Human Factors Review of EMS Ground Ambulance Design

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In 2011, Alberta Health Services (AHS) standardized the design of their new ground ambulances to improve provider safety in the event of a collision. Human Factors methods and design principles were used to examine the new ambulances and provide recommendations to further improve the workspace, functionality, and design for the next generation of ambulances. Human Factors consultants participated in ride-alongs within the urban Calgary area, observing patient care, staff interactions, and workflow. A total of 32 recommendations were suggested for future design iterations of the ambulance. Next steps include utilizing simulations and usability testing to ensure their feasibility and effectiveness.

INTRODUCTION

Within emergency medical services (EMS) both patient safety and care provider safety are essential requirements. EMS is recognized as a fairly dangerous and unpredictable profession in which vehicle collisions are known to be the most likely factors in fatalities (Macguire, 2003). The National Highway Traffic Safety Administration (NHTSA) analyzed fatal ambulance collision data from a 10 year period (1987-1997) and found approximately 340 ambulance crashes in the United States that contributed to the deaths of 405 people and over 800 injuries to ambulance occupants, with the most fatal and serious injuries occurring with unrestrained passengers and those in the rear patient compartment of the vehicle (Kahn, Pirrallo, & Kuhn, 2001; Becker, Zaloshnja, Levick, Li, & Miller, 2003). Due to these risks, a lot of attention has been focused on improving the crashworthiness of ground ambulance vehicles (Levick, 2007; Levick & Li, 2000; Levick, Shelew, & Blatt, 2001). Poor ambulance design and a lack of restraints for passengers in the rear compartment have been cited as being contributing factors in both injuries and fatalities during ambulance collisions (Sanddal, Alberta & Hansen, 2008). However, even with restraints available in the rear compartment of ambulances findings show that compliance using these safety belt systems is low due to perceptions that they limit patient care, are inconvenient, and restricted movement (Larmon, LeGassick, & Schriger, 1993).

There are many standards and regulations that dictate the physical design requirements of ground ambulance vehicles (Alberta Health and Wellness, 2010). But there is very little research on how to organize the required equipment within the interior of the ambulances based on ergonomic evaluations and principles to reduce musculoskeletal injuries and maximize provider efficiency and safety while providing patient care (Ferreira & Hignett, 2005; Gilad & Bryan, 2007). Human Factors considerations of care provider ergonomics, equipment layout and access and evaluating the effectiveness of proposed safety systems would be beneficial to enhance safety within the vehicles (Levick, 2007).

Prior to April 2009, Emergency Medical Services within Alberta, Canada were provided by 74 different municipalities and organizations across the province. As part of the transition of healthcare services in Alberta, EMS was brought under the umbrella of Alberta Health Services (AHS), creating a single provider for EMS for the entire province. This has created a unique opportunity to standardize how care is provided (i.e., policies and procedures, equipment, and ambulance design) throughout Alberta. Currently there are over 550 ground ambulances in use across the province. Due to each previous municipality ordering and purchasing their own vehicles, there is a huge variance in the design of these vehicles. One of the major milestones that were undertaken was to begin the standardization of ground ambulance vehicles across the province.

In recent years a move toward more crashworthy designed vehicles has occurred, but generally these have
been one off prototype vehicles that were never fully implemented into the system. The majority of the vehicles in use within AHS include such known risks as bench seats with lap belts, chairs that maintain a sideway facing orientation, lack of child restraints, and equipment storage and securing issues that dramatically increase passenger risk in the event of a collision. Taking into account previous research and design recommendations a “safety” vehicle was designed to improve EMS provider and passenger safety in the event of a collision. Safety enhancements such as forward facing Captain’s chairs in the patient compartment, as well as improved access to controls and supplies, were included to achieve an environment whereby staff could remain seated and belted while delivering patient care during transport. While in theory this seems straightforward, it does require a change in culture and practice for all EMS staff. In an effort to involve users in the design of the new ambulances, staff needs and requirements were recorded at multiple EMS engagement sessions across the province and changes to the design were made based on this information and known safety enhancements. However, user testing in the proposed environment was not completed prior to implementing over 50 of these new vehicles for use on the roads. Immediately staff concerns regarding changes to the design of the vehicles were voiced. A general perception that the new design limited patient care and did not function well for frontline staff requirements was observed. Therefore, Human Factors evaluations were requested to assist in examining the new design and provide recommendations for the next generation ambulances to further improve the ambulance workspace, functionality, and design to maximize compliance and safety within ground ambulances.

Human Factors studies how people interact in their surrounding environments, examining the equipment they use, the tasks they perform, and the physical environment in which it all takes place. By examining these interactions changes can be made to the equipment, task, or environment to improve efficiency, safety and reduce frustrations. The main goal is to optimize the design of the product in order to meet the users’ needs rather than forcing the user to adjust their behaviours to accommodate the product, which in this case was the ambulance design that staff were being forced to work with and felt did not support their behaviours and requirements.

METHODS

To determine what common tasks were required within the vehicles and gather information on staff workflow and concerns, two Human Factors Consultants participated in eight ride-along sessions in busy urban metro vehicles. During these sessions observations were made on patient care, staff interactions and workflow to highlight any difficulties or inefficiencies encountered while working within the new ambulances. Feedback from both urban and rural EMS personnel was gathered via interview over the course of the evaluations.

RESULTS

Based on observation data, Human Factors principles, and staff feedback, over 30 recommendations for changes to the ambulance design were made to the ambulance design committee. To date, 25 of those recommendations have been either included in the most recent design or are in progress for the next round of vehicle purchases. Three main areas of concern were identified: availability of workspace, labeling of supplies and medications, and access to both the patient and required equipment.

Workspace

The replacement of the large bench seat with the individual Captain’s chairs was done with the intention to improve safety. Previous findings have shown that side facing bench seats are less than optimal in the event of a collision (Levick, 2007; Levick & Li, 2000; Levick, Shelew, & Blatt, 2001). In comparison, the Captain’s chairs are able to rotate to a forward facing position which reduces injury risk in a crash situation. However, this new seat arrangement reduced both the amount of physical space and available workspace in the new ambulances making it difficult to move around the compartment and deliver patient care, forcing providers to take on awkward working positions.
These chairs tend to be large and bulky and protrude into the aisle along with the large stretcher wheels that stick out to the side. These issues increase the tripping hazard within the vehicle and reduce provider safety (Figure 2). Furthermore, because of the lack of foot space around the stretcher area EMS personnel were observed to take on suboptimal working positions (Figure 3) to accommodate for the space issues. By reducing the bulkiness of the Captain’s chairs and potentially reducing the depth of the supply cabinets, a clear path around the stretcher for care providers to move around the patient compartment safely would be created as well as allow workers to maintain better posture to avoid musculoskeletal injuries.

Figure 2. Physical space issues within the vehicle

Figure 3. Suboptimal working postures

Workspace is essential in the small confines of ambulances; multiple pieces of equipment and supplies are required for a single patient and these supplies need to be readily available when needed. In previous models of ambulances the providers were accustomed to using the large bench seat as a worksurface to place equipment bags and kits while in use. This allowed them to have the equipment they required conveniently located while they were treating the patient. On the downside, laying out all necessary equipment also increased the amount of projectiles and risk should a collision occur.

Figure 4. Previous bench arrangement used as a worksurface

Unfortunately, by replacing the large bench seat with individual Captain’s chairs, this previously used flexible workspace is also removed. In addition, an adequate work area replacement has not been provided in the new ambulances and as such, there are very little work surfaces available. The largest work surface provided is a drawer with a plexi-glass lid that when opened and covered, is intended to convert to a work surface. Unfortunately, some design issues impact its usefulness. For example, this surface is too small for the amount of equipment that is required, the drawer does not stay open and supplies tend to then roll onto the floor. Due to these challenges the providers do not use this work drawer and instead place equipment on their Captain’s chair (meaning they are no longer seated), on the patient, and on the floor in bins.

Figure 5. Workspace availability issues
Recommendations were made to improve the usability of the drawer work surface. Specifically, it was recommended to increase the size of the drawer to enlarge the available work area. In addition, installing a friction locking mechanism on the drawer to keep it open while in use and including a lip around the perimeter to prevent supplies from rolling onto the floor would improve the design and functionality of the workspace. In the next ambulance design, a separate extendible worktable was installed above the drawers with a friction locking mechanism for added workspace beside the attendant’s chair.

Labeling

The location of equipment within the new ambulances is still being determined and standardized. Therefore, the ambulances in use during the observation sessions did not include any labeling to assist users in performing their tasks, forcing staff to open multiple drawers to search for supplies.

There are a number of functions associated with the labeling of supplies. For example, labeling helps reduce search time and uncertainty when trying to locate a particular item, assists in maintaining standardization, and reduces the time required to restock the vehicles. There are two levels of labeling that are required to be functional for the tasks above. Level one labeling is used to locate supplies by providing general labels on the outside of the cabinets and drawers to indicate their contents. Currently all drawers and cabinets are only numbered, there is no indication from the outside of the cabinet or drawer as to what is currently stocked within it. By including general labels (i.e., medications, solutions and sets, cardiac medications, airway supplies) staff know the contents of each drawer or cabinet without having to open it. General labels should be as brief as possible as excessive labeling (i.e., every item housed in that drawer) will actually increase the search time for supplies.

The second level of labeling will occur within the cabinets and drawers themselves and are essential in maintaining standardization and assisting during the restocking process. Once staff have opened a drawer or cabinet, they then need to quickly locate the specific item they require. As such detailed labels are needed to ensure equipment is pulled from the appropriate bin, as well as facilitate the restocking of items. Each bin or medication pocket should contain the following pieces of information: the generic name of the item, size or concentration (if needed), and the stocking quantity. All of these will assist in improving standardization of stocking locations and quantities, as well as reduce search time for staff.

Ongoing work has occurred with EMS services to finalize the design of their labels and storage of equipment within the new vehicles. Recommendations for labels include avoiding the use of ALL CAPITAL lettering as this increases reading time and takes away word shape cues (MIL-STD-1472F, 1999; Safety signage at hydropower projects, 2001), maximizing contrast between the background and font on the label (i.e., black writing on a white background or vice versa) (NASA-STD-3000, 1995), and using a minimum of 16 point sans-serif font to maximize readability. A color coded bin technique was also suggested as a way to store supplies depending on their function. For example, airway supplies would be located in the blue bins, medications and drug in red bins, IV solutions and oral medications in yellow bins, and general supplies such as band-aids and gauze in green bins. Color coded bins will increase the efficiency of locating items by reducing the amount of bins that need to be searched.

Accessibility

During the observation sessions a number of accessibility and usability issues were identified that effected the provider’s ability to access both the patient, as well as some of the equipment within the ambulance (i.e., sharps containers). These issues impacted care and reduced the safety within the vehicles.

Patient access

Accessing the patient is essential at all times within transit; however, at times this was difficult due to the physical layout and equipment positioning. For example, EMS personnel were not able to adequately reach the patient to start IV’s or hook up lines from the CPR seat on the right side of the patient, as the seat was positioned too close to the patient’s head. In addition, access to the patient from the right side was compromised as large cabinets to the right of the CPR
seat impeded patient access and reduced the available work area around the CPR seat. As a result, providers were forced to stand and bend over the patient, or crouch at the side of the stretcher to perform common tasks (Figure 7).

To properly access the patient from the CPR seat it was recommended to adjust the positioning of the chair further back in the vehicle, so that providers would have more space to access the patient to start IVs and hook up lines. In order to do so, the equipment cabinets were shortened to allow for adequate space and the CPR seat was repositioned 7 inches further back in the vehicle. These changes have improved patient accessibility and usefulness of the CPR chair. Another recommendation to include a sliding track under this seat for better flexibility is currently under consideration.

**Equipment access**

Other equipment issues involved the usability of the Captain’s chairs, as well as the safe disposal of sharps while in transit and when providing patient care.

While the majority of staff understands the rationale behind the addition of the Captain’s chair in the new vehicles, the acceptance of the chair as a positive change is hindered due to a variety of design deficiencies. As mentioned previously, the chairs tend to be very bulky and impede into the available space around the patient stretcher. These chairs are designed to be flexible in that they will rotate to both a side and forward facing position depending on the nature of the task, allowing providers to better access the patient while still being able to wear their seatbelts while in transit. Specifically, staff are meant to adjust the seat in a forward facing position, for safety, while in transit. This is the key benefit and the most valid equipment design feature to reduce injury in the event of a collision. Unfortunately the chairs are difficult to adjust as the pull knobs for seat adjustment are not easily accessible and are difficult to engage. As a result, rather than adjust the seat to a good working position, the EMS providers were observed turning their torso while seated, taking on a poor working posture. Furthermore, the seatbelt is not height adjustable and tended to dig into the providers necks rather than be located across their shoulders.

While in theory the addition of the Captain’s chair is suggested to improve safety within the vehicle, design changes are needed to make the chair more functional, improve provider compliance, and make it more user friendly. Doing so may assist in increasing the compliance of seatbelt use within the patient compartment as none of the staff during any ride along sessions were observed using this seatbelt.
Lastly, the accessibility of the sharps container within the vehicle was identified as a concern. Needlestick injuries can increase the risk of blood borne virus transmission to staff (Needlestick safety and prevention, 2000). To reduce this risk, sharps are disposed of in biohazard containers (i.e., sharps containers); the location of one of the sharps container in the new ambulances negatively impacted this safety risk. Specifically, the opening was often blocked by the attendant’s chair requiring the provider to adjust the position of the chair while holding onto the sharp, which tended to be difficult. The sharps container was also positioned too low and required a “blind drop” when disposing the needle. In addition, the opening was not fully sealed and needles would fall between the container and the outside wall or remain on the lip of the sharps container, increasing the risk of needlestick injuries.

Improving the accessibility of the sharps containers involved relocating the sharps container to an alternate location within the vehicle. Rather than having the sharps container located within the cabinets it is now being placed to the right of the attendant’s chair on the back wall (Figure 10). This position optimizes visibility of the opening of the container and is accessible from a seated position on the attendants chair without requiring any adjustments. It is also positioned in a location which does not impede on other equipment and tasks within the vehicle.

CONCLUSIONS

Optimal healthcare environments are essential in providing the best patient care possible and increasing staff satisfaction. By testing and evaluating equipment and environments prior to implementation, changes can be made in a timely and cost effective manner that will improve patient care and safety and assist in changing the culture within the organization. A great deal of useful information and feedback was gathered throughout this evaluation. Recommendations were implemented where possible to ensure that improvements were made to the functionality, efficiency, and safety of the staff and passengers of these vehicles. These vehicles have been designed to optimize staff safety based on known risks and potential design improvements (Levick, 2007; Levick & Li, 2000; Levick, Shelew, & Blatt, 2001) but have not been designed to optimize workflow or meet care provider needs. Consequently, compliance to the use of these safety enhancements (i.e., seatbelts) was non-existent, nullifying their benefits and increasing the risk to care providers. Such safety aspects such as the occupant restraint net, which would normally “catch” any unrestrained passengers in the patient compartment, is not required when an individual chair is installed in the place of a squad bench (Alberta Health and Wellness, 2010). As such, the combination of providers not wearing their seatbelts and not having a restraint net installed in the ambulances, there is very little to stop/catch care providers in the event of a collision.
To improve compliance and further gather useful information on EMS provider workflow, patient care, and equipment requirements, additional Human Factors evaluations are recommended. By using patient simulation and scenario enactments within the new ambulance environment (Caird, et al., 2010; Chisholm et al., 2008) we can achieve a better understanding of EMS behaviours and dispel some of the myths (i.e., the need to stand up while providing patient care in transit) that are impacting safety within these vehicles. These user testing and simulation sessions can be beneficial to increase frontline staff buy-in for future changes by eliciting their feedback and providing behavior based evidence to validate the design, which in turn should improve the compliance rates for safety engineered systems in future generation vehicles.

REFERENCES


Levick, N., Shelew, W.B., & Blatt, A. (2001). Occupant injury hazards in ambulance transport, findings from full vehicle crash testing. Academic Emergency Medicine, 8(5), 527


