CALLING 911: Emergency Medical Services in Need of Human Factors

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Applying HF/E principles to paramedics’ jobs and equipment could increase their effectiveness, reduce injuries, and improve patient care.

To maintain our health, we choose a healthy diet, take nutritional supplements, and engage in regular exercise. If preventive efforts fail, we research health information and choose providers with state-of-the-art medical knowledge, equipment, and procedures. If we call 911 for immediate help, however, we have no choice – we get the closest available ambulance. Thus, both as individuals and as a nation, we must depend on the quality of our emergency response system, and in most cases our trust is justified. Paramedics are dedicated, but as HF/E professionals, we know that dedication is not enough. This is especially true considering that most emergencies are characterized by task complexity, changing demands, and time pressure.

To react to these challenges flexibly and reliably, paramedics have to be well trained, well equipped, and supported by an efficient infrastructure. Given the complexities involved in emergency medical services (EMS), it is surprising that only recently have U.S. HF/E professionals begun to address potential issues in patient safety (e.g., Fairbanks, et al., 2008; O’Connor, 2002; Schwartz, Burgess, Craig, & Wichman, 2006). Occupational health (e.g., Ferreira & Hignett, 2004; Kluth & Strasser, 2005) and communication issues related to EMS (e.g., Furniss & Blandford, 2006) have been addressed mainly in European health systems.

To learn more about EMS in the United States, we observed ambulance crews housed in fire stations typical of the U.S. EMS system in terms of equipment, staffing, and organizational structure. Our observations spanned more than 60 hours during four daytime shifts and three evening shifts. Most observations were completed in metropolitan fire stations; one was performed in a suburban fire station. We scrutinized the physical features of the EMS work environment and conducted interviews focusing on decision making and organizational aspects of EMS.

In this paper, we report on our observations and highlight key areas where HF/E interventions may help improve the quality of EMS systems and make the lives of paramedics and their patients safer and easier. We will follow one EMS run to illustrate what we found.

Getting to the Scene

5:44 pm: The alarm sounds, signaling a medical emergency. Grabbing the remainders of their lunch, the crew listens to the page: “Station 12 Medic 2: Respiratory distress, overweight female, 154 Main Street.” Those on fire duty are laughing at the ambulance crew because they cannot finish their lunch. While the rolling door of the fire station goes up, the siren starts sounding; one paramedic checks the route and directs his colleague through dense afternoon traffic.

Dispatching. A 911 call initiates EMS. Callers have to declare the nature of the emergency. For a medical emergency, the dispatcher transfers the call to the fire department communication center. There, the call taker queries regarding the patient’s complaint and location. This information is entered into the computer and processed to a dispatcher, who assigns the run to a fire station. Using the patient’s location, the computer system provides a list of ambulances to be assigned. If the ambulance of the closest fire station is unavailable, the next closest available ambulance is assigned.
The dispatcher computer system is connected to terminals in the fire stations as well as to mobile systems in the ambulances. It provides information regarding current medical runs, assigned ambulances, and the status of hospitals and ambulances. Paramedics and firefighters also carry radio sets and mobile phones in case one of the connections breaks down. Special radio frequencies are reserved for talking to hospitals and fire stations.

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Despite redundancies in communication channels, inaccurate information may still hamper service delivery. We observed two cases in which the dispatch system provided either wrong or incomplete addresses. The paramedics had to make several calls to clarify the correct location, causing a delay of approximately 5 minutes. More in-depth analyses of critical cases may show how these problems can be counteracted. For an example study on UK dispatchers, see Furniss and Blandford (2006).

HF/E research on EMS deployment strategies can make important contributions to patient safety. For example, strategies that match incident criticality with levels of qualification of the to-be-assigned paramedics have been shown to lead to improved medical outcomes (Persse, Key, Bradley, Miller, & Dhingra, 2003).

Taking Care of the Patient

5:55 pm: Paramedics arrive on the scene. They take the airway management bag and the LifePak unit to measure blood pressure (BP) and blood oxygen concentration. Running to the second floor, they find a female patient lying on the floor. The patient is in obvious distress, short of breath and pale. One paramedic checks breathing, pulse, and pupil dilation and then starts querying for complaints, problem history, and medications taken. The other focuses on symptom control and starts measuring BP and blood oxygen. Because of the patient’s weight (> 200 pounds), one paramedic calls the fire station for backup. After securing the oxygen supply, the other paramedic begins writing the EMS report.

Treatment preparation and diagnosis. After being assigned to a run, paramedics prepare for the case. The dispatch center often provided enough detail to categorize the patient’s problem. The paramedics knew in advance which equipment to take, how to approach the problem, and what complications to expect. When the information from the dispatcher was insufficient, however, the paramedics diagnosed the problem on location.

Paramedics used three diagnostic tools: Interviews, physiological tests such as electrocardiograms (ECGs), and physical exams (e.g., pupil dilation, muscle tonus). Sometimes this evaluation procedure helped paramedics decide what treatment to initiate, but most often it did not result in a clear treatment plan. In ambiguous cases, paramedics called the hospital for medical direction from an emergency physician or, most often, stabilized and transported patients to the hospital for diagnosis and treatment. Whether communication via phone or radio can support accurate and timely treatment decisions remains to be tested in future research. Mobile computing devices may provide alternatives (see Lu, Xiao, Sears, & Jacko, 2005).

Medical knowledge, rules, and skills. The national training guidelines for EMS personnel (e.g., National Highway Traffic Safety Administration, 2007a) specify criteria for paramedic certification and provide standards of care, which enable paramedics to deal with most common problems. From our observations, it was clear that paramedics possess a repertoire of well-trained skills (e.g., injecting IV medication; physically stabilizing a patient) and highly automated routines. For instance, several times, paramedics decided to administer IV saline solution. According to them, to determine appropriate drip rates, they rely on rules of thumb (e.g., adults get a higher rate than do children) rather than calculations based on the size, height, and age of the patient, as required by national guidelines.

Although heuristics can facilitate and improve performance, especially under stress and time pressure, they can be dangerous in situations that deviate from the norm. For special cases, such as the treatment of infants or adolescents, paramedics are neither prepared nor allowed to go beyond the scope of their officially sanctioned skills and procedures (see National Highway Traffic Safety Administration, 2007b). In the observed cases, paramedics typically radioed the hospital for further instructions.

Currently, there is a dearth of research on how paramedics’ decision-making skills relate to their legally defined and actual scope of practice. Critical incident analyses would be one way to help better understand and, consequently, support paramedics’ medical knowledge and intuitions as well as their skills and procedures as these relate to acute treatment situations.
**Coordinating Work and Technology**

6:18 pm: The fire engine crew arrives, providing four more people and a stair chair. Although the stair chair facilitates transport, three firefighters are required to roll the patient down the stairs. One paramedic is carrying the patient’s oxygen supply and the LifePak unit; the other is preparing the ambulance. Four men are necessary to transfer the patient onto the ambulance stretcher.

In the ambulance, two firefighters begin hooking up the patient to the ECG; the paramedics try to insert an IV line in the patient’s arms. While working, the paramedics reach across the patient for new needles; one paramedic discards his gloves (for improving the feel) by throwing them across the ambulance into a trash bin. They do not succeed in gaining IV access and decide to take the patient to the hospital immediately. It is 6:25 pm.

**Physical equipment.** Emergency medical care must be delivered at locations such as homes, shopping malls, or busy highways, which are not designed to support medical services. Depending on the emergency and the patient, postures during treatment and transportation vary considerably. In many observed cases, undue physical effort was required, which may lead to occupational injuries. In our example case, a stair chair had to be used to transport a 200-pound patient. The full strength of three firefighters was required to control the chair. Stretchers allow height and tilt adjustment to ease patient transfer, but most transfers required more than two paramedics, the standard ambulance complement. These problems are becoming more serious, as the average weight of patients is increasing. Several paramedics complained that equipment – particularly the stretcher – was not designed to accommodate obese patients.

**Medical equipment.** Medical equipment was well maintained and organized. Before each shift, the paramedics checked equipment and restocked materials when necessary. Medic units had an identical layout, so paramedics could easily switch ambulances and/or provide backup to fellow paramedics. Frequently used equipment was organized in separate bags according to function and patient group. This way, paramedics could easily locate materials they needed, such as a bag for pediatric care or a bag for airway management. However, we observed several common problems with accessing medical equipment during care (compare Gilad & Byran, 2007).

Most equipment was stored on the patient’s side, opposite the paramedic, so access during care required leaning across the patient. In particular, paramedics found it inconvenient that containers used to store syringes and bandages were stored on a counter across from the paramedic. To circumvent this situation during en route care delivery, the syringe box was typically placed unsecured on the bench next to the paramedic (Figure 1, previous page). During several observations, this box was about to fall, and once it fell off the narrow bench in the back of the ambulance.

**Paramedics possess a repertoire of well-trained skills and highly automated routines.**

Even when these containers were kept in the appropriate location, it was not possible to secure them in a moving ambulance (Figure 2); boxes could, and sometimes did, fall off the shelves or benches, creating a hazard. Similarly, used syringes and needles were to be placed in one of two sharps containers. Because these containers were inconvenient to access during care, crews used a seatbelt to secure a third container on the bench next to the paramedic (Figure 3).

In addition, some common care activities were not accommodated. For example, Figure 4 shows a suboptimal workaround paramedics used to keep their equipment clean. Also, there was no storage place for prepared but soon-to-be-used syringes. Some crews taped syringes with commonly needed solutions to the back of the bench. During care, the paramedic had to put prepared syringes on the patient’s lap or on the bench next to him. These syringes rolled onto the floor during several runs, and in one case a paramedic forgot he had a syringe on the seat and sat on it.
Extending our findings, a recent HF/E analysis of urban EMS identified a potential for medication errors arising from ambiguous drug labeling, poorly designed packaging, and poor storage designs (Schwartz et al., 2006). More HF/E research focusing on the usability of medical and physical EMS equipment is needed.

Teamwork. EMS provides a good example of the challenges and benefits associated with distributed work. Teams are created and dissolved flexibly in reaction to changing situations. Even though the paramedics make and execute treatment-related decisions, in critical situations they depend on the help of fellow firefighters, physicians at the hospital, and/or police officers.

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Usually, before a medic unit leaves the fire station, the division chief decides whether two paramedics can handle the situation or if backup is necessary. If backup becomes necessary during a run, paramedics can request help by radiosing the fire station. In about 70% of the observed cases, backup support by a second ambulance or by a fire or rescue truck was provided. As backup arrives at the scene, firefighters have to quickly assess what is going on and begin to work on the next most pressing task. This is important because paramedics often have no time to provide detailed instructions.

For difficult or urgent procedures, several emergency medical technicians attend to the task simultaneously. In one case, a patient with small veins required IV medication. Three paramedics, one at each elbow and one at the left hand, simultaneously attempted to find a vein and administer the drugs. In other instances, up to four additional paramedics provided physical support. In addition, rescue units were called on for special skills, such as cutting somebody out of a car or opening locked doors.

If law enforcement is required, the police are notified. The hospital is always available via phone or radio for medical decision support. Before the ambulance starts, the EMS team notifies the chosen hospital of the patient’s imminent arrival and current status. If the patient’s condition requires immediate help, as with a heart attack, emergency personnel will be prepared to meet the ambulance on arrival at the hospital.

In sum, the coordination of personnel, information, and resources during all phases of EMS is critical to care quality and may benefit, for example, from HF/E perspectives on crew resource management training (e.g., Geis & Madsen, 2001).

Working in Motion

One paramedic calls the hospital to announce they are coming with an obese patient suffering from rapid heartbeats. The other paramedic starts driving. En route, the paramedic in the back continues controlling oxygen levels, monitoring heart rate, and unsuccessfully trying to insert an IV needle into the patient’s arms. Shortly before arrival, the paramedic queries the patient’s name and medical information for the EMS report. It is 6:31 pm.

Some of the most important work by paramedics is done while the ambulance is in motion. This complicated many of the paramedics’ activities. Most notably, paramedics routinely struggled to insert IV lines while the vehicle was moving. A lack of ergonomic support made it practically impossible for the paramedic to keep the patient’s hand steady while controlling his or her own movement sufficiently to insert the needle. To compensate, paramedics often used uncomfortable postures, such as kneeling next to the stretcher (Figure 1). If the paramedic is attempting to administer multiple forms of care, as in this case, he or she has to move around the ambulance to access resources. Several paramedics complained about the difficulties of delivering care in motion because they couldn’t stabilize themselves sufficiently to interact with the patient and equipment.

Initial studies recommend the replacement of rigid ambulance benches with adjustable seats, the use of height-adjustable stretchers to improve patient accessibility (Gilad & Byran, 2007), and skid-resistant foot rests/clamps that assist in stabilizing the paramedic during work in motion (Ferreira & Hignett, 2004). More such research is needed to improve patient safety and reduce occupational strain.

Changing Organizational Values

Historically, EMS developed out of underutilized fire departments. Firefighters had to acquire additional credentials as paramedics to be able to provide EMS to their community. Interviews showed that although many younger firefighters seemed to enjoy their EMS work as a welcome enrichment of their firefighter job, older firefighters often disliked their paramedic duties. Part of this dissatisfaction may exist because of an organizational emphasis on firefighting, leading to a disproportionate allocation of work, personnel, and equipment.
Whereas ambulances have to run practically all day, firefighters may have only one or two runs a day. Similarly, most fire stations are staffed with two paramedics, compared with two to eight firefighters, and may have two fire trucks but only one ambulance.

The imbalance between the emphasis on firefighting and the need for EMS may reduce worker motivation and decrease the efficiency of EMS. Given the increasing need for EMS and a call for nationwide emergency preparedness, fire stations may have to move away from an emphasis on extinguishing fires to increasing efforts toward meeting the challenges of EMS as a vital part of local health care systems. This changed situation may require a rethinking of fire departments’ organizational structures and equipment ratios and the adequacy of 24-hour shifts, which are typical for firefighters.

**Discussion and Summary**

Emergency medical systems are and will remain crucial in providing medical care for our communities. The need for effective EMS systems carries additional urgency with emerging efforts to augment national security and disaster preparedness. Our intention for this work is to raise awareness of the many efforts to augment national security and disaster preparedness. Whereas ambulances have to run practically all day, firefighting stations are staffed with two paramedics, compared with two to eight firefighters, and may have two fire trucks but only one ambulance.


- Effective treatment depends on well-designed equipment. Although most EMS equipment supports paramedics at work, usability research – particularly regarding activities during transport – is needed to maximize patient safety, treatment efficiency, and occupational health.
- EMS decision making relies on overtrained routines and heuristics for common problems. Critical care requires expert support, which is now available only via phone or radio. This mode of communication is inefficient and may delay treatment and/or transportation. Future studies should investigate the effectiveness of paramedics’ decision making during critical episodes and the possible use of decision aids.
- Teamwork is essential for the success of EMS. During our observations, communication among dispatchers, ambulances, and fire stations was the most common source of coordination problems. Research investigating the communications patterns and contingencies in EMS may help in the development of better coordination tools and procedures.
- As in the observed cases, paramedics are often firefighters with EMS training. Although this dual competency is resource efficient, the organizational culture of fire stations favors firefighting over medical care. The increased need for emergency preparedness may require the restructuring of current EMS systems. Future research should identify modifications that will allow community emergency systems to better balance firefighting needs with those of providing EMS.

**References**


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