Vertical Evacuation Simulation of Critically Ill Patients in a Hospital

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Abbreviations:
BP = blood pressure
HR = heart rate
ICU = intensive care unit
VR = ventilatory rate

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Abstract

Introduction: The world's new social environment dictates the need for preparedness should a disaster occur. One caveat in the realm of disaster preparedness is the vertical evacuation of hospital patients. Little data regarding the evacuation of patients are available, and the consequences of not being prepared could be devastating. Therefore, if the vertical evacuation of critically ill patients was thrust upon a community hospital, the response of emergency services and ancillary staff is largely unknown.

Methods: The vertical evacuation of 12 simulated critically ill patients from the fourth floor of a newly constructed and vacant critical care unit was undertaken by local fire fighters, on-staff nursing, residents, and ancillary staff, all under the direction of the hospital Emergency Management Committee. Four randomly selected groups of firefighters, two teams consisting of three personnel and two teams of four personnel, were timed and had vital signs assessed prior to ascending to the fourth floor to retrieve a patient and upon each subsequent decent. Each team, dressed in full turnout gear, retrieved three patients. Each simulated patient was fashioned with mock endotracheal tube, intravenous lines, monitor, and a Pleurovac® was attached in three of the four patients. Vital signs were analyzed for significant changes or patterns due to exertion and or stress during the drill. Evaluations were distributed to all participants upon completion of the drill.

Results: Mean values for the vital signs of the members of each team showed minimal increases from baseline to completion with the exception of heart rate. A decrease in systolic blood pressure was present in both of the four member teams. Subjective evaluation by the firefighters, indicated a "minimal" increase in exertion. Mean extraction time was 14.7 minutes. Patient transfer and evacuation was completed without complication to the patients or staff. Only one firefighter requested a replacement. Completed evaluations indicated above average or outstanding performance on organization, commitment, security, and care. Comments included statements regarding equipment management during transport, better communication, stairwell width, difficulty with ventilating intubated patients, improvement of evacuation time, and organization as drill progressed; three member teams, spatially, worked better than four.

Conclusion: This drill reflected an impressive level of preparedness by firefighters, nurses, and ancillary staff both physically and organizationally. Should a vertical evacuation of critically ill patients be necessary, a four firefighter extraction team and accompanying nurse and respiratory therapist would be able to evacuate one patient at a rate of 3.75 minutes per floor.

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Introduction

Recent events in the United States, as well as in other parts of the world, have heightened the awareness of the lack of and need for preparedness in disaster situations.[1] As such, intricate disaster planning and drills have been undertaken by many hospitals. One of the areas of interest in disaster planning is the vertical evacuation of patients from a healthcare facility.

Team	Vital Sign					
A1	x BP	x HR	x VR	x SpO_2	x Exert	x Age (years)
B	137.5/79.5	66.50	19.20	98.25	4.75	36.25
1	155.5/87.2	132.0	26.75	96.50	3.50	
2	143/83.2	158.0	31.00	96.50	3.75	
3	151.2/83.2	139.0	30.00	96.00	4.00	
A2						
B	127.5/82.5	93.75	16.00	98.25	5.00	31
1	141.5/85	155.75	19.50	97.75	4.50	
2	133/82.5	156.25	27.00	95.50	4.00	
3	128.3/82.8	158.25	321.00	96.50	4.25	
B1						
B	138/95.6	67.20	19.60	99.00	5.00	34
1	146/101.6	139.0	29.60	96.20	3.80	
2	149/87	151.0	31.40	96.40	4.20	
3	134/69	149.2	33.40	95.40	3.40	
B2						
B	132.6/82	95.20		98.40	5.00	
1	136/92.8	144.8		95.20	4.60	
2	129.6/72.8	167.8		96.20	3.80	
3	133/79.6	172.4		94.80	3.60	

Table 1—Summary of physical assessment of firefighters extricating mock victims (values are means; BP = blood pressure; HR = heart rate; VR = ventilatory rate; SpO_2 = oxygen saturation; Exert = exertion rating; B = baseline)

Unfortunately, little data regarding vertical evacuation of patients are available. Without additional data, preparedness may suffer. Therefore, it is necessary to incorporate a realistic vertical evacuation plan based on past incidents and drills.[2]

Since this topic is relatively unchartered, the questions regarding vertical evacuation are: (1) What is the fitness level of firefighters in full turn-out gear when given the scenario of vertical evacuation (e.g., how many patients could a team evacuate before becoming exhausted)?; (2) What is the best method to be used for vertical evacuation (drag sheet vs. Stokes stretcher, other)?; (3) What is the level of patient safety during vertical evacuation (injury or dislodgement of necessary monitoring and resuscitative equipment)?; and (4) What is the optimal number of firefighters (carrying/maneuvering of patients) required when accompanied by a nurse and physician (monitoring/resuscitating patients) to efficiently vertically evacuate patients?[3]

Team	$t_{arrival}$	t_{depart}	$t_{extraction}$	Rest
A1				
B		10:07		
1	10:22	10:32	0:15	0:10
2	10:47	11:05	0:15	0:18
3	11:18		0:13	
A2				
B		10:08		
1	10:24	10:49	0:16	0:25
2	11:07	11:21	0:18	0:14
3	11:40		0:19	
B1				
B		10:27		
1	10:37	11:03	0:10	0:26
2	11:13	11:32	0:10	0:21
3	11:44		0:12	
B2				
B		10:20		
1	10:34	10:43	0:14	0:09
2	10:59	11:10	0:16	0:11
3	11:28		0:18	

Table 2—Extraction and rest times in minutes (B = baseline; t = time)

This vertical evacuation exercise provided a unique opportunity to utilize a recently completed and vacant, multi-floor, critical-care addition to the main structure of a 379-bed, community medical center. These conditions allowed a closely simulated exercise in the conditions of vertical evacuation of critically ill individuals without disturbing or being disturbed by the daily operations of this institution.

Material and Methods

In March 2003, a code red (fire alert) was initiated at a 379-bed, community-based medical center. This was a simulation intended to test the level of preparedness and capabilities of surrounding emergency medical support, volunteer fire, police, and hospital (ancillary, administrative, and medical) personnel. One hour before the start of the evacuation, firefighters were selected to be in one of two groups: Groups A or B. In each Group, there were two teams: Teams 1 and 2. In Group A, each team would consist of three firefighters, and in Group B each team would have four firefighters. Each team was allotted one additional firefighter, as reserve personnel, to be utilized in the event of injury or illness of an original team member. The teams were instructed that if, after a replacement was used and another of the team was injured or became ill, the team would then cease evacuating patients.

The team members were briefed on the task before it began. The only information they were provided was that there was a fire in the hospital and that critically ill patients on the fourth floor needed to be vertically evacuated using Stokes stretchers. They also were informed that a nurse and doctor would accompany each patient from the patient's

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Group: _____ Team: _____

Name: _____

____ Male ____ Female

Vitals	BP	HR	VR	Temp	SpO_2	Exertion	$t_{arrival}$	$t_{departure}$
1								
2								
3								
4								
5								
6								

Age: _____

Injury: ____ Yes ____ No If Yes, Explain: _____

Figure 1—Firefighters physical assessment (BP = blood pressure; HR = heart rate; VR = ventilatory rate; Temp = temperature; SpO_2 = oxygen saturation; t = time)

room to the staging area, and that those individuals would be monitoring the condition of the patient being evacuated. In addition, the teams were made aware that their vital signs would be assessed prior to their first ascension into the hospital and at the completion of each descension. A maximum of 10 minutes would be allowed for rest between the time of arrival on the ground floor and departure to evacuate another patient. Lastly, they also were directed to continue to evacuate patients until the evacuation was completed, and that there would be no substitution of team members other than for the reasons noted above. The fire department members in Groups A and B were in full turn-out gear: coat, overalls, gloves, boots, self-contained breathing apparatus, and helmet, all of which weighs approximately 75–80 pounds. Stokes stretchers were used for the vertical evacuation of patients.

The mock patients were junior and senior students from a local high school medical occupations class. Simulated intravenous lines were taped to their skin and endotracheal tubes were taped on the stretcher next to the mock patient's neck.[4] Consent for the mock patients to participate in the drill was given to the hospital through the students' high school.

The nurses involved were volunteers from the medical centers' nursing pool and the doctors were residents or interns based at this same center. Their role was to act as they would in an actual evacuation scenario, i.e., ventilating intubated patients with a bag-valve-mask, monitoring vital signs, and ensuring that the intravenous lines remained intact.

Two residents and two interns were assigned the task of obtaining vital signs on the fire department members in Groups A and B. Heart rate (HR), ventilatory rate (VR), blood pressure (BP), and pulse oximetry were assessed on the ground floor before the groups left for their first patient and upon their arrival to the ground floor with each subsequent evacuee. During this assessment, each team member also was instructed to indicate their level of exhaustion (energized; tired; need rest; weak; or exhausted) by pointing at a series of drawings symbolizing their respective level of physical exertion.

Therefore, the evacuation of patients went as follows. Each member of a team had his or her vital signs assessed (Figure 1). Then, the team left from the ground floor in full gear, climbed three flights of stairs, and proceeded to the next patient to be evacuated. A nurse and doctor were, and remained at, the patient's side attending to monitors, intravenous lines, and ventilation using bag-valve-mask while the teams moved the patient to a Stokes stretcher, and then, proceeded down the stairs to the staging area on the ground floor. At this time, the team members again had their vital signs assessed. This series of events was repeated three times per team.

For each team, vital signs, the number of patients, and the amount of complications during vertical evacuation were tabulated for each team member, and organized using a vertical evacuation assessment form. At the completion of the drill, all participating individuals were to be asked to complete the Vertical Evacuation Evaluation Form. This Form requested the responder to identify his role and to respond to four questions: (1) organization of drill; (2) level of commitment of personnel; (3) security of patient; and (4) appropriateness of patient care and treatment (Figure 2). The recording of each individual's responses was encouraged.

Results

This vertical evacuation simulation took place on 10 March 2003. At 08:45 hours (h) on this day, the firefighters participating in the drill were briefed on the protocol for the vertical evacuation simulation and all questions were addressed. Teams had been chosen by the Fire Chief. Age,

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Role in Drill: ____ Firefighter ____ Patient ____ Doctor ____ Nurse

Scale: 5 = Outstanding; 4 = Above Average; 3 = Average; 2 = Below Average; 1 = Poor

Organization of Evacuation	5	4	3	2	1
Level of Commitment of Personnel	5	4	3	2	1
Security of Patient	5	4	3	2	1
Appropriate Care/ Treatment of Patient	5	4	3	2	1

Comments/ Suggestions for Improvements _____

Figure 2—Vertical Evacuation Evaluation Form

experience, and stature of the firefighters were distributed equally; all were male. Two interns and two residents collecting and tabulating the vital signs were briefed and given materials at 09:15h. Staging areas for the teams were assigned and signs were posted for team identification. Simultaneously, mock patients were escorted to the fourth floor of the hospital for briefing of and preparation for their role. Prior to this drill, it had been determined that a total of 12 mock patients would be evacuated, and that each team of firefighters would transport three of the mock patients. Additional medical occupations students, who would assist in the assessment of vital signs, arrived in the firefighters staging areas and were assigned to a particular resident or intern.

Activation of the fire alarm occurred at 09:45h. Arrival of firefighters and equipment occurred at 09:48h. At this time, the hospital's Incident Command Center was being set-up and organized, and at 10:07h, the evacuation of patients from the fourth floor of the south wing was ordered.[5] In the interim between their arrival and the command to evacuate the critically ill patients from the fourth floor, the firefighters had been suiting up in full turn-out gear.

At 10:07h, Team A1 departed from the staging area to retrieve their first patient. Team A2 departed at 10:08h. Though Teams A1 and A2 had been informed to use Stairway 3A, and Teams B1 and B2 to use Stairway 3, there was some confusion, mostly brought about by Incident Command and Fire Command. Consequently, Team A1 used Stairway 3A and Team A2 used Stairway 3. In the same manner, Team B1 was directed to use Stairway 3A and Team B2 used Stairway 3. Fire Command also restricted the movement of teams in that no team would depart to retrieve a patient until the other team using the same stairwell had returned to the staging area.

Obtaining vital signs from the teams went as planned with the exception of ages and VR on Team B2. Heart rates as high as 182 beats per minute (bpm)(age: 28 years), 190 bpm (age: 33 years), 187 bpm (age: 50 years) and 178 bpm (age: 27 years) were recorded. The most elevated blood pressure was 170/83 mmHg, baseline 140/90 mmHg in a 35-year-old. Ventilatory rates as high as 36 breaths/minute were seen in a 31 year old. Pulse oximetry showed no hypoxia, and levels of exertion ranged from 3–5. Some individuals did show progressive elevation of vital signs objectively indicating increased levels of exertion. However, subjective evaluation by the firefighters indicated "minimal" increase in exertion.

Mean values for the vital signs for each of the teams for each run did show increases from baseline to completion (Table 1). However, with the exception of HR, these were minimal. Further scrutiny actually showed a decrease in systolic BP of 4 mmHg and diastolic BP of 26.6 mmHg from baseline to Run 3 in Team B1 as well as a decrease in diastolic of 2.4 in Team B2. Overall, the collected vital signs reflected good physical conditioning.

Extraction times (Table 2) had a mean duration of 14.7 minutes (range: 10-19 minutes). The mean time consumed for the rest periods was 16.8 minutes (9-26 minutes). Extraction times increased by an average of 1.75 minutes; Team B2 required four additional minutes by Run 3, whereas Team A1 improved their time by two minutes.

Information from the fourth floor indicated that transfers from patient beds to Stokes stretchers were relatively smooth. At 11:44h, all twelve patients had been evacuated. No complications or injuries to staff or patients occurred during the drill. There was no dislodgement of simulated intravenous lines or endotracheal tubes. There was one documented request (Team B2), upon completing extraction of their second patient, to have a reserve carry the next patient because the firefighter was experiencing cramps. Near the end of the drill, it became apparent that the reserve firefighters in all teams were not being used as instructed.

At the completion of the drill, all participants were requested to complete the Vertical Evacuation Evaluation Form. There were 70 respondents. Of these respondents,

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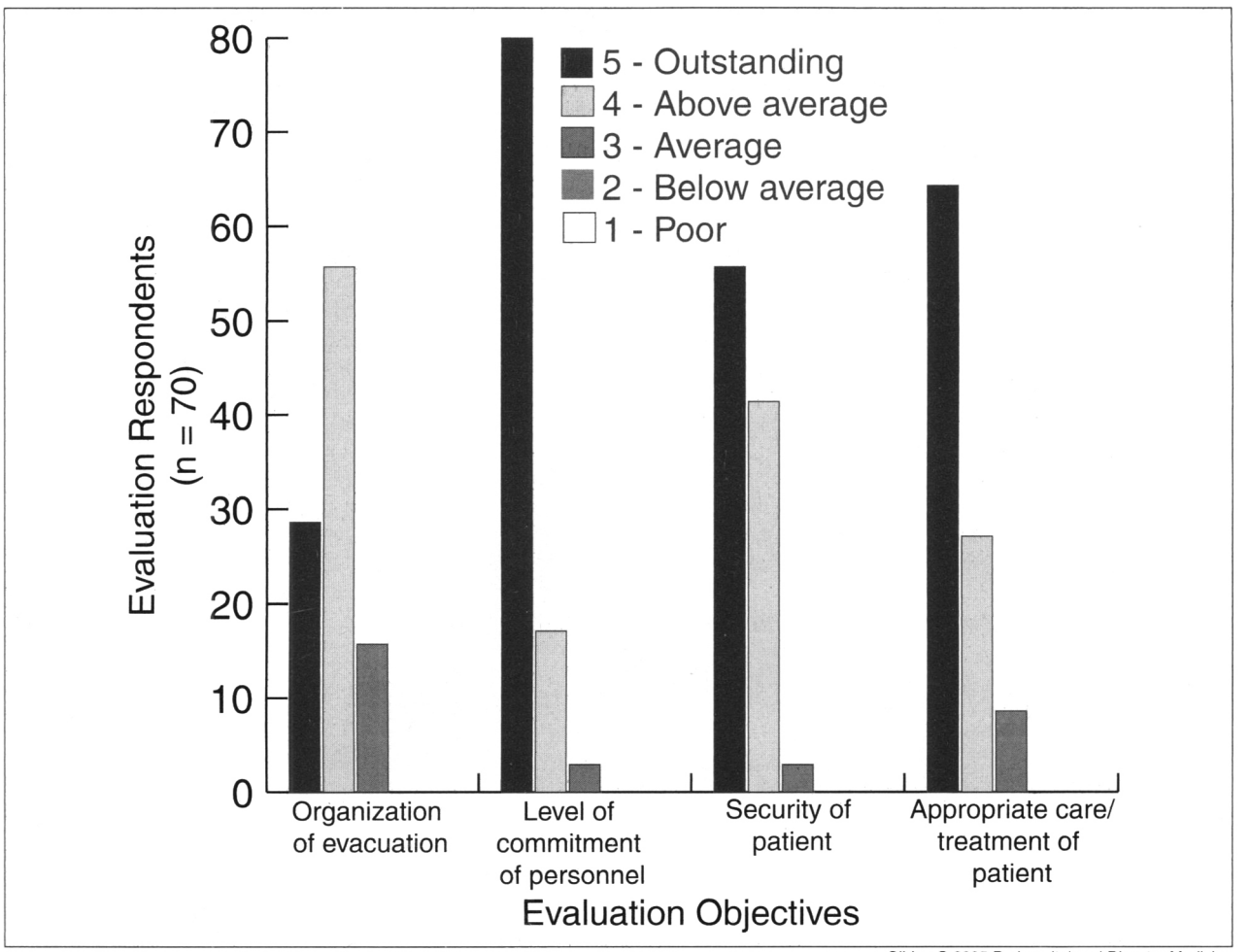

Figure 3—Vertical evacuation evaluation summary on a 5-point scale

there were 28 firefighters, 12 mock patients, eight other students, nine doctors, and 13 nurses. The distribution of responses is listed in Figure 3. Most responses reflected outstanding or above average performance on organization, commitment, security and care. No below average or poor ratings were recorded. Comments by participants included: (1) nurses and firefighters were unsure how to manage intravenous line pumps and Pleurovacs on the stretchers; (2) communication between nurses and firefighters was lacking; (3) there was only enough room for one medical person to assist the patient; (4) stairwells were too narrow; (5) ventilating intubated patients using a bag-valve-mask was difficult; (6) improvement occurred as the drill progressed; (7) three-man teams were better than four-man teams; and (8) the Stokes stretchers worked well.

Discussion

The majority of firefighters were in good physical condition and did not tire easily. Two-thirds of the firefighters showed a decrease in systolic blood pressure as they progressed through the drill; however, <25% had lower HR. If these BP findings are real, they could be explained by the initial excitement and unfamiliarity with their task being replaced by confidence and decreased effort as the teams began working in a more coordinated fashion. One confounding factor was the inappropriate use of reserve personnel. These individuals were used as the teams saw fit to improve their performance. This may have been appropriate in an actual incident but not for this drill. These reserves were there to help ensure that the team would complete the extraction of all three patients if one of their teams' members became unable to do so. By switching these reserves at will, the vital signs of the initial team(s) were confounded.

Though the firefighters believed the three-person team was superior to the four-person team, it should be noted that the mock patients did not accurately reflect the typical intensive care unit (ICU) patient. These volunteers were young individuals weighing between 45 and 72 kilograms whereas most ICU patients likely would be conservatively 20 to 30 kg heavier. This could have a significant impact on the number of firefighters required. Therefore, in an actual evacuation, although the three-person team allows for more agility in the stairwells and access to the patient by medical personnel, four firefighters may be required due to the patient's weight, equipment, and need for stability.

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This exercise was very controlled, and in an actual evacuation, extraction teams would be going up and down the same stairwell simultaneously and there would not be the excessively long rest periods between extractions. These two factors would introduce different problems and complications, and increase the level of exertion by the firefighters.

Using the mean value for the extracting time of 15 minutes in this study and the need for four firefighters per team to extract a patient from the fourth floor of a building, one could quantify the time required to remove X number of patients from Y numbers of floors. As well, the number of firefighters required to extract A number of patients in B amount of time could be estimated.

$$t_e = 3.75 \times F \times P / T$$

Where: t_e = evacuation time in minutes; F = number of floors; P = number of patients; and T = a four-person carrying team.

This study was biased and limited first by the non-random selection of teams. The most likely scenario for an actual evacuation is a more random grouping of firefighters as they arrive on scene. The selection of teams for this drill, though with good intentions, may have just as likely adversely affected team performance. The second limitation was the inability to test the physical limits of the firefighters. This limit was due to the use of alternates, rest periods, and the number of patients evacuated. The prior two have already been addressed. The latter was a result of time constraints and staffing. Third, the load/weight of mock patients was decreased as compared to actual patients. Lastly, the study was limited by the acquisition of vital signs, most notably BP and RR. Pulse oximetry and HR were determined using hand-held pulse oximeters. Asssesesments of BP and ventilation were obtained using a manual sphygmomanometer and visualization of chest wall excursion respectively. At least half of the vital signs were assessed by volunteers from the local high school medical occupations class. Proficiency in their ability to obtain vital signs had not been assessed prior to this study.

Conclusion

This simulated vertical evacuation produced better than expected performances by all those who participated. Three-member extraction teams carrying patients were supported by feedback from firefighters, however, the body habitus of patients in an actual evacuation would be as much as 50 kilograms heavier. Given this and the more realistic fact of minimal rest between extractions in an actual event, it seems that a four-person team would be more efficient.

The results of this study shed light on the capabilities of EMS and hospital staff, and thus, in future evacuations of patients from multilevel hospitals, the time required and manpower needed can be more accurately estimated.

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