Paper 229-2017

Using SAS® to Estimate SE, SP, PPV, NPV, and Other Statistics of Chemical Mass Casualty Triage

Abbas S. Tavakoli, DrPH, MPH, ME[1]; Joan Culley PhD, MPH, RN, CWOCN[1]; Jane Richter, DrPH, RN[1]; Sara Donevant, RN, MSN, CCRN, PhD Student[1]; Jean Craig, PhD[2],

[1]University of South Carolina, College of Nursing
[2]Medical University of South Carolina, Charleston

ABSTRACT

Chemical incidents involving irritant chemicals such as chlorine pose a significant threat to life and require rapid assessment. This paper used data from the Validating Triage for Chemical Mass Casualty Incidents – A First Step R01 grant to determine the most predictive signs and symptoms (S/S) for a chlorine mass casualty incident. SAS® 9.4 was used to estimate sensitivity, specificity, positive and negative predictive values, and other statistics of irritant gas syndrome agent S/S for two exiting systems designed to assist emergency responders in hazardous material incidents (Wireless Information System for Emergency Responders [WISER] and CHEMM Intelligent Syndromes Tool [CHEMM-IST]). The result for WISER showed the sensitivity was .72 to1.0; specificity .25 to .47; and the positive predictive value and negative predictive value were .04 to .87, and .33 to 1.0; respectively. The results for CHEMM-IST showed the sensitivity was .84 to.97; specificity .29 to .45; and the positive predictive value and negative predictive value were .18 to 42, and .86 to .97; respectively.

Keywords: SAS, Chemical, Triage,

University of South Carolina, College of Nursing.

The project was supported by Funding from the National Library of Medicine: 1R01LM011648

INTRODUCTION

Disasters happen in the world every day. Disasters can be categorized into two categories: natural and unnatural.[1] One of the greatest challenges is effective disaster response to all hazards events.[2] Nearly 1.8 million railcars of chemical materials are transported in the United states every year[3]. Mass casualties can overwhelm healthcare capabilities, jeopardizing the lives of victims and healthcare provider's alike.[2] Chemical incidents involving irritant chemicals such as chlorine pose a significant threat to life and require rapid assessment and triage. None of the current hospital-based triage systems are effective in establishing a triage priority for victims exposed to chlorine, an irritant gas syndrome agent.[4]

PURPOSE

This paper used the SAS® 9.4[5] procedure to estimate sensitivity, specificity, positive and negative predictive values, and other statistics to determine the most predictive signs and symptoms (S/S) from two exiting systems designed to assist emergency responders in hazardous material incidents (Wireless Information System for Emergency Responders [WISER)] and Chemical Hazards Emergency Medical Management Intelligent Syndrome Tool [CHEMM-IST]) for a chlorine mass casualty incident.

BACKGROUND

To mitigate the "surge" of casualties into a healthcare facility after a mass casualty incident (MCI), emergency responders and hospital personnel use triage to rapidly assess patients and prioritize their care with the goal of saving as many lives as possible.[6,7] It is critical to efficiently and accurately classify and prioritize patients during mass causality events caused by disasters. Successful triage depends on the meaningful use of accurate, valid, and relevant data by all emergency responders. None of the triage systems examined in our previous study effectively

established a triage priority for victims exposed to chlorine, leading to faulty decisions and misdiagnoses. [4, 6] The National Library of Medicine (NLM) Wireless Information System for Emergency Responders (WISER) and Chemical Hazards Emergency Medical Management Intelligent Syndrome Tool CHEMM-IST are robust database of S/S that provides parameters for the early identification of chemical exposure. These two methods are used as baseline to develop new triage method for chemical exposure.

METHODS

This paper used data from the Validating Triage for Chemical Mass Casualty Incidents – A First Step RO1 grant. The data included 147 victims of a chlorine disaster and 150 patients that were not exposed to the chlorine disaster. All patients were treated at the same medical facility.

Proc FREQ was used to estimate sensitivity, specificity, positive and negative predictive values, and other statistics with the 95% confidence interval and test both asymptotic and exact. It is important to select the proper row or column from original tables to estimate the statistics. The option BINOMIAL used in the exact statement provided all of the exact tests of the proportion. Macro was used to reduce coding. All data analyses were performed using SAS/STAT® version 9.4[6].

RESULTS

Table 1 shows descriptive statistics for WISER signs/symptoms by chlorine exposure. The results indicate the percentage of cough, shortness of breath, burning irritation, chest discomfort, choking, and hypoxia was higher among exposed group as compare to non-exposed for WISER.

Table 1: Frequency distribution of signs/symptoms WISER by exposure.

Variables	Chlorine Exposure			
	No		Yes	
	N	%	N	%
Cough				
No	**20**	**66.7**	**10**	**33.3**
Yes	**42**	**39.6**	**64**	**60.4**
Mouth Irritation				
No	**30**	**100**	**0**	**0.0**
Yes	**101**	**96.2**	**4**	**3.8**
Cardiovascular				
No	**34**	**68.0**	**16**	**32.0**
Yes	**92**	**63.9**	**52**	**36.1**
Shortness of Breath				
No	**38**	**86.4**	**6**	**13.6**
Yes	**43**	**32.3**	**90**	**67.7**
Wheezing				
No	**37**	**88.1**	**5**	**11.9**
Yes	**71**	**55.5**	**57**	**44.5**
Burning Irritation				
No	**1**	**33.3**	**2**	**66.7**
Yes	**2**	**13.3**	**13**	**86.7**
Chest Discomfort				
No	**25**	**71.4**	**10**	**28.6**
Yes	**45**	**45.5**	**54**	**54.5**
Choking				
No	**20**	**66.7**	**10**	**33.3**
Yes	**45**	**40.5**	**66**	**59.5**

Hypoxia				
No	**2**	**100**	**0**	**0.0**
Yes	**16**	**39.0**	**25**	**61.0**
Nausea				
No	**25**	**71.4**	**10**	**28.6**
Yes	**63**	**68.5**	**29**	**31.5**
Vomiting				
No	**25**	**78.1**	**7**	**21.9**
Yes	**76**	**80.9**	**18**	**19.1**

Table 2: Frequency distribution of signs/symptoms CHEMM-IST exposure.

Variables	**Chlorine Exposure**			
	No		**Yes**	
	N	**%**	**N**	**%**
Burning Throat				
No	**36**	**97.3**	**88**	**75.9**
Yes	**1**	**2.7**	**28**	**24.1**
Wheezing				
No	**36**	**87.8**	**74**	**57.8**
Yes	**5**	**12.2**	**54**	**42.2**
Shortness of Breath				
No	**44**	**86.3**	**54**	**38.9**
Yes	**7**	**13.7**	**85**	**61.1**
Wet Lungs				
No	**38**	**97.4**	**90**	**81.8**
Yes	**1**	**2.6**	**20**	**18.2**
Eye Irritation				
No	**37**	**92.5**	**78**	**63.4**
Yes	**3**	**7.5**	**45**	**36.6**

Table 2 shows descriptive statistics for CHEMM-IST signs/symptoms by chlorine exposure. The results indicate the percentage of burning throat, wheezing, wet lungs, burning irritation, and eye irritation was higher among exposed the group as compare to the non-exposed group for CHEMM-IST.

Table 3: Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value (WISER)

Variables	**Sensitivity**	**Specificity**	**Positive Predictive Value**	**Negative Predictive Value**
Cough	.86	.32	.60	.67
Mouth Irritation	1.0	.23	.04	1.0
Cardiovascular	.76	.27	.36	.68
Shortness of Breath	.94	.47	.68	.86

Variables	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Wheezing	.92	.34	.45	.88
Burning Irritation	.87	.33	.87	.33
Chest Discomfort	.84	.36	.55	.71
Choking	.87	.31	.59	.67
Hypoxia	1.0	.11	.61	1.0
Nausea	.74	.28	.32	.71
Vomiting	.72	.25	.19	.78

Table 3 indicates the results of sensitivity, specificity, positive predictive value, and negative predictive value for WISER. The results showed the sensitivity was from .72 to1.0. The specificity was from, .25 to .47. The positive predictive value and negative predictive value were from .04 to .87, and .33 to 1.0; respectively.

Example 1. SAS output for Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value for cough (WISER)

Binomial Proportion Sensitivity	
dei_chlorineexposure = A-Yes	
Proportion (P)	0.8649
ASE	0.0397
95% Lower Conf Limit	0.7870
95% Upper Conf Limit	0.9428
Exact Conf Limits	
95% Lower Conf Limit	0.7655
95% Upper Conf Limit	0.9332

Binomial Proportion Specificity	
dei_chlorineexposure = B-No	
Proportion (P)	0.3226
ASE	0.0594
95% Lower Conf Limit	0.2062
95% Upper Conf Limit	0.4389
Exact Conf Limits	
95% Lower Conf Limit	0.2094
95% Upper Conf Limit	0.4534

Binomial Proportion Positive Predictive Value	
r01_wiser_mouth_coughchk = A-Yes	
Proportion (P)	0.6038
ASE	0.0475
95% Lower Conf Limit	0.5107
95% Upper Conf Limit	0.6969
Exact Conf Limits	
95% Lower Conf Limit	0.5041
95% Upper Conf Limit	0.6975

Binomial Proportion Negative Predictive Value	
r01_wiser_mouth_coughchk = B-No	
Proportion (P)	0.6667
ASE	0.0861
95% Lower Conf Limit	0.4980
95% Upper Conf Limit	0.8354
Exact Conf Limits	
95% Lower Conf Limit	0.4719
95% Upper Conf Limit	0.8271

Example 1 indicates part of the SAS output for sensitivity, specificity, positive predictive value, and negative predictive value for cough for WISER. From this table sensitivity, specificity, positive predictive value, and negative predictive value for cough with 95% CI for both asymptotic and exact can be obtained. For example 95% Ci for sensitivity for cough is .79 to .94.

Table 4: Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value (CHEMM-IST)

Variables	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Burning Throat	.97	.29	.24	.97
Wheezing	.92	.33	.42	.88
Shortness of Breath	.92	.45	.61	.86
Wet Lungs	.95	.30	.18	.97
Eye Irritation	.94	.32	.37	.93

Table 4 indicates the results of sensitivity, specificity, positive predictive value, and negative predictive value for CHEMM-IST. The result showed the sensitivity was from .84 to .97. The specificity was from, .29 to .45. The positive predictive value and negative predictive value were from .18 to 42, and .86 to .97; respectively.

Table 5: False Positive Probability, and False Negative Probability (WISER)

Variables	False Positive Probability	False Negative Probability
Cough	.68	.14
Mouth Irritation	.77	*
Cardiovascular	.73	.23
Shortness of Breath	.53	.06
Wheezing	.65	.08
Burning Irritation	.67	.13
Chest Discomfort	.64	.16
Chocking	.69	.13
Hypoxia	.89	*
Nausea	.71	.26
Vomiting	.75	.28

*Small sample size

Table 5 indicates the results of false positive and negative probability for WISER. The results showed the false positive probability was from .53 to .89. The false negative probability was from .06 to .28.

Example 2. False Positive Probability and False Negative Probability for cough (WISER)

Binomial Proportion False Positive Probability	
dei_chlorineexposure = A-Yes	
Proportion (P)	0.6774
ASE	0.0594
95% Lower Conf Limit	0.5611
95% Upper Conf Limit	0.7938
Exact Conf Limits	
95% Lower Conf Limit	0.5466
95% Upper Conf Limit	0.7906

Binomial Proportion False Negative Probability	
dei_chlorineexposure = B-No	
Proportion (P)	0.1351
ASE	0.0397
95% Lower Conf Limit	0.0572
95% Upper Conf Limit	0.2130
Exact Conf Limits	
95% Lower Conf Limit	0.0668
95% Upper Conf Limit	0.2345

Example 2 indicates part of the SAS output for false positive and negative probability for cough for WISER. From this table false positive and negative probability for cough with 95% CI for both asymptotic and exact can be obtained. For example 95% Ci for false positive for cough is .56 to .79.

Table 6: False Positive Probability, and False Negative Probability (CHEMM-IST)

Variables	False Positive Probability	False Negative Probability
Burning Throat	.71	.03
Wheezing	.67	.08
Shortness of Breath	.55	.08
Wet Lungs	.70	.05
Eye Irritation	.68	.06

Table 6 indicates the results of false positive and negative probability for CHEMM-IST. The results showed the false positive probability was from .55 to .71. The false negative probability was from, .03 to .08

CONCLUSION

SAS procedure was used to estimate sensitivity, specificity, positive and negative predictive values, and other statistics to determine the most predictive signs and symptoms of irritant gas syndrome agents for two exiting systems designed to assist emergency responders in hazardous material incidents (Wireless Information System for Emergency Responders (WISER) and CHEMM-IST). The results indicated good sensitivity for both WISER and CHMESIT. However, the specificity was very poor for both WISER and CHEMM-IST. The results show very poor false positive probability for both WISER and CHEMSIT. The results for negative false positive were better for CHEMM-IST as compared to WISER. PROC FREQ in SAS provided all of these estimates with 95 % confidence interval.

References

1. Shaluf IM. An overview on the technological disasters. *Dis Prev and Mang*. 2007;16(3):380-390.

2. Culley JM. & Effken J. A. Development and validation of a mass casualty conceptual model. *Journal of Nursing Scholarship*. 2009; 42(1): 66-75. DOI:10.1111/j.1547-5069.2009.01320.x
3. Parker M. Critical care and disaster management. *Crit Care Med*. 2006; 34(3 Suppl): S52-55.
4. Culley, JM, Svendsen, ER, Craig, J. & Tavakoli, A. (2014). A validation study of 5 triage systems using data from the 2005 Graniteville, South Carolina, chlorine spill. *Journal of Emergency Nursing*, 40(5): 453-460. DOI:10.1016/j.jen.2014.04.020, PMID:25063047, PMCID:PMC4157946.
5. SAS Institute Incorporated. (2013). *SAS for Windows 9.4*. Cary, NC: SAS Institute Inc.
6. Kirk M, Deaton M. Bringing order out of chaos: Effective strategies for medical response to mass chemical exposure. Emerg Med Clin N Am. 2007; 25: 527-548. DOI: 10.1016/j.emc.2007.02.005.
7. Culley, JM, & Svendsen, ER. (2014). A review of the literature on the validity of mass casualty triage systems with a focus on chemical exposures. American Journal of Disaster Medicine, 9(2):137-150; DOI: 10.5055/ajdm.2014.0150, PMCID: PMC4187211, NIHMS585712.

Contact Information

Your comments and questions are valued and encouraged. Please contact the authors at:

Abbas S. Tavakoli, DrPH, MPH, ME
College of Nursing
University of South Carolina
1601 Greene Street
Columbia, SC 29208-4001
Fax: (803) 777-5561

FUNDING

This study was funded by the National Library of Medicine: 1R01LM011648

ACKNOWLEDGEMENT

Findings from this study are based on records from medical records abstracted from Aiken Regionjal Hopsital.

Appendix

SAS Syntax

```
ods rtf;  ods listing close;
proc freq data=three;
          Tables dei_chlorineexposure*( r01_WISER_mouth_coughchk  r01_WISER_mouth_mthirrit
               r01_WISER_card_tachycardia r01_WISER_resp_sob r01_WISER_resp_wheezing
                r01_WISER_resp_burnittit r01_WISER_resp_chstdiscmf r01_WISER_resp_coughchk
           r01_WISER_resp_hypoxiacyan r01_WISER_gast_nausea r01_WISER_gast_vomit
                r01_chemm_burnthrtnose   r01_chemm_wheezing       r01_chemm_sob
                     r01_chemm_wetrales       r01_chemm_eyeirrit )/chisq;
title ' frequency tables / by exposure and non- exposure';     run;
ods rtf close; ods listing;  quit ; run;


*** Calculate Sensitivity  **;

ods rtf; ods listing close;
%macro se (q);
    proc freq data=three order= formatted;
      where &q =1;
```

```
        tables  dei_chlorineexposure / binomial(level="A-Yes");
       exact binomial;
       title 'Sensitivity/ exposure as test/variables as response' &q;         run;
 %mend se;
%se (r01_WISER_mouth_coughchk );
%se (r01_WISER_mouth_mthirrit);
%se (r01_WISER_card_tachycardia);
%se  (r01_WISER_resp_sob);
%se (r01_WISER_resp_wheezing);
%se (r01_WISER_resp_burnittit);
%se (r01_WISER_resp_chstdiscmf);
%se (r01_WISER_resp_coughchk);
%se (r01_WISER_resp_hypoxiacyan);
%se (r01_WISER_gast_nausea);
%se (r01_WISER_gast_vomit);
%se (r01_chemm_burnthrtnose);
%se (r01_chemm_wheezing);
%se (r01_chemm_sob);
%se (r01_chemm_wetrales) ;
%se (r01_chemm_eyeirrit);
run; ods rtf close;  ods listing;  quit; run;

 *** Calculate Specificity  **;

ods rtf; ods listing close;
%macro sp (q);
     proc freq data=three order= formatted;
       where &q =0;
        tables  dei_chlorineexposure / binomial(level="B-No");
       exact binomial;
      title 'Specificity / exposure as test/variables as response' &q;       run;
 %mend sp;
%sp (r01_WISER_mouth_coughchk );
%sp (r01_WISER_mouth_mthirrit);
%sp (r01_WISER_card_tachycardia);
%sp  (r01_WISER_resp_sob);
%sp (r01_WISER_resp_wheezing);
%sp (r01_WISER_resp_burnittit);
%sp (r01_WISER_resp_chstdiscmf);
%sp (r01_WISER_resp_coughchk);
%sp (r01_WISER_resp_hypoxiacyan);
%sp (r01_WISER_gast_nausea);
%sp (r01_WISER_gast_vomit);
%sp (r01_chemm_burnthrtnose);
%sp (r01_chemm_wheezing);
%sp (r01_chemm_sob);
%sp (r01_chemm_wetrales) ;
%sp (r01_chemm_eyeirrit);
run;   ods rtf close; ods listing;  quit; run;


 *** Calculate Positive Predictive Value **;

ods rtf; ods listing close;
%macro PPV(q);
  proc freq data=three order= formatted;
       where  dei_chlorineexposure =1;
        tables  &q / binomial(level="A-Yes");
       exact binomial;
        title 'Positive predictive value/exposure as test/variables as response' &q;         run;
%mend PPV;
```

```
%ppv(r01_WISER_mouth_coughchk );
%ppv (r01_WISER_mouth_mthirrit);
%ppv (r01_WISER_card_tachycardia);
%PPV  (r01_WISER_resp_sob);
%PPV (r01_WISER_resp_wheezing);
%PPV (r01_WISER_resp_burnittit);
%PPV (r01_WISER_resp_chstdiscmf);
%PPV (r01_WISER_resp_coughchk);
%PPV (r01_WISER_resp_hypoxiacyan);
%PPV (r01_WISER_gast_nausea);
%PPV (r01_WISER_gast_vomit);
%PPV (r01_chemm_burnthrtnose);
%PPV (r01_chemm_wheezing);
%PPV (r01_chemm_sob);
%PPV (r01_chemm_wetrales) ;
%PPV (r01_chemm_eyeirrit);
 Run;  ods rtf close; ods listing; quit; run;

*** Calculate Negative Predictive Value **;

ods rtf; ods listing close;
%macro NPV(q);
  proc freq data=three order= formatted;
        where  dei_chlorineexposure =0;
         tables   &q/ binomial(level="B-No");
        exact binomial;

          title 'Negative predictive value/exposure as test/variables as response' &q;
            run;
%mend NPV;

%Npv(r01_WISER_mouth_coughchk );
%Npv (r01_WISER_mouth_mthirrit);
%Npv (r01_WISER_card_tachycardia);
%NPV  (r01_WISER_resp_sob);
%NPV (r01_WISER_resp_wheezing);
%NPV (r01_WISER_resp_burnittit);
%NPV (r01_WISER_resp_chstdiscmf);
%NPV (r01_WISER_resp_coughchk);
%NPV (r01_WISER_resp_hypoxiacyan);
%NPV (r01_WISER_gast_nausea);
%NPV (r01_WISER_gast_vomit);
%NPV (r01_chemm_burnthrtnose);
%NPV (r01_chemm_wheezing);
%NPV (r01_chemm_sob);
%NPV (r01_chemm_wetrales) ;
%NPV (r01_chemm_eyeirrit);
 Run; ods listing; quit; run;


*** Calculate False Positive Probability **;

ods rtf; ods listing close;
  %macro FPC(q);

  proc freq data=three order= formatted;
        where &q  =0;
         tables dei_chlorineexposure / binomial(level="A-Yes");
        exact binomial;


     title 'False Positive Probability (Col)/exposure as test/variables as response ' &q;     run;
```

```
%mend FPC;

%FpC(r01_WISER_mouth_coughchk );
%FpC (r01_WISER_mouth_mthirrit);
%FpC (r01_WISER_card_tachycardia);
%FPC  (r01_WISER_resp_sob);
%FPC (r01_WISER_resp_wheezing);
%FPC (r01_WISER_resp_burnittit);
%FPC (r01_WISER_resp_chstdiscmf);
%FPC (r01_WISER_resp_coughchk);
%FPC (r01_WISER_resp_hypoxiacyan);
%FPC (r01_WISER_gast_nausea);
%FPC (r01_WISER_gast_vomit);
%FPC (r01_chemm_burnthrtnose);
%FPC (r01_chemm_wheezing);
%FPC (r01_chemm_sob);
%FPC (r01_chemm_wetrales) ;
%FPC (r01_chemm_eyeirrit);
 Run;   ods listing; quit; run;


*** Calculate False Negative Probability  **;
ods rtf; ods listing close;
   %macro FNC(q);
  proc freq data=three order= formatted;
        where   &q=1;
         tables  dei_chlorineexposure/ binomial(level="B-No");
        exact binomial;
      title 'False Negative Probability (Col)/ exposure as test/variables as response' &q;
        run;
%mend FNC;
%FNC(r01_WISER_mouth_coughchk );
%FNC (r01_WISER_mouth_mthirrit);
%FNC (r01_WISER_card_tachycardia);
%FNC  (r01_WISER_resp_sob);
%FNC (r01_WISER_resp_wheezing);
%FNC (r01_WISER_resp_burnittit);
%FNC (r01_WISER_resp_chstdiscmf);
%FNC (r01_WISER_resp_coughchk);
%FNC (r01_WISER_resp_hypoxiacyan);
%FNC (r01_WISER_gast_nausea);
%FNC (r01_WISER_gast_vomit);
%FNC (r01_chemm_burnthrtnose);
%FNC (r01_chemm_wheezing);
%FNC (r01_chemm_sob);
%FNC (r01_chemm_wetrales) ;
%FNC (r01_chemm_eyeirrit);
Run;   ods listing; quit; run;
```