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Validating Signs and Symptoms from An Actual Mass Casualty Incident to Characterize An Irritant Gas Syndrome Agent (IGSA) Exposure: A First Step in The Development of A Novel IGSA Triage Algorithm

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Abstract

Introduction—Chemical exposures daily pose a significant threat to life. Rapid assessment by first responders/emergency nurses is required to reduce death and disability. Currently, no informatics tools for Irritant Gas Syndrome Agents (IGSA) exposures exist to process victims efficiently, continuously monitor for latent signs/symptoms, or make triage recommendations. This study describes the first step to developing emergency department informatics tools for chemical incidents: validation of signs/symptoms that characterize an IGSA syndrome.

Methods—Data abstracted from 146 patients treated for chlorine exposure in one emergency department during a 2005 train derailment and 152 patients not exposed (comparison group) were mapped to 93 possible signs/symptoms within two tools (i.e., WISER and CHEMM-IST) designed to assist emergency responders/emergency nurses with managing hazardous material exposures.

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Inferential statistics (Chi Square/Fisher's exact test) and diagnostics tests were used to examine mapped signs/symptoms of those exposed/not exposed to chlorine.

Results—Three clusters of signs/symptoms are statistically associated with an IGSA syndrome ($p<0.01$):

- Respiratory: shortness of breath, wheezing, coughing, choking
- Chest discomfort: tightness, pain, burning
- Eye, nose and/or throat: pain, irritation, burning

The syndrome requires the presence of signs/symptoms from at least two of these clusters. The latency period must also be considered for exposed/potentially exposed individuals.

Discussion—This study uses actual patient data from a chemical incident to characterize and validate signs/symptoms of an IGSA Syndrome. Validating signs/symptoms is the first step in developing new emergency department informatics tools with the potential to revolutionize the process by which emergency nurses manage triage victims of chemical incidents.

Introduction

Acute chemical exposures occur on a daily basis and pose a significant threat to life. Rapid medical assessment and accurate identification of a chemical exposure by first responders and emergency nurses are crucial in reducing death and disability.[1–4] A study of the January, 2005 Graniteville, SC chlorine disaster that killed nine and sent hundreds to the local community hospital found that usual triage systems do not recognize signs/symptoms (S/S) specific to irritant gas syndrome agents (IGSA), or latent signs of respiratory distress associated with chemical exposures.[1–4] IGSA gasses/liquids (also known as choking, lung or pulmonary agents) include such chemicals as chlorine, anhydrous ammonia and sulfur dioxide, may cause severe irritation and swelling of the respiratory tract (lining of the nose, throat, and lungs).[5,6] None of the triage systems analyzed in our previous study[1] demonstrated efficacy in establishing priorities for treatment of chlorine victims. Furthermore, no informatics tools currently exist to assist first responders and emergency nurses in processing victims efficiently, to continuously monitor for latent S/S, or to provide triage recommendations for IGSA exposures.[1–4] To mitigate the "surge" of casualties into emergency departments after a chemical mass casualty incident (MCI), informatics solutions are needed for emergency nurses to quickly and accurately identify, process, and triage patients. This study describes the validation of the S/S of an IGSA syndrome using patient data from an actual incident. This is the first step in the development of an IGSA triage algorithm that will soon be incorporated into a new prototype informatics tool to revolutionize the process by which emergency nurses manage triage victims of chemical incidents.

Significance

IGSAs are important manufacturing raw materials and are transported daily through communities by railcar, truck and barge.[7,8] Exposure to IGSAs can happen in a variety of settings, including those which involve a deliberate release of these agents (e.g., global

terrorism), resulting in injury or death to hundreds or thousands of people. The U.S. Department of Homeland Security estimated that an attack on a large urban chlorine gas storage tank, used in municipal water supply and sewage treatment, could kill 17,500 people, severely injure 10,000, and hospitalize 100,000.[9] Even the best prepared city is not capable of coping with a MCI of this magnitude. To manage the “surge” of casualties into a healthcare facility after a MCI, emergency responders and emergency nurses use triage to rapidly assess patients and prioritize their care with the goal of saving as many lives as possible.[10,11]

Typical field triage such as Simple Triage and Rapid Treatment (START)[12] uses only four parameters to assess a triage treatment priority: ability to walk, respirations, perfusion (pulse or capillary refill) and ability to follow simple directions. ED triage such as the Emergency Severity Index (ESI)[13] includes the assessment of patients requiring immediate life-saving interventions (i.e., Level 1), and high risk situations, such as patients who are confused, lethargic, disoriented, in severe pain, or have danger zone vital signs (i.e., Level 2). Data analysis for the Graniteville study showed an overestimate of the victims classified as Level l and Level 2 using the ESI triage system and an underestimate of red (immediate) victims by the START/JumpSTART (pediatric START) system.[1] Patients exposed to chemicals can experience dramatic and latent changes in S/S, (specifically low oxygen saturation), requiring ongoing monitoring and evaluation, which current triage systems do not consider.[1] Triage algorithms specific to IGSA exposures are needed to accurately determine the priority of care.[1,4]

Purpose

Two main challenges are encountered in the treatment of victims of IGSA MCIs: 1) rapidly identifying the chemical involved; and 2) identifying, triaging and processing those exposed accurately, precisely and efficiently to improve patient outcomes.[1] Informatics solutions that improve early identification, processing, and triage for patients admitted to the emergency department following an IGSA exposure will enhance the application of science in emergency nursing and disaster informatics. The use of actual data from a chemical incident to validate of the S/S of an IGSA syndrome will be used in the development of a new ED triage algorithm specific to IGSA incidents. This is the first step in the development of an informatics tool that will incorporate the IGSA triage algorithm to assist emergency nurses to accurately and efficiently: 1) detect a MCI; 2) identify an IGSA syndrome; and 3) triage patients during a chemical MCI.[4,26]

Methods

Only de-identified data were used for this study. The Office of Research Compliance at the University determined this study exempt from the protection of human subject’s regulations. All information from the paper medical records of the 198 patients seen in the emergency department at the local hospital within 24 hours of the chlorine incident were abstracted (146 patients were exposed to chlorine and 52 were not exposed). Ten years later, in the same hospital and in the same month of the year, information was abstracted from the first 100 patients admitted to the emergency department that day. These 100 patients plus the 52

patients not exposed the day of the actual disaster, serve as the comparison group for the study. The data were abstracted, organized and exported using Research Electronic Data Capture (REDCap)[14], a secure web application. All data were mapped (i.e., matched) to 93 S/S within two decision support tools designed by experts in medicine and emergency response (i.e., from the U.S. Department of Health and Human Services and the National Library of Medicine), to assist emergency responders and emergency nurses with hazardous material incidents. The Wireless Information System for Emergency Responders (WISER)[15] requires users to select S/S that a patient is experiencing from 79 possible S/S. The tool then queries its database to determine a list of possible chemicals to which the patient may have been exposed. CHEMM-IST[6] requires users to answer 14 questions about the patient's S/S and then the tool queries its database. This results in a prediction of the likelihood that the patient may have been exposed to a chemical(s) from one of 4 categories (i.e., Knockdown, Pesticide, Acute Solvent, and IGSA). These two tools provided a comprehensive framework of 93 S/S for mapping actual S/S of the 298 patients in order to characterize the IGSA syndrome. The S/S of those exposed and not exposed to chlorine were analyzed using inferential statistics (Chi Square/Fisher's exact test) and diagnostics tests (SAS/STAT® 9.4).[16] The mean number of S/S mapped to WISER and CHEMM-IST was then calculated.

Results

Table 1 shows actual patient S/S that mapped to WISER and CHEMM-IST.

Tables 2 and 3 show Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, False Positive Probability, False Negative Probability, and 95% CI for WISER and CHEMM-IST.

The results showed good sensitivity for both WISER and CHEMM-IST from .84 to .94 and .92 to .97, respectively; and poor specificity for both WISER and CHEMM-IST from .31 to .47, and .29 to .33, respectively. The positive predictive value and negative predictive values for WISER varied from .45 to .87, and .33 to .88, respectively; the positive predictive value for CHEMM-IST varied from .18 to .42, but the negative predictive value was excellent ranging from .88 to .97. The false positive probability for both WISER and CHEMM-IST was poor, ranging from .53 to .69 for WISER and .67 to .71 for CHEMM-IST. The false negative probability was excellent for both WISER and CHEMM-IST ranging from .06 to .16 for WISER and .03 to .08 for CHEMM-IST.

Table 4 shows the mean number of patient S/S mapped to WISER and CHEMM-IST by exposure.

The result showed the mean number of patient S/S for WISER was 7.2 as compared to CHEMM-IST, 2.2.

Discussion

Clinical S/S of an IGSA exposure depend upon the route of exposure (inhalation, skin/eye contact or ingestion).[15] The Graniteville 2005 incident related primarily to inhalational exposures; therefore, this study validated S/S based on such an exposure. During a chemical

MCI, when patient needs outstrip resources, patients must be triaged with particular emphasis given to the chemical's impact on the respiratory system - an impact that may not be evident until after initial triage occurs. Exposed or potentially exposed patients whose S/S have yet to manifest should be monitored until the end of the latency period for that specific chemical. The study data shows good sensitivity for the S/S mapped to WISER and CHEMM-IST (Tables 2 and 3): the sensitivity suggests that 84 to 97% of patients with S/S will be correctly categorized as having been exposed to the chemical. The study showed poor specificity for the S/S mapped to WISER and CHEMM-IST; (Tables 2 and 3): the specificity suggests that only 29 to 47% may be correctly diagnosed as not having been exposed.

Not all patients presenting to the emergency department during a chemical MCI have been exposed to the IGSA. For example, patients may present to the emergency department during a chemical MCI with coughing, a symptom commonly experienced with an Upper Respiratory Infection (URI). Table 2 indicates that a patient experiencing the S/S of a cough, has a 68% chance of being diagnosed with an IGSA exposure when actually experiencing a URI (false positive probability). This could result in over triaging for an IGSA exposure. Conversely this same patient has only a 14% chance of not being diagnosed with an IGSA exposure if exposed (false negative probability). During an MCI, categorizing patients wrongly as having not been exposed must be avoided to assure that a patient with a high priority for treatment is not missed. The false positives may be over triaged with a diagnosis of an IGSA exposure, especially in the winter months when URIs may have similar S/S as an IGSA.

Using the WISER and CHEMM-IST frameworks, the context of a chemical MCI, and analysis of the data, the IGSA Syndrome was characterized using the most sensitive S/S organized into 3 clusters. The following S/S are statistically associated with an IGSA syndrome ($p<0.01$):

- Respiratory: shortness of breath, wheezing, coughing and choking
- Chest Discomfort: tightness, pain, burning
- Eye, Nose and/or Throat: pain, irritation, burning.

Based on the mean number of S/S for WISER (7.2) and for CHEMM-IST (2.2), the analysis indicates that the characterization of an IGSA syndrome must include the presence of S/S from at least two of these clusters. Some IGSAs have a latency period which must also be considered when determining a plan of treatment for exposed or potentially exposed individuals.

Limitations

The ability to collect accurate, timely and valid data at the time of an incident is difficult. Data is often missing and/or challenging to collect.[1] Although this study used a small sample size, that was available, this is one of the first studies to use actual patient data from a chemical MCI to validate an ISGA Syndrome. In 2005 the community hospital that received the victims from the Graniteville disaster had not implemented electronic medical

records and used paper forms for documentation. In reality, during an MCI, many hospitals continue to have paper forms available as a back-up plan if computers are not available. Medical record data for this study were abstracted from over 20 different paper forms that contained conflicting information about the presence of relevant S/S. Documentation of time was often missing and notes were written in the margins of the forms. The abstractors used free text boxes during their data abstraction to note any problems or issues with illegible entries, unconventional abbreviations, etc. Three experienced emergency nurses on the research team conferred to resolve these issues. With the requirement that public and private healthcare providers comply with the American Recovery and Reinvestment Act[17,18] to adopt and demonstrate meaningful use of electronic records, the limitation of paper records as the primary form of health data collection is becoming obsolete. If the Graniteville data had been captured electronically, manual abstraction of the data would not have been necessary, thus minimizing the challenges.

Implications for Emergency Nurses

To mitigate the “surge” of casualties into a healthcare facility after an MCI, nurses use triage torapidly assess patients and prioritize their care with the goal of saving as many lives as possible.[1–9] Mitchell et al[1,19] stress the need for triage competency training of emergency nurses to manage chemical exposures. Usual ED triage is intended to sort traditional patients seen in the emergency department; it is not designed or effective for patients presenting with exposures to an IGSA. Depending on the dose and route of an IGSA exposure, S/S may not be evident until damage at the cellular level occurs. Irritation of the mucous membranes of the eyes, nose and throat is painful and obvious but it is the damage to the tracheobronchial tree and below that begins the cascade of physiological assaults that may result in death. The latency period from obvious damage to subtle and lethal destruction must be known so that the patient is monitored for sufficient time to detect and mitigate the damage. Pulse oximetry is an excellent indicator of the integrity of the respiratory tract[1,4] and will be a key parameter of the IGSA triage algorithm being developed and the informatics tool under design.

Conclusions

This is the first known study that uses actual patient data from a chemical incident to characterize the S/S of an IGSA Syndrome. The characterization of S/S related to an IGSA syndrome is the first step in the development of a triage algorithm specifically designed for IGSA incidents. Once the IGSA triage algorithm is fully developed and tested it will be incorporated into a computer informatics tool that is being designed to assist emergency nurses to accurately and efficiently: 1) detect a MCI; 2) identify an IGSA syndrome; and 3) accurately triage patients during a chemical MCI. A spill of such chemicals moving through a major city or used for global terrorism could injure or kill hundreds of thousands of people. Improvements in algorithms and disaster informatics related to ED triage during IGSA MCIs could save thousands of lives.

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Contribution to Emergency Practice

- Chemical exposures daily pose a significant threat to life. Rapid assessment by first responders/emergency nurses is required to reduce death and disability. Currently, no informatics tools for Irritant Gas Syndrome Agents (IGSA) exposures exist to process victims efficiently, continuously monitor for latent signs/symptoms, or make triage recommendations.
- This study uses actual patient data from a chemical incident to characterize and validate signs/symptoms of an IGSA Syndrome. Validating signs/symptoms is the first step in developing new emergency department informatics tools with the potential to revolutionize the process by which emergency nurses manage triage victims of chemical incidents.

Table 1

Frequency Distribution of Signs/Symptoms Mapped to WISER and CHEMM-IST by Exposure

Variables	Chlorine Exposure			
	No		Yes	
	N	%	N	%
WISER				
Cough/Choking				
No	20	66.7	10	33.3
Yes	43	39.6	64	60.4
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
Chest Discomfort				
No	25	71.4	10	28.6
Yes	45	45.5	54	54.5
CHEMM-IST				
Eye Irritation				
No	37	92.5	78	63.4
Yes	3	7.5	45	36.6
Burning Throat				
No	36	97.3	88	75.9
	1	2.7	28	24.1

Note: All variables are statistically significant at p<.001

Table 2

Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, False Positive Probability, False Negative Probability, and 95% CI for Signs/Symptoms Mapped to WISER

Variables	Sensitivity		Specificity		Positive Predictive Value		Negative Predictive Value		False Positive Probability		False Negative Probability	
	Se	95%CI	Sp	95%CI	PPV	95%CI	NPV	95%CI	FPP	95% CI	FNP	95% CI
Cough	.86	.79–.94	.32	.21–.44	.60	.51–.70	.67	.50–.84	.68	.56–.79	.14	.06–.21
Shortness of Breath	.94	.89–.98	.47	.36–.58	.68	.60–.76	.86	.76–.97	.53	.42–.64	.06	.01–.11
Wheezing	.92	.85–.99	.34	.25–.43	.45	.36–.53	.88	.78–.98	.65	.57–.75	.08	.01–.15
Burning Irritation of Eyes, Nose or Throat	.87	.69–1.0	.33	0.0–.87	.87	.69–1.0	.33	0.0–.87	.67	.13–1.0	.13	0.0–.31
Chest Discomfort	.84	.75–.93	.36	.24–.47	.55	.45–.64	.71	.56–.86	.64	.53–.76	.16	.07–.25
Choking	.87	.79–.94	.31	.20–.42	.59	.50–.69	.67	.50–.84	.69	.58–.80	.13	.06–.21

Table 3

Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, False Positive Probability, False Negative Probability, and 95% CI for Signs/Symptoms that Mapped to CHEMM–IST

Variables	Sensitivity		Specificity		Positive Predictive Value		Negative Predictive Value		False Positive Probability		False Negative Probability	
	Se	95%CI	Sp	95%CI	PPV	95%CI	NPV	95%CI	FPP	95 %CI	FNP	95 %CI
Burning Throat/Nose	.97	.90–1.0	.29	.21–.37	.24	.16–.32	.97	.92–1.0	.71	.63–.79	.03	.0–.10
Wheezing	.92	.84–.98	.33	.24–.42	.42	.34–.51	.88	.78–.98	.67	.59–.76	.08	.01–.16
Wet Lungs/Rales	.95	.86–1.0	.30	.22–.38	.18	.11–.25	.97	.92–1.0	.70	.62–.78	.05	.0–14
Eye Irritation	.94	.87–1.0	.32	.24–.41	.37	.28–.45	.93	.84–1.0	.68	.59–.76	.06	.0–1.3

Table 4

Mean Number of Patient Signs and Symptoms Mapped to WISER and CHEMM-IST by Exposure

Chlorine Exposure				
	Yes	**SD**	**No**	**SD**
	(n=146)		**(n=152)**	
Mean Number of WISER Signs/Symptoms	7.2	5.23	3.0	2.53
Mean Number of CHEMM-IST Signs/Symptoms	2.2	1.72	0.4	0.79