Simulation of a Hospital Disaster Plan: A Virtual, Live Exercise

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Abbreviations:
AAR = after-action report
CT = computed tomography
CTAS = Canadian Triage and Acuity Scale
UAH = University of Alberta Hospital
VLE = virtual, live exercise

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Abstract

Introduction: Currently, there is no widely available method to evaluate an emergency department disaster plan. Creation of a standardized patient database and the use of a virtual, live exercise may lead to a standardized and reproducible method that can be used to evaluate a disaster plan.

Purpose: A virtual, live exercise was designed with the primary objective of evaluating a hospital's emergency department disaster plan. Education and training of participants was a secondary goal.

Methods: A database (**disastermed.ca**) of histories, physical examination findings, and laboratory results for 136 simulated patients was created using information derived from actual patient encounters. The patient database was used to perform a virtual, live exercise using a training version of the emergency department's information system software.

Results: Several solutions to increase patient flow were demonstrated during the exercise. Conducting the exercise helped identify several faults in the hospital disaster plan, including outlining the important rate-limiting step. In addition, a significant degree of under-triage was demonstrated. Estimates of multiple markers of patient flow were identified and compared to Canadian guidelines. Most participants reported that the exercise was a valuable learning experience.

Conclusions: A virtual, live exercise using the **disastermed.ca** patient database was an inexpensive method to evaluate the emergency department disaster plan. This included discovery of new approaches to managing patients, delineating the rate-limiting steps, and evaluating triage accuracy. Use of the patient timestamps has potential as a standardized international benchmark of hospital disaster plan efficacy. Participant satisfaction was high.

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Introduction

Modeling emergency department disaster plans is difficult, as disasters represent high impact, low-probability events. In most cases, the hospital staff must be prepared for an event of a magnitude they have never experienced. As a result, disaster plans must be based on a number of assumptions regarding how patients will be treated during the event. In the absence of an actual disaster, many consider full-scale, live exercises to be the best test of a disaster plan. These exercises are expensive, time consuming, and impractical. In order to test hospital disaster plans, several other techniques have been used including computer simulation and tabletop exercises.

This study introduces a novel tool, the virtual, live exercise (VLE), which provides many of the benefits of full-scale exercises in a more manageable and less costly form.

Methods

Settings

The University of Alberta Hospital (UAH) is a large teaching hospital located in Edmonton, Alberta Canada. It services >70,000 emergency department visits per

	n
Patients	152
Pediatric (≤16 years of age)	23
Adult (>16 years of age)	129
Male	111
Female	41
X-rays	108
Computed tomographies	67
Intubations	7
Laceration repairs	31
Surgeries	25
Admissions	58

Table 1—Characteristics of the **disastermed.ca** patient database

	NATO	CTAS	START
T1	12		
T2	62		
T3	78		
T4			
1		13	
2		53	
3		59	
4		25	
5		2	
Red			12
Yellow			62
Green			78
Total	152	152	152

Table 2—Number of patients per triage code in the **disastermed.ca** patient database (CTAS = Canadian Triage and Acuity Scale; (NATO = North Atlantic Treaty Organization; START = Simple Triage and Rapid Treatment)

Procedure	Time Assignment/ Minute
Blood Testing	30
Arterial Blood Gas	10
Plain Film X-rays	30
Computed Tomography	30
Magnetic Resonance Imaging	60
Intravenous	15
Transfusion	45
Foley Catheter	15
Tetanus Toxoid	5
Fracture Splinting	15
Consultation	45

Table 3—Workup delay associated with various procedures

year. The Edmonton community has a population of approximately one million people and is managed by a single health authority. There are eight acute care hospitals in the Capital Health Region. All but three hospitals are urban teaching hospitals staffed by full-time emergency physicians, whose responsibilities include medical student and resident education.

The UAH has a detailed, written disaster plan that has been coordinated by the principal author (JFL) for approximately eight years. The written details of the plan are accessible to staff in both paper and electronic formats. The plan is based on an all-hazards approach. It includes an incident command system structure and pullout "cue-cards" detailing the duties of each role. During a disaster, unless power has been interrupted, the hospital will continue to use its day-to-day emergency department information system (HASS/iSoft) (iSoft, Branbury, UK). In addition, the hospital will continue to use computer-assisted triage based on the 5-level Canadian Triage and Acuity Scale (CTAS).[1] All physicians on-staff are oriented to the disaster plan as a requirement of employment. In addition, residents in the two emergency medicine training programs (Royal College of Physicians of Canada and College of Family Physicians of Canada) are oriented to the plan on a recurring basis with Web-tutorials, teaching sessions, and tabletop exercises.

Model

The model includes two distinct parts: the **disastermed.ca** patient database and a real-time VLE. The **disastermed.ca** patient database was developed to provide a set of simulated patients to represent disaster victims (Table 1). The database is written in MySQL (MySQL AB, Uppsala, Sweden).[2] Approximately 150 patient records were chosen, a number previously suggested as appropriate for disaster planning.[3] The database is a collection of historical, examination, and laboratory results and diagnostic imaging reports. The goal was to provide a scenario that was applicable to a variety of settings and contained realistic patient data. A scenario of a multiple vehicle collision, followed by a domestic disturbance was chosen. The distribution of patients by time and triage code was based loosely on the well-detailed Enschede fireworks disaster, which was the best-published description of a similarly sized mass-casualty incident.[4] All patient clinical details were extracted from actual UAH patient presentations. In addition, the triage codes in the database are those that were assigned to the patients when they presented to the UAH emergency department. To facilitate future exercises and to allow for international applicability, triage codes using the Simple Triage and Rapid Treatment (START) (four color) and the North Atlantic Treaty Organization (NATO)

HISTORY **Disastermed.ca**

PatientNumber	76
Arrival Time: Min	66.00
Age	20
TriageComplaint	Major Trauma: Intubated
Gender	m
GCS	3
Allergies	None
Medications	None
Tetanus Status	Current
NursingHistory	Intubated trauma. Motor vehicle collision, possibly driver, ran into building. Found be EMS underneath another victim in back seat. Apneaic with extensor posturing when found by EMS.
PresentHistory	High speed motor vehicle collision. Likely unrestrained driver, found in the rear seat entangled with another victim. GCS=3/15 on scene, intubated by EMS.
Past Medical History	Nil Contributory
SocialHistory	Non contributory
ExamGeneral	Intubated, unresponsive.

☐ Ambulatory

Time of start of Initial assessment: ___________

Minimum (minutes) 20

Time of Completion of Initial assessment: ___________

Minimum (min) 45

Time at departure from Department: ___________

You may check STAT CXR and ABG (if ordered) 10 min from time of ordering
You may check other Xray and Lab (if ordered) 30 min from time of ordering

Figure 1—Sample history form

(four number) system also are included in the **disastermed.ca** patient database (Table 2).

Since there was no actual patient contact and the exercise was to run in real time, it was necessary to establish certain delay times. These delays simulate the time the physician would spend with the patient and the time the patient would remain in the department awaiting evaluation. To simplify the simulation for the participants, two delay times were calculated: (1) MD-delay; and (2) Workup-delay. The *MD-delay* represented the time spent by the physician interviewing the patient, performing a physical examination, performing any procedures, documenting the encounter, and any time spent traveling through the department to see the next patient. MD-delay was calculated using a base time for each triage code and additional time for each procedure performed. *Workup-delay* represented the time the patient was in the emergency department before disposition. This included all time spent after the initial physician assessment before the patient physically left the department. During this time, the physician was not directly attending to the patient. This included time for laboratory studies, radiographic imaging, consultations, and all procedures performed by ancillary staff (respiratory therapy, nursing, and orthopedic technologists). The equation to calculate Workup-delay assumed many processes would occur concurrently. Therefore, as an estimate, the equation set the delay time to the time assignment for the process of the longest duration (Table 3). Moreover, the maximum Workup-delay was set to 120 minutes regardless of procedures performed.

The VLE was performed at the University of Alberta computer training facility, and was based on a training version of the hospital's current patient management system. During the VLE, the computers were staffed by a team of emergency physicians, emergency medicine residents, nurses, and registration clerks to represent the true staffing that would be available during a mass-casualty incident. To ensure that the starting point of the VLE was realistic, data from the live version of the HASS were downloaded onto the training software to represent the baseline status of the department at a time and day randomly chosen by a computer. Staff members were told that they would have access to all the resources, including staff and supplies that reasonably would be expected at that time.

To facilitate the exercise, exercise management staff were designated in the manner suggested by Glooven *et al.*[5] The exercise controller was responsible for ensuring that all aspects of the simulation progressed smoothly, including creation of the scenario, preparation of all equipment and participants, coordination of the exercise during the application phase, and facilitating the after-action review (AAR). A system controller was designated to prepare and implement the technical aspects of the exercise.

To prepare for the exercise, all participants were trained using two Web-based tutorials. The first tutorial described the UAH disaster plan in detail.[6] The second tutorial specifically addressed the content and procedures of the VLE.[7]

Three liaison officers were appointed. The Executive Liaison served as the higher control, simulating all interactions between higher levels of the organization. The Physician Liaison acted as flank control, simulating all activities of the other physicians within the hospital and surrounding community. Finally, the Staff Liaison served as lower control, and represented all non-executive and non-physician staff such as nursing, respiratory therapists, security, and housekeeping. To assist the officers in answering questions likely to have been posed by the exercise participants, a short information sheet containing suggestions for responses was provided.

A patient chart was created for each of the simulated patients. The chart was comprised of six sheets of paper:

1. Patient History Information Sheet (Figure 1);
2. Patient Physical Examination Findings (Figure 2);
3. Standard Hospital Emergency Department Chart;
4. Standard Hospital Diagnostic Imaging/Laboratory Testing Order Sheet;
5. Medication and Procedure Order Sheet; and
6. Patient Laboratory/Imaging Results

The VLE was scheduled for a four-hour session. Because of the limitation in time, and to allow for adequate briefing and debriefing, only the first 180 minutes of the **disastermed.ca** database (136 patients) were used.

To initiate the exercise, the Executive Liaison contacted the charge nurse with a brief description of the event. Organizational structure was left to the discretion of the participants. Two volunteers then assured that the simulated patients arrived at the triage desk at the time detailed on the history form. Simulated patients were triaged, and patient movement was simulated on the tracking software. Patient care physicians completed disaster charts for the patients, and ordered simulated laboratory tests, radiographic studies, and procedures while adhering to the MD-delay and Workup-delay parameters. Participants were allowed to view the results of "stat" investigations (arterial blood gas and portable chest x-ray) 10 minutes after ordering. All other results were available 30 minutes after ordering. Then, patients were admitted, discharged, or sent to the operating room or morgue.

Following the exercise, participants and hospital management were encouraged to provide written feedback regarding the exercise. An exercise evaluation form was provided, using a modified Likert scale.[8]

Data Collection

The following parameters of patient flow were the primary endpoints: (1) arrival time to triage; (2) arrival time to room assignment; (3) arrival time to physician assessment; (4) arrival time to admission; and (5) arrival time to discharge.

Data were analyzed using **OpenOffice.org** (Sun Microsystems, San Diego, CA) and the "R" statistics package (The R Foundation, Vienna, Austria) for SuSe Linux (Novell, Waltham MA).

Results

Thirty-three participants (15 physicians and 18 nurses) joined five facilitating staff members for the VLE. During the exercise, participants evaluated 136 patients. Resource utilization included 71 intravenous starts, 58 laboratory requests, and 16 electrocardiograms. In addition, there were six intubations, seven chest tube placements, 16 laceration repairs, and 42 requests for consultation. Radiographic studies were requested for 76 patients, including computed

Examination Disastermed.ca

PatientNumber	76
GCS	3
Pulse	87
Saturation	100
Resp	0
Temperature	36.1
BP	96/64
Ambulatory	☐
Pupils	3mm reactive right; 3 mm fixed left
ExamGeneral	Intubated, unresponsive.
ExamHEENT	Racoon eyes, bleeding from right ear canal. Large posterior scalp laceration.
ExamChest	Good air entry bilaterally.
CervicalSpine	No deformity noted. In spinal collar.
ExamCardiac	Normal
ExamAbd	Normal
ExamPelvis	Normal
ExamGU	Normal
ExamNeuro	No response to pain.
ExamSkin	Normal
ExamExt	No evidence trauma
ExamRectal	Normal Tone, no blood
ExamBack	No evidence trauma.
ExamPulses	Strong all extremities

Figure 2—Sample examination form

	Under Triage			Same	Over Triage		
Difference	*-3*	*-2*	*-1*	*0*	*+1*	*+2*	*+3*
n	15	25	32	34	13	8	2

Table 4—Under- and over-triage of virtual live exercise patients

CTAS Code		VLE	VLE (corrected)	CTAS Guidelines
1	Arrival to triage	4	5	Immediate
	Arrival to MD	6	4	
	Arrival to admission	57	57	
	Arrival to discharge home	NA	68	
2	Arrival to Triage	10	10	15 minutes
	Arrival to MD	15	17	
	Arrival to admission	74	72	
	Arrival to discharge home	42	64	
3	Arrival to Triage	9	9	30 minutes
	Arrival to MD	15	23	
	Arrival to admission	66	49	
	Arrival to discharge home	55	49	
4	Arrival to Triage	12	13	60 minutes
	Arrival to MD	26	23	
	Arrival to admission	53	19	
	Arrival to discharge home	62	51	
5	Arrival to Triage	9	NA	120 minutes
	Arrival to MD	25	NA	
	Arrival to admission	29	NA	
	Arrival to discharge home	48	NA	

Table 5—Virtual, live exercise (VLE) timestamps (time in minutes) (CTAS = Canadian Triage and Acuity Scale)

tomography (CT) for 53 patients. Fourteen patients received an ultrasound in the emergency department.

During the VLE, the participants introduced novel patient care approaches. For instance, participants opened an ambulatory care area and transferred patients with minor injuries directly to the ambulatory areas, bypassing the emergency department. Participants also created additional patient care beds by adding a stretcher into larger emergency department rooms.

During the exercise, CT scanning was found to be a major rate-limiting step of this emergency department's patient flow.

Triage codes assigned to the 129 patients who were triaged during the VLE differed substantially from those of the **disastermed.ca** database (Table 4). In particular, there was a substantial degree of under-triage during the VLE, with a total of 72 patients receiving triage scores higher (less acute) during the VLE then they had received in real-life. By contrast, only 23 patients were assigned lower triage scores (more acute). Overall, 26% of patients received the same triage code in the VLE as they had during their original emergency department visit.

Timestamps for the various patient markers were obtained and compared, when possible, to the response times recommended by the CTAS guidelines (Table 5).[9]

When rated on a 10-point modified Likert scale, overall participant satisfaction with the exercise was high (8.7/10). Most participants felt that the exercise effectively simulated the emergency environment and the emergency response activities (7.5/10). In addition, most participants felt that the simulation adequately tested the readiness and capacity to implement the disaster plan (7.6/10).

Discussion

The **disastermed.ca** patient database was a workable solution to simulate a disaster scenario. The type of patients within the database, mostly consisting of blunt trauma injuries, commonly are seen in most hospitals worldwide, and were felt to be realistic by the participants. This is advantageous, as the goal of the database is to test the coordination of the hospital disaster plan, not individual physician's medical knowledge. Had the database been created on a more esoteric injury mechanism (such as biological or chemical terrorism), it would be more difficult to account for individual physician variation in the treatment of patients.

It is difficult to provide universal benchmarks for the evaluation of disaster plans. When testing a disaster plan, individual evaluators often create their own patient data sets used for tabletop simulations. Often, these are overly simplistic. This may leave the participants of the exercise feeling content with their overall performance and allow familiarization with the plan, but it does little to provide any objective measurements of the effectiveness of the plan. Conversely, the **disastermed.ca** patient data set is far more detailed and designed to provide severe stress to the emergency department while allowing numerical endpoints for evaluation. The database is publicly available worldwide. It is hoped that the database will be used in a variety of testing settings. The benchmarks from these simulations may be published on the Website, allowing evaluators of disaster plans to compare the effectiveness of their plans with others internationally.

The VLE was useful in modeling the human behaviors that influence patient flow. During the VLE, the participants used of a variety of novel approaches to patient flow. This was informative for the disaster planners, suggesting the possibility of including these novel solutions into future iterations of the hospital's disaster plan. Exposure of the major rate-limiting step (CT) was valuable information attained from the VLE. During the AAR, many participants identified this limitation. In the future, the UAH emergency department disaster plan will have a more structured approach to CT resource utilization, including the addition of a dedicated CT gatekeeper.

During the simulation, the participants chose not to use the hospital's computerized triage system. Since most triage scores were assigned by a single senior emergency physician using an intuitive approach, it is difficult to make any generalizable conclusions about the implications of the variation in triage assignment. Undoubtedly, it would be useful to analyze triage scores assigned during multiple repetitions of the same VLE, and if the difference persists, it may be necessary to adjust the hospital's disaster plan to use a more simplified triage system.

Benchmarks of patient flow obtained from the VLE compared favorably with CTAS targets (Table 5). However, the true value of the benchmarks undoubtedly will be obtained by the repeated use of the same patient set in a multitude of scenarios. For instance, if changes are made to the hospital's disaster plan, the exercise could be repeated, and benchmarks could be compared. Furthermore, repeated use of the same patient dataset in different hospital's could lead to established times for objective benchmarking of disaster plans.

Overall, the high participant satisfaction is encouraging and indicates the utility of VLEs as training exercises. Since it often is difficult to recruit healthcare providers for training exercises, VLE can make these exercises more engaging to the participants compared to more traditional methods such as lectures.

Limitations

There are several limitations associated with the **disastermed.ca** database. Although the database is modeled after a set of actual patients, the patient set is not based on true disaster victims. Thus, the patient characteristics may vary from those encountered during an actual disaster. In addition, triage codes given to the database victims represent those given to the patients during their actual emergency department visits. Since the triage codes of the actual patient visit were based on a single encounter and were assigned by a single triage nurse using a computerized decision-support triage system, it is likely that greater variability should be expected during a disaster setting using nurses triaging from memory.

The VLE, though a useful adjunct to disaster plan evaluation, also has limitations. Although it is impossible to assess the accuracy to the VLE to reflect real life in this study, most of the staff involved in the exercise felt that the VLE patient flow was much faster and much more efficient than would be expected in a real disaster situation. A comparison of the VLE to an actual disaster is needed. Ideally, this would occur prospectively. However, this is unlikely to occur, since disasters are unpredictable. An alternative would be to use the patient data set from a disaster retrospectively in a VLE, preferably using volunteers who were not involved in the original disaster and who were blinded to its result. A less accurate, but more simplistic situation may be to compare the results of a VLE against an actual live exercise.

The provision of MD-delay and Workup-delay was a source of frustration for several participants. Since the time delays of MD-delay and Workup-delay were calculated mathematically prior to the simulation, they represent an approximation that may bias the results. Although in informal comments, most participants remarked that the delay times were realistic, others felt they were not. Unfortunately, provision of delay times was felt to be necessary as simulation of real-time patient management was required. Most simulations, including tabletop scenarios and live exercises, run faster than would be expected in reality. This increased speed may not be harmful if the primary goal of the exercise is education. Increased speed may allow the rehearsal of a larger number of tasks. However, slowing the speed to a realistic time frame is mandatory if any real-world estimations of patient flow are to be provided. Although the provision of MD-delay and Workup-delay was not ideal, it was felt to be the best available way of approximating real-time. This weakness largely has been corrected as an upgrade to the **disastermed.ca** database that will allow for future VLEs to have delay times that will be calculated by the computer during the simulation in live-time and be directly related to those studies and procedures actually performed.

Conclusions

The VLE appears to be a useful exercise for disaster plan evaluation. It is useful to help identify the creative solutions that participants are able to invoke during disaster situations. The exercise may help to expose rate-limiting steps in disaster management and useful estimates of patient flow can be computed. In the future, repeated uses of the same database in a number of scenarios could be useful in establishing benchmarks useful for disaster plan evaluation.

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