmann, 1999).

Health Resources and Services Administration (HRSA): A branch of the Department of Health and Human Services partially responsible for the disaster preparedness of the United States (Trust for America's Health, 2006).

Joint Commission on Accreditation of Healthcare Organizations (JCAHO): Compliance agency responsible for evaluating healthcare organizations in the United States according to standards they have set with whom most healthcare organizations comply (Schultz, Mothershead, & Field, 2002).

Occupational Safety and Health Administration: A federal agency responsible for enforcing regulations governing the health and safety of workers in most businesses in the United States and falls under the Department of Labor (OSHA, 1970).

Personal Protective Equipment (PPE): Special clothing worn to protect an individual from specific hazards and reduces the risk of exposure to hazards and prevents secondary contamination (Cox, 1994).

Post-decon: The status of a victim after decontamination has taken place.

Secondary contamination: Contamination that remains on a casualty's clothing or body that exposes healthcare workers within a hospital to the toxic effects of the contaminant (Cox, 1994).

Weapons of Mass Destruction (WMD): Any type of weapon, whether biological, radioactive, chemical or explosive, with the capacity to inflict serious injury and/or death and destruction on a massive scale (Bennett, 2006).

1.8 Importance of this Study

This study appears to be the first of its kind in the United States applied to hospital-based decon team protocol. To date, there have been no consistent guidelines to assist in standard decontamination of mass chemical or biological contamination. This has been suggested in the literature as something to be determined. It is of great importance for hospital decon teams to experience the effectiveness of their decon procedures before a real event occurs; some chemical and biological agents are quite effective in causing morbidity and mortality in very small quantities, such as soman or sarin (chemical) and Ebola or Marburg (biological) (Raber et al., 2001). Preventing secondary contamination of emergency department staff is of primary importance when in the midst of chemical or biological catastrophes when the already thin resources of hospitals will be stretched.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Introduction

While the military has vast experience and training in dealing with exposures or potential exposures to chemical, biological, and radioactive agents, the majority of hospitals have not received the benefit of equivalent training, nor do they have much experience in dealing with decontamination of victims of such exposures. A mass casualty event of this nature has not occurred in the United States to date, but there are lessons to be learned from the military and from other countries that have experienced such events. While concerns were raised in the literature pre-September 11, the bar has been raised since then to ensure that hospital-based decontamination teams are prepared to handle mass casualty events, whether intentional or unintentional.

2.2 Primary Theories and Historical Background

Exposure to chemical or biological agents can occur through hazardous material releases, military stockpile accidents or terrorist or military attacks (Kenar & Karayilanoglu, 2004). All known secondary exposures of emergency department (ED)

personnel to chemicals in the United States have occurred due to non-terrorist events (Horton, Berkowitz, & Kaye, 2003). There have been several documented incidents where ED workers have become ill while caring for patients who were inadequately decontaminated or not decontaminated prior to arriving for treatment. These incidents primarily involved malathion, pepper spray, hydrofluoric acid, chlorine gas, and methamphetamine-related chemicals. The healthcare workers in the EDs who were exposed to these substances experienced transient symptoms and no deaths occurred (Horton, Berkowitz, & Kaye, 2003). The terrorist attack on the Tokyo subway system in 1995 with the release of sarin gas should serve as a model of the realities of mass casualty exposure to a chemical agent and the challenges associated with the hospital response. More than 100 hospital workers experienced symptoms from secondary exposure to sarin gas, which was mainly on the clothing of the victims, and over 500 casualties were seen in one hour in an emergency department in Tokyo as a result of this event (Okumura et al., 1998). It is estimated that if such an event recurs, the vast majority of the victims will not receive pre-hospital decontamination because over 80% of them will self-direct from the scene to the emergency departments of hospital, bypassing on-scene efforts to decontaminate victims (Koenig, 2003; Hick et al., 2003). In these incidents, it is anticipated that most casualties will arrive at the ED via means other than the emergency medical services (EMS), exhausting the already inadequate resources of the hospital EDs (Bradley, 2000).

The lack of standardization of decontamination practices, inconsistent healthcare worker competencies in decontamination practices, and the lack of adequate

decontamination facilities are contributing factors to hospitals' general lack of preparedness (Hsu et al., 2006; Schultz, Mothershead, & Field, 2002; Raber, Jin, Noonan, McGuire, & Kirvel, 2001; Koenig, 2003). The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) requires hospitals to develop comprehensive emergency management protocols that encompass the four stages of emergency management, which are preparedness, response, recovery, and mitigation (Koenig, 2003; JCAHO, 2003), but currently has no recommendations regarding a standard approach to decontamination protocols or personal protective equipment (PPE). Lack of federal funding has been one of the biggest barriers that hospitals have faced since 2001, with only small amounts of money allocated for hospital preparedness reaching the intended destinations (Fong, 2003). Many hospitals have either funded the disaster preparedness out of their own pockets or have implemented only the basic needs. In one recent study, only 66% of hospitals had written protocols for decontamination of casualties of biological or chemical disasters and as much as 30% had not participated in a drill designed to evaluate, treat, and decontaminate victims of such disasters (Greenberg, Jurgens, & Gracely, 2002). In another study, a large majority of hospitals were found lacking in their preparedness to evaluate and decontaminate victims of chemical contamination, and there was a common misconception that the emergency medical services (EMS) would have adequately decontaminated victims prior to arriving at the hospital (Cone & Davidson, 1997).

It is not known how much of a particular agent is required to cause morbidity and mortality from secondary contamination (Raber et al., 2001). Many agents take

minute amounts to cause illness in those in contact with them, while some take significantly larger amounts to cause illness (Raber et al, 2001). Exposure limits are not available for most chemical or biological agents that could potentially be used as Weapons of Mass Destruction (WMD), so it is difficult to establish how much residual contamination is acceptable. Most decontamination studies have been directed toward military training, so it is difficult to extrapolate the "lessons learned" to a civilian population. One reason is that the idea of "acceptable loss" is probably not applicable to civilian populations since there is no acceptable number of emergency department workers that can be sacrificed for the "greater good" as in military exercises (Koenig, 2003).

2.3 Theoretical Model

While dealing primarily with unknown materials regarding the efficacy of hospital-based decon team decontamination protocols and the amount of residual necessary to cause illness or death from secondary exposure, it is possible to simulate contamination and to measure simulated post-decon residuals. This model capitalizes on two theoretical concepts. First, most contaminants, whether biological, chemical, or radioactive, are not visible to the naked eye, which makes evaluation of effectiveness of decon difficult, if not impossible. This could jeopardize the health and safety of the decon team members and the staff in the emergency department. Secondly, providing visual feedback to decon team members regarding the areas that are most difficult to

decontaminate and potential weaknesses in technique can vastly improve decon procedures in the future.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

The objectives of this research were met by completing the following methodology:

1. Determination of efficacy of current decontamination methods:
    a. Simulated decontamination drill was performed with two hospital decon teams who used the same protocol and the same decon shower facility.
    b. Simulated contaminants were placed on "victims" in the same strategic areas of the body in the same amounts.
    c. A simulated contaminant that was visible to the eye was placed on half of the subjects; a simulated contaminant that was not visible to the naked eye was placed on the other half of the subjects. Both simulants consisted of theatrical body paint (one contained a pigment, one did not) and Bengay®. Both simulants are visible under black light conditions.
    d. In the decon scenario, the type of contaminant was not known; the only information given to the decon and ED staff was that there had been a mass casualty event involving some type of chemical which caused many deaths at

the scene. They were also previously instructed to process the subjects per current protocol. The subjects were incapable of showering themselves due to various patient scenarios, thus decon was performed by the decon team member rather than the subjects themselves.

e. All post-decon residuals were viewed under black-light and traced onto transparencies denoting site of residual, subject number and run number.

f. Observations of technique were documented and decon technique was also videotaped.

g. Timing of decon showering process for each victim.

h. Feedback provided to decon team regarding areas to improve and how to improve decon procedure after viewing of residual contamination under black light. .

2. Determination of efficacy after evaluation and debriefing:

   a. All steps repeated.

3. Determination of perception of decon victims with process:

   a. Questionnaire was administered to subjects regarding the perceived level of professionalism, maintenance of privacy during decontamination, and perceived confidence in the staff during a true emergency.

3.2 Experimental Design

The data were tabulated using Microsoft Excel and analyzed using SPSS® version 14.0 statistical software. The results of the data analysis were interpreted under the assumptions and limitations of this research.

The contaminant residuals were measured by scanning the transparency tracings and using Image J software (National Institutes of Health) to calculate body surface area of the residual simulant that was "visualized" under black light. Analysis of data was as follows:

1. The differences in the mean amounts of residuals were compared between visible and invisible contaminants.
2. The differences in the mean amounts of residuals were compared pre-training and post-training.
3. Inference regarding shower time and amount of residual contamination was analyzed.
4. General sentiment with the decon process from the subjects' perspective was analyzed.
5. The most difficult areas to decontaminate were also identified using total body surface area of all residual contaminants per site.

A total of ten subjects were contaminated with visible simulants and ten were contaminated with invisible simulants only. Simulants were applied using a 2.5 x 5 cm make-up applicator wedge and a syringe. Exactly ½ ml of simulant was placed in each

of six locations on every victim using a body template for distribution of the simulants (Figure 1). All subjects were administered the questionnaire.

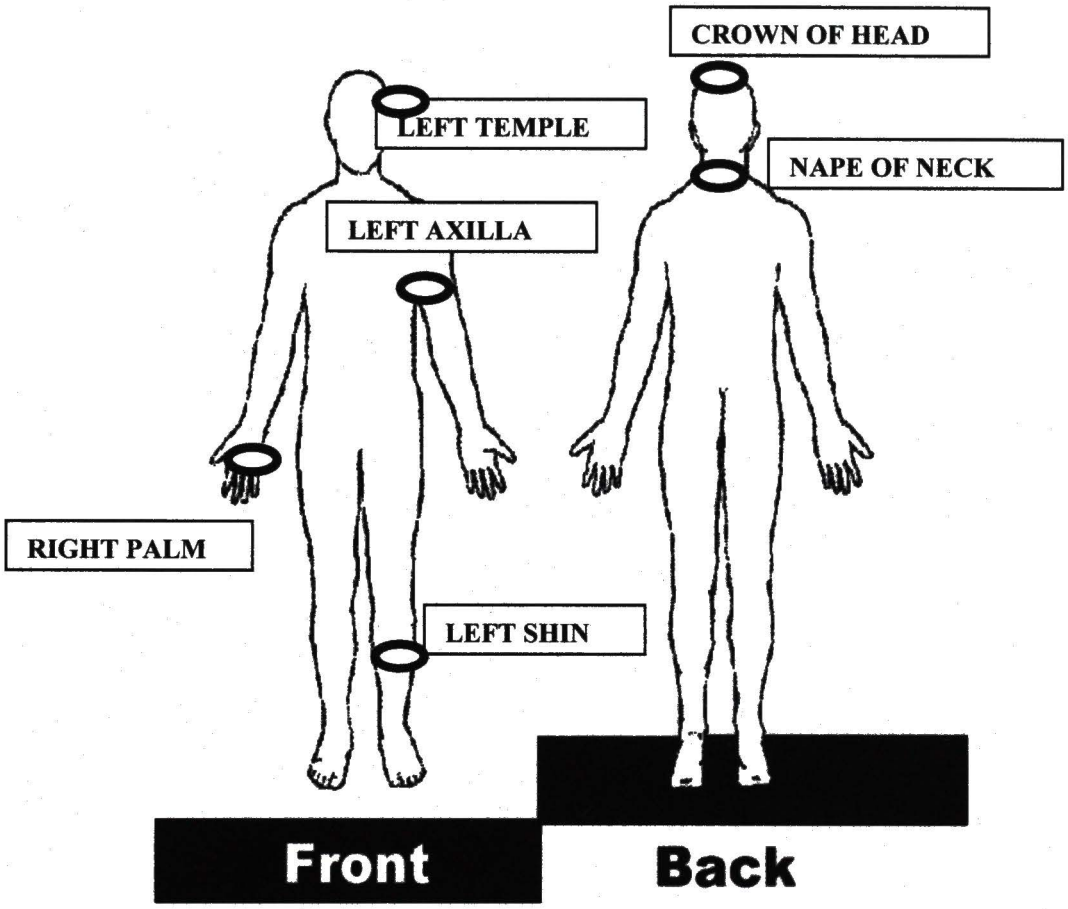

Figure 1: Template for simulant application.

3.3 Instrumentation

Appendix A contains an example of the questionnaire administered to subjects after undergoing decontamination. A black light was used to visualize residual contamination after decontamination was performed. Stopwatches were used to time the showers.

Cameras were used to record residual contaminants viewed under black light and video cameras were used to record the decontamination process.

3.4 Data Collection and Treatment of Data

Institutional Review Board approval was obtained from the University of North Texas Health Science Center at Fort Worth, Harris Methodist Fort Worth Hospital, and Cook Children's Health Care System prior to data collection. Experimental data were collected in a mobile laboratory provided by Hazmat Science Applications of Santa Fe, New Mexico. The mobile laboratory was set up outside of the decontamination facilities of Harris Methodist Fort Worth Hospital and Cook Children's Medical Center. The mobile laboratory provided the black-light visualization and photography. Study personnel recorded "start" and "stop" time of each subject's decontamination shower using a stopwatch.

3.5 Data Analysis and Methodological Issues

Data was collected utilizing body surface area pre-decon (constant) and post-decon. Videotapes were reviewed for potential weaknesses in technique. A questionnaire was administered to subjects regarding general sentiment regarding the decon procedure. Stopwatches were used to record shower times.

1. After transfer of residual tracings to graph paper, area was calculated using Image J software, tabulated into a spreadsheet according to pre- and post-training

status of the subject and visible versus non-visible contaminant status of the subject. All areas of contamination are measured in cm^2.

2. SPSS® version 14.0 software to perform statistical analysis.
3. Decontamination process was also videotaped for review for opportunities for improvement.
4. Questionnaire results were tabulated using Excel.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

The morning of February 28, 2007, the decon team was paged and assembled in the decontamination area of Harris Methodist Fort Worth Hospital. Subjects were "contaminated" per the pre-determined protocol and each was provided with a scenario that rendered them incapable of washing themselves. Standard operating procedure was to be followed for ambulatory patients as noted in Table 1. It was observed that it took the team members more than 40 minutes to "suit out" in their decontamination gear. Some team members were unsure of how to don PPE and it seemed cumbersome to don. During the first run, the mean shower time for all 10 subjects was only 2 minutes 12 seconds. Soap had not been utilized during the first run although it was readily available in both the hot and warm zones. Post-decon, residual contamination was documented and the decon team was assembled for debriefing and general overview of opportunities for improvement. Subjects took a regular shower with soap away from the decon site to remove any simulant residuals that remained. The subjects were then "re-contaminated" and the procedure repeated. Noted improvement in technique and the use of soap ensued, reflecting a "training effect". The scenario was repeated in the afternoon

utilizing 10 subjects and new members of the decon team. This study was also utilized as the decon team's required annual training.

Hot zone	Warm zone	Cold Zone
• Personnel performing patient decontamination need to don appropriate PPE before making patient contact. Establish an initial triage point to evaluate and direct casualties. • Direct patients to the appropriate decontamination corridor. • Remove patient's clothes, jewelry, and personal belongings. These items should be placed in appropriate containers using plastic bags with labels for identification. • Adult: Have adult remove clothing.	• Personnel performing patient decontamination need to don appropriate PPE before making patient contact. • Take the patient to the shower area and wash the entire body head to toe. The patient will be washed with solution A, B, C, or D with a soft bristle brush or sponges for three to five minutes then rinse. • Adult: Each adult should be directed to wash with the solution provided. • Decontamination of the eyes is performed using a saline solution via nasal cannula. Remove the patient's contacts before decontamination of the eyes. • Adult: Have adult remove contacts before decontamination of the eyes. • In extreme cases, hair clipping may be needed. • If patient received solution B or C, they will need to be rinsed with large amounts of water.	• Personnel performing patient decontamination need to don appropriate PPE before making patient contact. • Patient is dried off and provided a disposable gown and foot covers. Adult: As adult, they are provided a towel and disposable gown and foot covers. • Take patient to triage area for medical evaluation.

Table 1: Decontamination procedure used by teams during exercise.

Figure 2 demonstrates the team in their PPE during the drill as they assumed their positions. Each decon team member was to take a place in the "hot" zone, "warm" zone or "cold" zone and decontaminated as prescribed in Table 1. Team is entering in the area where triage and clothing removal typically takes place.

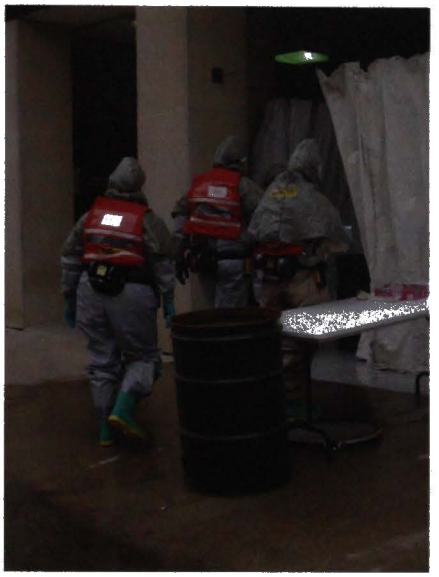

Figure 2: Decon team members during drill.

4.2 Data Analysis

During the first decontamination run, there was a nearly 2-fold spread of contaminated surface area (from 75 cm^2 per subject to a mean of 133.7 cm^2 per subject) indicating that the contaminated surface area was increased during the first decon procedure. Using an independent samples T-test to determine the difference in the means of both groups (AM and PM pre-brief and post-briefing), it was determined that there was a statistically significant improvement in the amount of residual contaminants in the PM group after the team was debriefed and critiqued (t (15) =3.24, p = .005), but no statistically significant change in the AM group (t (13.56) = 1.97, p = .07). Figure 3 demonstrates box plot comparisons of these groups and Table 2 contains specific descriptive statistics for the box plots.

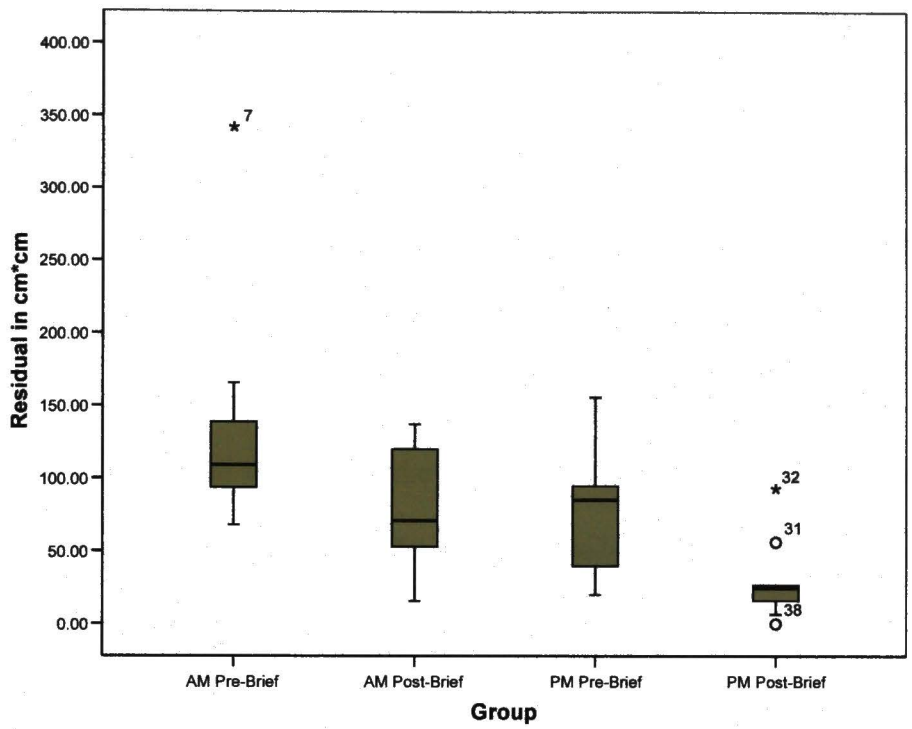

Figure 3: Box plot comparisons of pre-debriefing and post-debriefing residual contaminants. PM post-brief run was the only run with a statistically significant difference in residual contamination, as noted (N = 40, n = 10).

Group	IQR	Median	Mean
Am Pre-Brief (n = 10)	56.3	109.2	133.7
AM Post-Brief (n = 10)	73.2	71.1	78.3
PM Pre-Brief (n = 10)	62.3	85.5	79.7
PM Post-Brief (n = 10)	93.1	24.7	29.4

Table 2: Descriptive statistics for box plots comparing pre-brief and post-brief residual contamination for AM and PM runs.

Residual contaminants were analyzed for the group with visible contaminant applied and the group with invisible contaminant applied. Using a T-test for the

difference of the means of these two groups, it was determined that there was no statistically significant difference in the residual contaminant of those subjects (t (32) = 2.89, p=.055). Since contaminants in real life would likely be invisible, this was a positive finding in the study and demonstrated that the team members did not depend upon being able to see the contaminant in order to decontaminate effectively.

The effect of decontamination shower time was also measured. The mean shower time for the first run of the day was two minutes, twelve seconds, which was much below the procedural guidelines. An analysis was performed regarding the shower time versus the amount of residual contaminant. A scatter plot (Figure 4) demonstrates no true correlation between shower time (in seconds) and the amount of residual contaminant (in cm^2). Using a t-statistic for regression to determine slope, it was determined that the slope could be a non-zero slope (t = 2.92, p=.006). By the end of the day, the mean shower time had increased to seven minutes, six seconds.

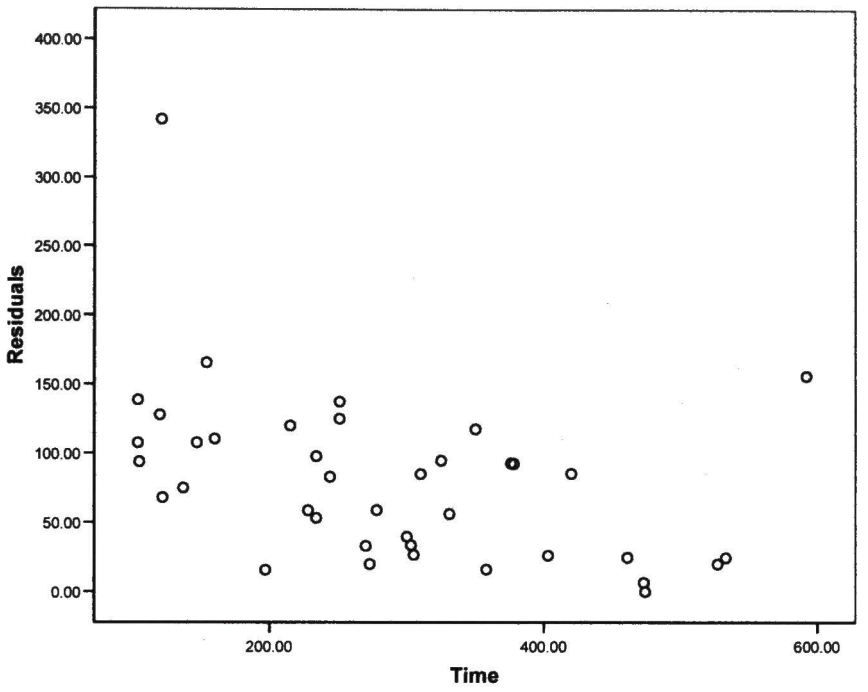

Figure 4: Scatter plot demonstrating relationship between shower time (in seconds) and amount of residual contaminant (in cm^2).

Figure 5 denotes the relationship of the surface area of residual contamination as compared to shower time. The shower times in run 4 were at or above the OSHA recommended time of five minutes or more. This finding is significant because if shower times of at least 5 minutes (or more) are what is needed to effectively decontaminate, being effective in a mass casualty event may be problematic and result in delays and crowding.

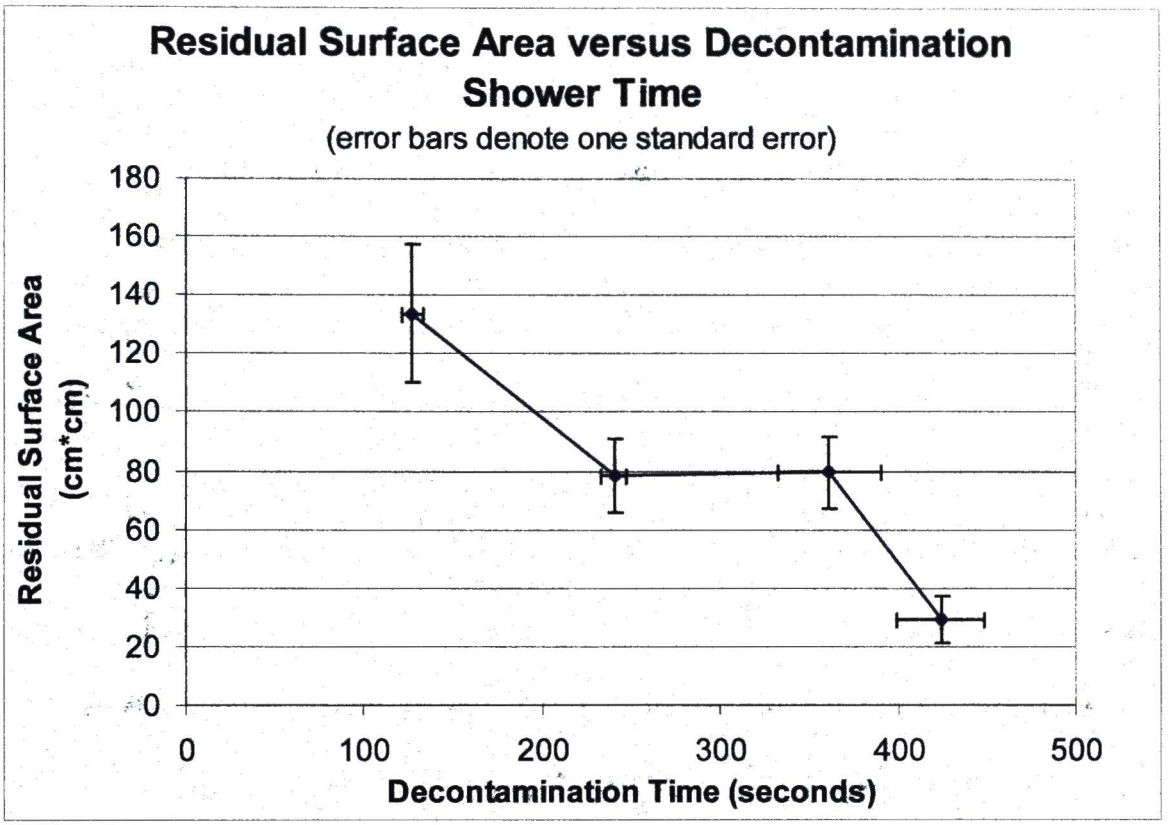

Figure 5: This figure reflects the "x" decontamination time standard error bars compared to the "y" error bars showing the standard errors of residual surface contamination. Runs 1 through 4 are denoted from left to right, with the far most left data set representing the data from run 1 and the far most right data set representing data from run 4. Error bars indicate standard error. Run 4 was the shower run that was statistically significant and was related to the least amount of residual contamination.

A negative correlation between mean residual contamination and mean shower time was identified by regression analysis ($R^2 = .84$). A Spearman's Rank Correlation non-parametric test demonstrated that the ranks of the shower times and residual contamination were significantly correlated and not independent of one another ($p<.001$). An analysis of variance (ANOVA) with SNK post hoc test ($\alpha = .05$) was conducted to compare the mean residual contamination and mean shower times of three

groups. Group 1 included subjects who were decontaminated for less than 4 minutes. Group 2 included subjects who were decontaminated for 4-6 minutes and Group 3 included those who were decontaminated for over 6 minutes. The ANOVA demonstrated statistically significant differences in the means of residual contamination between the group that was decontaminated < 4 minutes and the group that decontaminated > 6 minutes ($p = .032$).

Individual areas of residual contamination were reviewed by site to determine if there were any areas that were more difficult to decontaminate than others. In Figure 6, an error bar chart of the means of residual contamination for each of the 6 sites that were contaminated denotes that the axilla (armpit), palm, and shin have higher means for all runs of the day than the other three sites. An ANOVA with an SNK post hoc test ($\alpha = .05$) was conducted to determine the significance of an observed difference between the sample means. This showed that there were no statistically significant differences in the means between groups ($p = .058$) and the groups were similar. After performing a T-test for the difference about the means for each individual site comparing the AM with the PM runs, the sites identified as being more difficult to decontaminate were the axilla ($p = .135$), the palm ($p = .743$) and the shin ($p = .100$). Since there was no statistically significant difference in the means of between the morning and afternoon runs for each site, there was demonstrated persistence in each of these three sites regardless of debriefing and practice. Decontamination teams may want to be aware of the possibility that these three sites may need to be cleaned with more care than others. The axilla in particular may need a sponge that molds to the concavity of the area. Palm surfaces may

be forgotten since the casualties may be removing their own clothing and cleaning themselves in these circumstances.

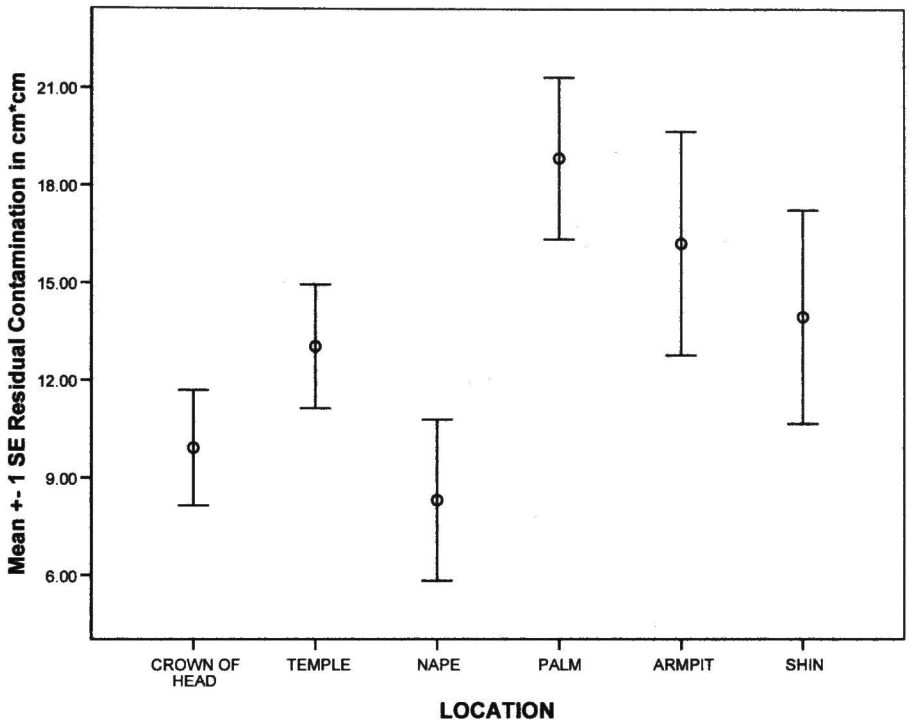

Figure 6: Error bar chart denoting mean residual contamination of each of the six areas of contamination (N = 40). The palm, armpit (axilla) and shin have higher means than the first three sites. An ANOVA with SNK post hoc demonstrated no statistically significant differences in the means between the groups though (p = .058).

Table 3 provides an overall summary of the data analysis performed in this study. Discussion regarding recommendations from the results will be discussed in the discussion and recommendations for further research sections.

Parameter measured	Statistical test used	Result	Conclusion/ Implications
AM and PM pre-briefing and post –briefing residual contaminants	T-test for difference of the means (N=20, n=10, $\alpha = .05$)	AM: t (13.56) = 1.97, $p = .07$ PM: t (15) = 3.24, $p = .005$	Training and immediate feedback improves decon effectiveness.
Comparison of visible versus invisible residual contaminant	T-test for difference of the means (N=40, n=20, $\alpha = .05$)	t (32) = 2.89, p=.055	Decon effectiveness not dependent upon seeing contaminant.
Comparison of shower time versus residual contaminant	T-statistic for regression to determine slope (N=40,$\alpha = .05$)	t= 2.92, p=.006	Slope is a non-zero slope and infers some relationship.
Ranks of shower time to determine if they are independent of each other	Spearman's Rank Correlation (N = 40).	p<.001	Shower times ranks and residual contamination are significantly correlated and not independent of each other.
Determination if shower time and residual contamination are related.	ANOVA with SNK post hoc (N = 40, $\alpha = .05$)	p=.032 for group 1 (shower times less than 4 minutes) and group 3 (shower times greater than 6 minutes)	This supports the OSHA recommendation that shower times should be at least 5 minutes in length for optimal cleaning.
Comparison of contaminated sites for differences in residual contamination.	ANOVA with SNK post hoc (N = 40, $\alpha = .05$)	$p = .058$	The six sites that did not exhibit any difference between them and were similar:
Comparison of the residual contamination of the morning and afternoon runs for each site that was contaminated	T-test for difference of means comparing am and pm runs per site (N = 40 $\alpha = .05$).	Palm (p=.743), axilla (p=.135) and shin (p=.100) were not statistically different between AM and PM runs	Three sites showed resistance to removal and persistence. Careful attention to the palm, axilla and shin when decontaminating

Table 3: Summary of results of statistical analysis.

Figure 7 depicts the post-decon residual contamination on the subjects as viewed under the black light in the mobile laboratory. These residual contaminants were not visible to the decon team members during the procedure but were clearly identified as post-decon residual contamination when viewed under black light. One problem identified in this study was that it was more difficult to visualize residual contamination on dark skinned subjects than light skinned subjects.

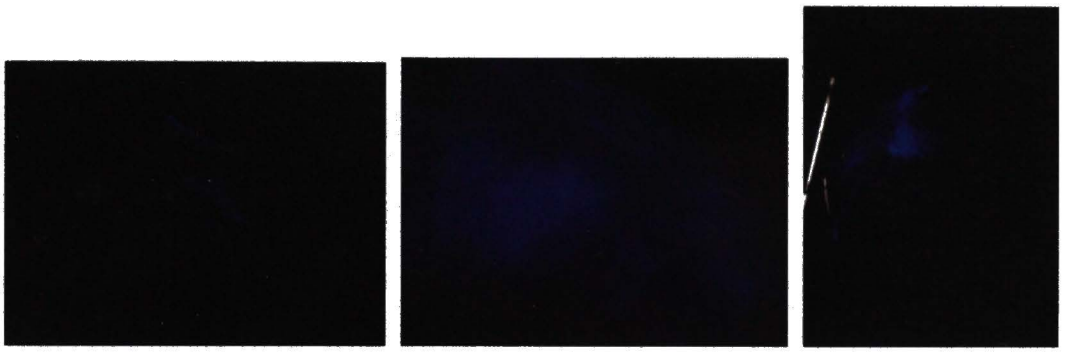

Figure 7: Post-decon visualization of residual contaminants on the palm (at left), scalp (center), and temple (at right), as viewed under a black light.

A post-decon questionnaire was administered to subjects regarding three areas of concern and perception from a "casualty" perspective. The questionnaire is located in Appendix A. Figures 8, 9, and 10 denote the results of the questionnaire. Figure 8 shows that 46% of the subjects felt they were treated with a "high" level of professionalism and 50% felt they were treated with a moderate amount of professionalism. In the open ended question section, the subjects stated specific areas that could be improved were better communication (the masks made it difficult to communicate with the subjects) and attentiveness to the subjects' complaints. Many subjects stated that the decon team member "ignored" their physical complaints and proceeded with decon in spite of a reported "broken arm" or other symptoms. Communication in general appeared to be

problematic throughout the procedure, either due to radios not being turned on, or the PPE prohibiting proper communication with subjects and others. It is also a possibility this was not noted on the decon tag after triage was performed.

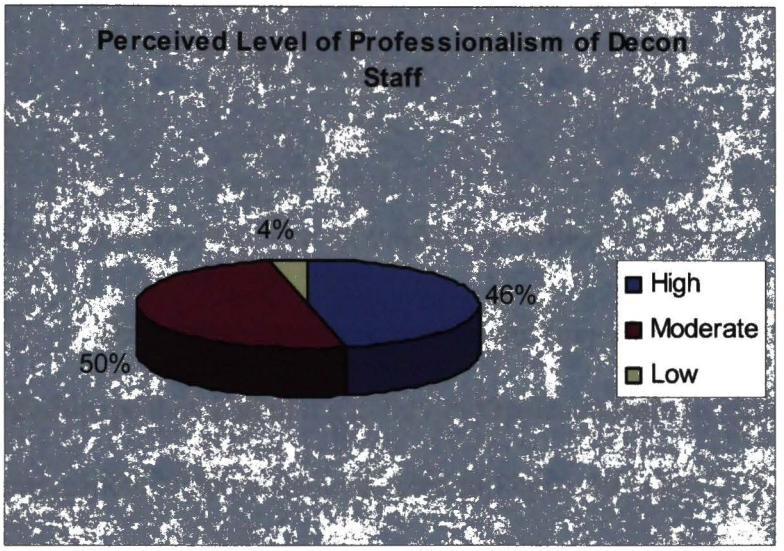

Figure 8: Perceived level of professionalism of the decon team members.

Figure 9 shows that 83% of the subjects felt that they were provided with a high level of modesty during the procedure. The fixed decon shower set up with multiple curtains helped to facilitate the maintenance of modesty.

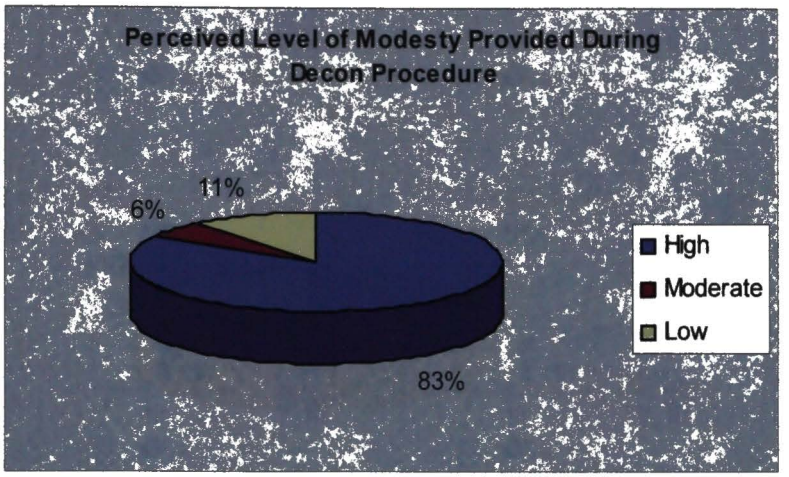

Figure 9: Perceived level of modesty provided to subjects during decon procedure.

The most dramatic perception the subjects reported back was the level of confidence they had in the ability of the decon team to effectively decontaminate in a real emergency, which is demonstrated in Figure 10. Only 39% of the subjects expressed confidence in the team's ability to perform adequate decontamination during a real hazmat emergency. 61% expressed low to moderate confidence in the team to perform adequately in a real emergency. In the open ended question section, this perception was attributed to the team member not attending to their special physical needs or the lack of communication throughout the procedure.

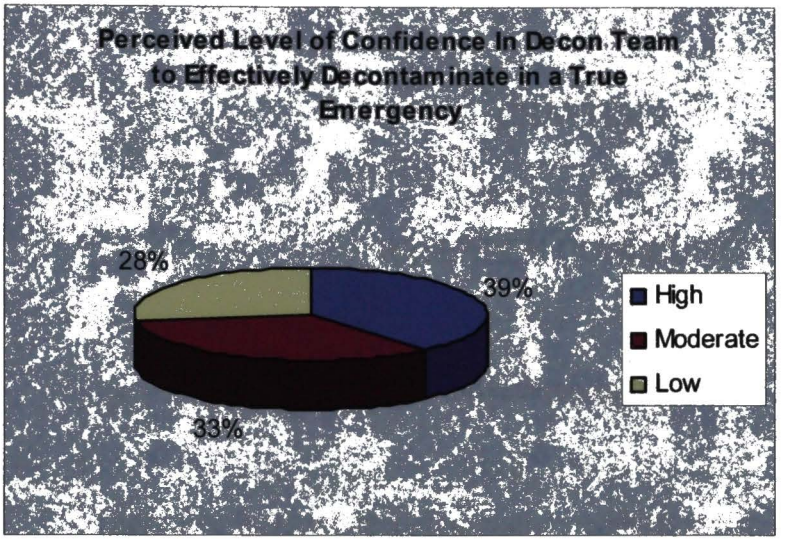

Figure 10: Perceived level of confidence of subjects in team to perform during a real decon emergency.

Most of the subjects were professionals who had some prior knowledge about decontamination procedures, so their perception of the abilities of the decon team to perform in a real emergency is concerning, but also correlates with other data collected during the study. Also, if a casualty perceives a staff member as incapable of performing the procedure, anxiety may also play a role in decon effectiveness.

CHAPTER 5

RESEARCH CONCLUSIONS

5.1 Research Implications

These two hospital decontamination teams had participated in running water decon drills once in the past 3 years, partially due to drought conditions in the area within the past year and due to the limited resources of each hospital. Both hospitals are urban hospitals: one is a designated Level II trauma center, the other a children's hospital. Based on this study, hospital-based decontamination teams are not fully prepared for a real mass casualty incident involving the release of hazardous substances, both by quantitative analysis and by analysis of the questionnaires regarding perception by the subjects. Since urban hospitals tend to be better prepared to deal with decontamination issues than most rural hospitals, this raises a serious concern for the preparedness of rural hospitals (Wetter, Daniell, & Treser, 2001). Recommendations from this study highlight the importance of full-dress, running water decon drills at least annually, with consideration being given to the possibility of qualitative analysis during the drill similar to what was performed in the study. This could include "contaminating" the casualties with similar substances and then viewing under black light for opportunities for improvement and immediate feedback to the decon team members. Shower times should be at least 5 minutes in length (OSHA, 2005). Since under stressful conditions, people

are not aware of the time, a clock or timer in the shower bays would be helpful. Particular attention should be paid to the soap used for decontamination; it is important that one be used that can thoroughly clean areas such as the palm and axilla from contaminants exhibiting persistence. Special consideration should be given to the type of cleaning implement used that would provide the best surface contact and applied friction; standard synthetic sponges may be too large and too stiff to provide adequate cleaning. Drills that include PPE training and PPE donning/doffing should be also be conducted more frequently in order for the team members to become familiarized with them in a non-emergent setting; this would assist in streamlined donning in a real emergency. Should a real life situation arise similar to the Tokyo sarin gas release, the EDs would be overwhelmed almost immediately with an increased risk of secondary contamination if the team is not familiar with donning procedures. The marked improvement in post-decon residuals after debriefing highlights the importance of providing tangible feedback to the team rather than theoretical role-playing. Hands-on competency training for decontamination should be treated as any other skill or competency in the medical setting.

Most hospital decon team members are volunteers and do not receive any compensation for their time, training, and competency, other than normal salary. Turnover tends to be high; training new staff is labor intensive and can be expensive. Hospitals should consider paying an annual stipend or bonus to those who continue to receive annual training, participate in drills, and demonstrate competency in the procedure. Inexperienced decon team members performing decontamination procedures

would be a hindrance to the overall effectiveness of the team and would perhaps jeopardize the health and safety of all involved. As HRSA funds become more readily available to hospitals, some of that funding should be set aside for recruitment, retention, and training of the decontamination team.

5.2 Recommendations for Further Research

Real life simulation drills will present the best training opportunities for hospital decontamination teams due to the low frequency, high risk nature of actual decon emergencies. Attention should be paid to the research and development of training tools that could actually provide hands-on opportunities and feedback during the training session. Currently, no regulatory agencies have made specific recommendations regarding PPE for use in hospital decontamination. When doing so in the future, they should consider the time and limitations in using gear that may not allow an optimal emergency response time. More studies are needed regarding the type of soap to use, cleaning implements to use, and optimal shower time. A standardized approach to cleaning should be considered in order to avoid confusion and has been recommended in previous studies (Hick et al., 2003). While "self-decontamination" is recommended whenever possible, this may not provide the highest level of decontamination and may not be possible when victims are incapacitated to any extent (Macintyre et al., 2000). Difficult-to-reach areas or difficult to clean areas should also be considered when developing such protocols. A "best practice" training model should be utilized and

standardized for all hospitals within a region who may be receiving victims from the same emergency.

United States government officials have reiterated that another terrorist attack is probable, if not imminent, in the near future: hospitals must be prepared for this inevitability. Decontamination teams are part of that preparedness and further studies are needed to guide them in the best practice preparation. Since real-life decontamination scenarios happen infrequently, developing real-life simulations for practice, participating in running water drills annually, practicing donning procedures semi-annually, and standardizing training within each region are at minimum what is required for the future.

APPENDIX A

SAMPLE PARTICIPANT QUESTIONNAIRE

Participant Questionnaire

1. What did you think of the level of professionalism of the decon team staff member you had contact with?

   Highly___ Medium___ Low___

2. What level of modesty were you able to maintain or was afforded to you during the decon procedure?

   High___ Medium___ Low___

3. If this were a true emergency, what level of confidence would you have in the staff to decontaminate you efficiently?

   High___ Medium___ Low___

4. What suggestions do you have to make this a better process should there ever be a real emergency?

5. What was the most positive thing you experienced during the procedure?

6. What was the worst thing you experienced?

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