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Task Analysis of Paramedics in the Ambulance Patient Compartment

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Abstract. An ambulance is designed through the modification of an existing standard vehicle body. By converting, renovating and equipping a standard vehicle body with a patient stretcher, paramedic seats, nearside seats, and related medical equipment, the vehicle becomes an ambulance. Therefore, the requirements and layout of the ambulance interior are constrained by the space available and dimensions of the adopted vehicle. Ambulance occupant protection, safety and ergonomic aspects are usually compromised. High quality and consistent emergency care demand continuous quality improvement and is directly dependent on the effective monitoring, integration, and evaluation of all components of the patient's care. Currently, there is no standard or guideline regarding patient compartment layout to help ambulance manufacturers to improve this confine working space. This study aims to assess and evaluate ambulance patient compartment and its effect on the paramedics in performing their tasks. Since the paramedics have to respond to emergencies, their comfort, safety and ease of handling the various equipment in the ambulance has to be considered. A combination of techniques was applied to collect comprehensive data, including interviews, observations and questionnaires which outcomes are used as a basis of suggestions for the improvement in ambulance layout design. By analyzing the tasks performed, a proper layout which considers the ergonomic aspects will ensure that the first response is efficient and reliable.

Introduction

Ambulance is a specialized vehicle use in pre hospital service, built and equipped for a special application. The design, construction, accommodation, and safety of the patient compartment are important to ensure this first response service is efficient and reliable.

Usually a standard van body is converted to an ambulance by renovating and equipping it with a patient stretcher, paramedic seats, nearside seats, and related medical equipment. The design of an ambulance patient compartment is a complex challenge with design options constrained by space limitations and the requirements of emergency driving. As the space is tightly confined, the patient compartment is difficult to design because altering the specification to support one clinical task will affect other areas of equipment placement and storage. The design challenges reflect the current experience and working environment of ambulance personnel. There is no international standard for designing or arranging the patient compartment layout [1].

This is particularly true of ambulances used by the Ministry of Health in Malaysia. No studies have been done on the effect of the ambulance design on the performance of Malaysian paramedics. The comfort, safety, and ease of handling of equipment in the ambulance compartment for Malaysian paramedics have never been investigated. The study will be carried out for the van (standard body) because Malaysia currently uses fleets of automotive vans, designed and manufactured with specialized aftermarket additional retrofits to adapt them to the ambulance market. Four existing ambulance chassis model which are used as Advance Life Support (ALS) ambulance were involved in this study.

This study aims to highlight some of these issues by identifying the tasks carried out by the paramedics and the difficulties they faced in terms of clearance and reach-ability of essential equipment during their tasks. This analysis is an important input in designing the layout of the ambulance compartment. The stakeholders consisting of doctors, paramedics, medical assistance, engineers and ambulance drivers were considered.

Background of study. The paramedic's work environment is largely unpredictable and is well established as a source of considerable stress [2]. Much of the paramedic's time is spent providing patient care while transporting one or more patients in the patient compartment of the ambulance. The confined space of the patient compartment, the task requirements, and the configuration of equipment within the patient compartment contribute to risk of musculoskeletal injury (MSI) by requiring the paramedic to adopt and maintain awkward postures [3]. As with other health care providers, the requirements for patient handling present a significant risk of injury to paramedics [4, 5]. The interface between the ambulance and loading system is also one of the activities that contribute to Musculoskeletal disorders (MSDs) problem.

Lavender , et al. [5] analyzed the biomechanical stresses placed on the body based on simulations of frequently performed tasks. The relative risk of low back disorders was quantified using a trunk motion model. The hazardous tasks performed included pulling a victim from bed to stretcher, the initial descent of stairs using a stretcher, and lifting a victim on a back board from the floor. The data indicated where engineering changes to equipment regularly used by ambulance personnel would have the greatest impact in reducing the risk of MSI.

Harmful postures are a feature of working in an ambulance. Doormaal, et al. [6] assessed tasks using the Ovako Working posture Analysis System (OWAS) and the Work and Health questionnaire. A biomechanical model was applied to several specifically strenuous simulated conditions. The results showed that 16–29% of a work shift was spent in a harmful posture The recommendations included issues around the equipment in ambulance, training of ambulance assistants and adaptations of working procedures, including the position of the attendant to the side and not at the head of the patient.

Nine design challenges have been identified by The National Patient Safety Agency, The Helen Hamlyn Research Centre, [7] to provide a basis for future evidence-based standardization. Significant improvements in safe and effective working environment will be delivered by solving these challenges in a consistent way across the full range of vehicle used now, and in the future. This will also enhance patient safety, patient experience/satisfaction, and facilitate cost-efficient purchasing and procurement. The challenges are:

1. Ensure safe and effective access and egress
2. Improve working space and layout
3. Effectively secure people and equipment in transit
4. Ensure effective communication
5. Address security, violence and aggression
6. Facilitate effective hygiene and infection control
7. Maximize equipment usability and compatibility
8. Improve vehicle engineering
9. Humanize the patient experience

Material and methods

A combination of techniques was chosen to gather comprehensive data about the workspace and the patient care tasks performed including interviews, observations and questionnaires. Outcome from the observation, questionnaire and interview can be used as a basis for the suggestion for the improvement in ambulance layout design.

Interview. The interview guides were tailored to the different stakeholder groups, but all focused on identifying the strengths and weaknesses of the current patient compartment. Questions from the engineers and medical staff interviewed include the following:

- Malaysian policies in providing standard ambulance
- Aspects of equipment and layout standardization
- Procedure in providing care in ambulance
- Infection control

- Ambulance technical specification
- Comfort
- Medical equipment and consumable items

Questionnaire. A questionnaire on evaluation of performance were distributed to paramedics and medical staff by sending copies to Hospital Putrajaya, Hospital Serdang, Hospital Kuala Lumpur and Hospital Selayang. The number of musculoskeletal complaints was recorded base on modified Nordic Body Map Questionnaire.

Results and Discussion

The data gathered from observation, interviews, questionnaire, and task simulation were analyzed and discussed. Information from literature and findings from existing layout will be integrated to propose the improved layout.

Questionnaire and Survey. Respondents for the questionnaire were 30 medical staff with 24 males and 6 females from Hospital Kuala Lumpur, Hospital Serdang, Hospital Selayang, and Hospital Putrajaya. The paramedics or medical assistants spent an average 5.6 h (70%) of an 8 h shift in the patient compartment. The information was collected by visiting the Emergency Department at these hospitals. They were asked to rate the adequacy of features in the patient compartment, within the context of performing their job safely. All the information was gathered either by questionnaire or interview session. Ranking of the most frequently occurring clinical tasks were:

- Check pulse/blood oxygen saturation (93% of calls)
- Check blood pressure (93% of calls)
- Administer oxygen (73% of calls)

Within the ambulance (Table 1), the most physically demanding activity reported by paramedics was performing cardiopulmonary resuscitation (CPR), which is inherently demanding due to the requirement for chest compressions. Paramedics also identified the effort required to access the patient and equipment within the ambulance as physically demanding.

Table 1: Physically demanding Tasks of managing patients in ambulance

Physically demanding aspect	Number of respondents
CPR	24
Accessing patient (e.g., right side, legs)	18
Accessing equipment (e.g., under bench, across patient)	17
Seating (e.g., bench high, seat belts, too deep, sideways)	15
Ride quality/bracing	12
>1 patient/ transfer of secondary stretcher to swivel seats	10
Confined space (e.g., head room, foot space, moving in vehicle)	7
Bending over (unspecified context)	6
Monitoring vitals	6
I.V.	5
Vomiting/ tuming patient	3
Writing (e.g., while in motion, no writing surface)	3
Bag valve mask	2
Repositioning patient	2
Communication / noise levels	2
Intubation	2

The level of effort required to perform tasks within the ambulance was perceived to be greatest for CPR, loading the stretcher, writing while the vehicle is in motion, and working from the jump seat (Table 2).

Table 2: Mean level of effort required to perform tasks within the ambulance

Physically demanding aspect	Level of Effort (1= very easy; 5= very difficult)
CPR*	4.0
Loading stretcher	3.8
Writing*	3.1
Working from the jump seat*	2.9
Intubating or initiating I.V.	2.8
Working from the bench seat*	2.7
Monitoring patient status*	2.6
Accessing cup boards*	2.2
Removing portable oxygen	2.1
Removing monitors	1.9
Raising head/ back rest*	1.8
Removing the jump kit	1.7

Note: * indicates tasks performed while vehicle is in motion

The paramedics and medical assistants rated the noise (63.3% poor and very poor) and vibration levels (60.0% poor and very poor) in patient compartment to be high. Medical staff rated poor and very poor the overall space (60.0%), overhead clearance (40.0%), access to the patient (43.3%), line of sight to patient (53.3%), ability to access equipment while seated (50.0%), access equipment while standing (46.7%), access to jump kit (56.7%) and arrangement of storage/equipment (56.7%). Majority of the staff had concerns regarding the overall space, line of sight to patient, access to equipment, access to the jump kit, and arrangement of storage/equipment. Table 4 provides a summary of the number of respondents indicating each rating category for the design features of the patient compartment.

Table 4: Rating of features within the patient compartment

	Very poor	Poor	Good	Very good	Excellent
Environment					
Lighting	0	12	15	2	1
Noise	1	18	10	1	0
Vibration	4	14	10	2	0
Layout					
Overall space	4	14	10	2	0
Overhead clearance	1	11	16	2	0
Access to patient	1	12	16	1	0
Line of sight to patient	2	14	13	1	0
Access to equipment while seated	3	12	14	1	0
Access to equipment while standing		14	15	1	0
Access to jump kit	1	16	12	1	0
Arrangement of storage/equipment	0	17	12	1	0
Seating					
Location	2	11	16	1	0
Comfort	1	7	19	3	0
Back support	2	13	12	3	0
Handles, Latches, Knobs					
Ease of opening	1	11	15	3	0
Comfort	1	9	17	2	1
Within reach	0	9	18	3	0
Adequate number of handheld	0	7	19	4	0

The data collected from the modified Nordic Body Map Questionnaire showed as in Table 5 that the major complain for critical musculoskeletal pains are on the neck (71.4%) and lower back (89.3%), and 50.0% in the right shoulder.

Loading/Unloading. The most hazardous activity identified was loading the ambulance stretcher and patient onto the ambulance. The ambulance stretcher height is not easily adjustable and the wheels are unsuitable for long-distance travel within the hospital. Literatures showed that the easy loader, winch & ramp, and tail lift were the most popular methods of lifting used.

The easy-loader stretcher had the highest REBA score (8.1) followed by the tail lift (5.8) and the ramp and winch (5.7). It was found that the easy-loader scored significantly higher than all of the other systems. The risk level using the easy-loader was high with action category of 3 (action is

necessary soon). For the other systems the risk level was medium with an action category of 2 (action is necessary). NIOSH was used to validate the REBA analysis [8].

Table 5: The number of complaints for each body part

No	Part of the body (Location)		Complaint	
			No of participant	%
1	Neck	-	20	71.4
2	Shoulder	Right	14	50.0
3		Left	12	42.9
4	Upper Back	Right	12	42.9
5		Left	8	28.6
6	Upper Arm	Right	10	35.7
7		Left	8	28.6
8	Lower Back	-	25	89.3
9	Forearm	Right	4	14.3
10		Left	5	17.9
11	Wrist	Right	5	17.9
12		Left	5	17.9
13	Hand	Right	5	17.9
14		Left	5	17.9
15	Hip/Buttocks	-		
16	Thigh	Right	8	28.6
17		Left	8	28.6
18	Knee	Right	11	39.3
19		Left	9	32.1
20	Lower Leg	Right	7	25.0
21		Left	7	25.0
22	Foot	Right	12	42.9
23		Left	12	42.9

Results of Interviews. Findings from discussion with respondents consist of working procedure, and comfort used as the basis of information for further investigation and recommendation. Activities that can contribute to the risk of injuries and musculoskeletal complain by users were identified.

*Work Procedures.*Ambulance services must carry equipment and medications as per requirement of Treatment Protocols, Ambulance services should not equip ambulances with equipment that is outside of scope of practice of its Emergency Medical Technician (EMT) employees. All equipment must be designed and constructed to meet medical performance objectives and must not endanger patients. In the new ambulances design such that the requirement of ambulance operators such as the accessibility to any equipment is within reach. The 'ergonomic layout concept' means that all-necessary facilities including equipment are accessible without much hassle.

Comfort. The clearances between the seating paramedics and the head of the patient must be defined and established. Besides, the clearances between the swivel chairs and the stretcher must allow for appropriate space for easy movement of people when required. The position of chairs is often debated on whether it should be fixed or a bench. During travelling, some ambulance operators prefer to sit facing forward rather than facing the patient.

Risk of Injuries. The greatest risk of injury exists when there is extreme exposure to any single risk factor, or when more than one risk factor occurs simultaneously [9].The primary risk factors for MSI were identified and summarized relative to specific awkward postures that were commonly observed.

Forward flexion of the trunk occurs in combination with rotation (twisting) and high forces during many activities that are common for paramedics. Flexion in excess of 90 degrees is often sustained for long periods in load-bearing positions. These factors present risk of injury to the lower back. Sitting postures within the patient compartment are generally unsupported due to the requirement to maintain proximity to the patient or equipment, and due to the height and depth of the seat. Flexion of the trunk is often accompanied by extension and rotation of the neck to maintain a forward visual field, which presents a risk of injury to the neck. Static extension of the neck in excess of 45 degrees accompanied by rotation in excess of 30 degrees was observed. Activities observed during task simulations that are associated with risk factors for low back injury are listed in Table 6.

Table 6: Activities presenting risk to the lower back and risk factors

Activity	Concurrent Risk Factors
Sitting (e.g., at station, waiting, in transit)	Prolonged, static flexion; rotation, vibration
Raising and lowering stretcher	High force, flexion
Raising stretcher wheels	Moderate forces; rotation, flexion, lateral flexion
Loading/unloading stretcher	High force
CPR	High force; flexion; repetition; static posture
Monitoring vital signs	Static flexion, rotation while seated
Reaching equipment in cupboards	High force (bracing); flexion, rotation
Reaching far side of patient (e.g., patient straps, dressing wounds, cutting clothes)	High force (bracing); flexion, rotation
Bag valve mask	Static posture; flexion
Accessing jump kit/ALS kit on seat beside paramedic	Rotation; lateral flexion; high forces (bracing)

Shoulder flexion and abduction occurs in combination with high forces and could be considered repetitive due to the range in activities that result in flexion greater than 45 degrees. Extreme postures of the shoulder (flexion and abduction greater than 90 degrees) that are often maintained for more than 30 seconds are utilized while using grab bars to brace against motion inside the vehicle or when accessing equipment in the cabinets. Removal of jump kits, monitors and portable oxygen from the ambulance require extreme postures, often combined with ballistic forces to jerk equipment into position. Loading the main stretcher into the ambulance requires that the bottom of the stretcher is lifted clear of the floor. This was observed to require a forceful shoulder elevation for paramedics of shorter stature or when the ambulance was parked on an incline. These factors present a risk of injury to the shoulder and upper back. Activities observed during task simulations that are associated with risk factors for injury to the shoulder or upper back are listed in Table 7.

Table 7: Activities presenting risk to shoulders or upper back and concurrent risk factors

Activity	Concurrent Risk Factors
Loading stretcher into ambulance	High forces, shoulder elevation
Releasing stretcher mount	High impact forces, flexion
Reaching equipment in cupboards	High force, extreme flexion and abduction
Bracing against motion (holding rails)	High unpredictable forces; static flexion and abduction
Removing jump kits	High ballistic forces; flexion or extension and abduction
Removing monitors	High ballistic forces; flexion
Removing portable oxygen	High ballistic forces; shoulder elevation and abduction
CPR	High forces; repetitive; static flexion
Raising head of stretcher from bench seat	High forces; flexion of right shoulder
Tending to patient (vitals, inspection, etc.)	Static posture; flexion; occasional high forces
Bag valve mask	Static flexion (may be supported by knees)

Petzall [10] and Ferreira and Hignett [11]discuss access/egress issues with respect to the design of doorways and the physical task of loading and unloading. Most of these issues were identified in the comparison of the three stretcher loading system.

The patient compartment layout of the ambulance and the time spent working in this confined space, added to the fact that it is increasing, presents a risk to staff and patients. Medical equipment and consumable items all have the potential hazards in the patient compartment. Ferreira and Hignett [11] looked at the layout of the patient compartment and [6] looked at the effect of the layout on operator posture. The design challenge of space and layout are clear issues that need to be addressed particularly with respect to the working procedure, work system and how medical staff work in the ambulance.

The range of medical equipment and consumable items is large because most of them are loose items and it is suggested the interfaces between the equipment and the vehicle would benefit from standardization. Providing standard placement with suitable receptacles/restrains would be beneficial to ensure the safety, usability, portability, maneuverability, and hygiene.

Conclusion and Recommendation

This project reviewed the tasks of paramedics and the problems faced in ambulance with respect to clinical efficiency and paramedic postural safety. The most frequently occurring clinical tasks were checking pulse/blood oxygen saturation, checking blood pressure, oxygen administration, and check

blood glucose concentration. The most physical demanding activity reported by paramedics and medical assistance was performing CPR. The level of effort required to perform CPR perceive to be greatest, followed by loading the stretcher, writing while the vehicle is moving and working from jump seat. The questionnaire analysis provided information on discomfort, and perceptions regarding causation of discomfort and injury and the design of the ambulance and patient compartment layout.

Additional research is needed about the tasks performed and postures adopted by paramedics for patient loading and unloading, treatment of critical patients and major disaster scenarios. A proper understanding of the safety and ergonomics of this work place would assist greatly in enhancing and optimizing ground ambulance vehicle design and safety for effective patient care during transport, and may facilitate in creating an environment where there is a decreased perceived need for risky driving practice.

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