ORIGINAL ARTICLE

# Safe access/egress systems for emergency ambulances

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**Objective:** To comparatively evaluate the three most widely used ambulance stretcher loading systems; easi-loader, ramp/winch and tail lift to identify a preferred system based on safety and usability evidence.
**Methods:** Three data types were collected in the field, the laboratory and from a national questionnaire. Field data were collected using the qualitative methods of observation (link analysis and hierarchical task analysis) and interview (critical incident technique) over 12 months during 2004–5. Laboratory data were collected for detailed postural analysis. A national ranking questionnaire was used to prioritise the resulting design issues.
**Results:** The field study data were analysed, triangulated and summarised in a taxonomy to identify the design and operational issues. A list of 14 criteria was used in a national ranking exercise with 134 ambulance staff and manufacturers. Patient and operator safety was ranked as the highest priority, followed by manual handling. The postural analysis found that the easi-loader system presented the highest postural risk.
**Conclusions:** The tail lift was found to be the preferred and safest loading system from both the field and laboratory research and is the recommended option from the evaluated loading systems.

One of the core services provided by emergency ambulances is the transportation of patients. Paramedics and medical technicians use mobility equipment, including stretchers, carry chairs and wheelchairs, to load patients safely into the ambulance. The design of ambulance loading systems has advanced in recent years to protect patients and staff.[1] In the UK, health and safety legislation was introduced in 1993 to reduce the risks associated with manual handling.[2] This resulted in an increased use of easi-loader stretchers followed by the development of ambulance loading systems—for example, ramp/winchs and tail lifts (fig 1). Easi-loader stretchers have retracting legs operated by a system of levers; ramp/winch systems pull or mechanically tow the stretcher into the ambulance up a slope; tail lift systems use a moving platform to lift the stretcher until it is level with the ambulance floor.

A UK national survey carried out in 2003 found that the three systems shown in fig 1 were widely used, with 42% of services using easi-loader stretchers, 29% using tail lifts and 29% using ramp/winch systems. More recent guidance has resulted in a gradual phasing out of easi-loader stretchers in favour of loading systems that facilitate the loading of carry chairs and walking patients as well as stretchers.[3 4] Although a number of ambulance loading systems have been analysed in the past,[5] there has been no comparative evaluation of the three systems, providing little robust scientific evidence on which ambulance services can base their purchasing decisions.

## BACKGROUND

Healthcare is recognised as a high-risk industry with regard to spinal pain, with half of all injuries caused through handling loads in the workplace[6] and ambulance workers exposed to a higher level of risk than other occupational groups.[7–10]

Several studies have found that loading the patient is a major contributory risk factor.[9–11] The poor design of ambulances and ambulance equipment was associated with a large proportion of accidents reported.[5 8] The high level of manual handling risks for staff results in patient safety risks, with patient injuries associated with manual handling being reported as the highest risk. It has also been suggested that ambulance personnel may be obliged to manually handle more than other healthcare workers due to patients having unrealistic expectations of the help provided by paramedics.[12]

Vehicles used by ambulance services in the UK have to be licensed by the Driver and Vehicle Licensing Agency and have to meet a type approval requirement from the Vehicle Certification Agency.[13] As part of this approval, the vehicles and equipment must comply with BS EN 1789 and BS EN 1865.[3 4] These standards provide a base line for safety in the design of emergency vehicles for electrical requirements, vehicle performance requirements, medical devices, fixation of the equipment, emergency exits, minimum seating dimensions, braking requirements, glass requirements, interior lighting and sound.[14] They require vehicle manufacturers to provide safe and reliable means of loading and unloading stretcher bound patients. A national framework agreement for supply of accident and emergency ambulances to the NHS has been established by the Purchasing and Supply Agency[15] to ensure compliance with BS EN 1789.[3] Further design requirements have been introduced by BS EN 1865 to ensure that during loading and unloading tasks the maximum burden on any member of staff is half of the total weight of the patient and stretcher, for the minimum time possible and in an optimal ergonomic position to minimise bending.[4] Each UK ambulance NHS service serves a large geographical area covering rural and urban districts. Ambulance manufacturers design, engineer, build and test vehicles to meet all the service requirements, crew needs and weather conditions.[1]

This project comparatively evaluated three ambulance loading systems to identify a preferred system on the basis of safety and usability evidence.

## METHODS

Three ambulance services participated in the study between 2004 and 2005. Figure 2 shows that data were collected from three services using a range of field and laboratory-based methods.

Ethical approval was given by the Multi-centre Research Ethics Committee, Ref No 04/MREC09/3. Additional local

**Abbreviations:** HTA, hierarchical task analysis; REBA, rapid entire body assessment

**Figure 1** Ambulance loading systems: easi-loader, ramp/winch, tail lift.

ethical approval was granted by the individual ambulance services.

## Field data

In all, 378 h of data were collected over several months to observe the loading systems at different times of day/night, and in a range of environments and weather conditions. Interview data on significant incidents were collected using the critical incident technique.[16] Additional interview data were collected about everyday problems experienced with the systems in semistructured interviews. Both sets of data were audiorecorded and transcribed; however, because of the emergency nature of ambulance work it was not always possible to audiorecord, so field notes were also collected. Interviews were conducted with 31 paramedics and ambulance technicians and the data were analysed thematically.[17]

Observational data were analysed using hierarchical task analysis (HTA) and link analysis. HTA gives an indepth analysis by dividing a task (goal) into a hierarchy of operations to show how the activities of the operator are linked to the requirements of the system so that interface design, work organisation, training and human error can be analysed.[18] Link analysis is a representative technique for analysing movement between components within a system or product to record and represent the nature, frequency and importance of the links. A link occurs when an individual shifts attention or physically moves from one part of the system to another.[18] The data from the critical incident technique, HTA and link analysis were triangulated and summarised as a taxomony of key design problems.

## Questionnaire

Each loading system was found to have limitations. To prioritise the design issues a national ranking exercise was conducted with ambulance staff and manufacturers. The questionnaire was circulated electronically with help from the UK Ambulance Service Association. Participants were asked to rank the design problems in order of perceived importance.

## Postural analysis

Experiments were carried out at each of the three ambulance services to collect postural analysis data. Paramedics and ambulance technicians simulated loading and unloading tasks using five scenarios (eg, a 54-year-old man with history of angina complaining of chest pains, weighing approximately 20 stone (127 kg)) to load/unload the patient on foot, using a stretcher and on a carry chair. Participants were regular users of the vehicles/equipment, fit and free of lower back pain. Although participants were asked not to change their usual activities and postures, it is possible that the presence of an observer may have influenced their behaviour.

Observational data were collected using multidirectional filming and large rulers were used for calibration of the motion analysis tool (http://www.siliconcoach.com/). Postural snapshots were collected every 2 s and analysed using rapid entire body assessment (REBA).[19] REBA was developed specifically for use in the healthcare industry and has high face validity from extensive international applications. Data are collected about the body posture, forces used, types of movement or action, repetition and coupling. The final REBA score gives an indication of the level of musculoskeletal risk and urgency with which action should be taken on a five-point action category scale from 0 (no risk) to 4 (high risk).

An inter-rater reliability assessment for REBA coding was conducted before the full analysis. 40 postures were randomly selected and coded independently by the two authors. This achieved >75% agreement for the body segment codes and >90% for the action categories, both acceptable levels for inter-rater reliability.[20]

A pilot study was carried out to develop the scenarios and check the measuring equipment, lighting and camera positions. Data were sampled and analysed every 2, 5 and 10 s of the task.

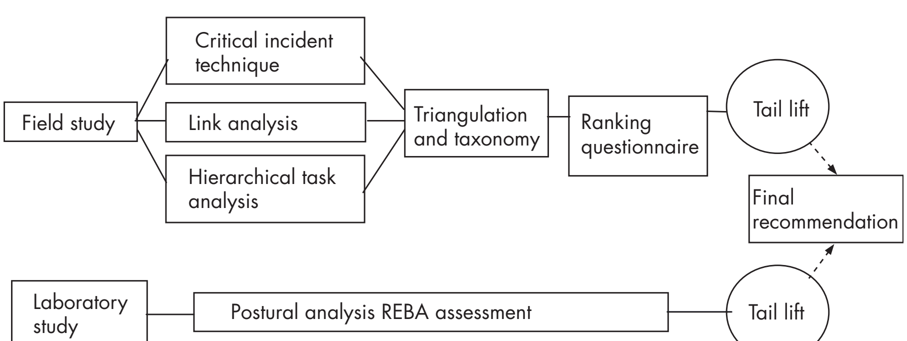


**Figure 2** Methods.

It was found that analysing the postures every 2 s of the task provided a detailed analysis without missing important postures from subtasks within the overall task.

The data were collated and the average REBA score calculated for each task giving a score for postural risk on a five-point action category scale of 0–4.

## RESULTS

### Field data

The empirical data from the interviews were entered into NVivo for detailed analysis.[21] Critical incidents were described in 10 of the 31 interviews. A detailed thematic analysis of the full interview data produced 53 codes. These were separated into the three loading systems and then further analysed to produce the taxonomies for the three loading systems. The codes were scrutinised for accuracy, consistency and duplication. Primary thematic coding elicited five higher level generic codes across all three systems: system failure, environment, patient-related, equipment and coping strategies, and adaptation. These codes were used as the framework taxonomy.

The link analysis data were mapped individually for each loading and unloading task of the stretcher loading system resulting in 170 datasets. These were summarised into 18 generic tasks and analysed to determine the average number of links per task. Loading and unloading tasks were found to be more complicated with the tail lift. For example, loading a stretcher using the tail lift was the most complex task requiring an average of 19.3 links to complete the task compared with 11.6 and 10.5 for the easi-loader and hydraulic ramp, respectively. Figure 3 shows the composite results for loading a stretcher with the tail lift. Each line represents a movement between the two components. It can be seen that most of the movements are located at the rear door of the vehicle, but that the air suspension control was located in the drivers cab and 7 links were needed between the cab and rear door to complete the task. The highest frequency of links was between the tail lift control and the tail lift, followed by the stretcher, head and foot end locks, and the tail lift.

For unloading, the tail lift had an average of 9.7 links compared with 7.4 and 3.9 for the hydraulic ramp and easi-loader, respectively. It was found that the winch was not used during any loading or unloading tasks in the ramp/winch system and that the core components (winch, stretcher locking bay and ramp) were not well aligned. The easi-loader appeared to be the least complex task when loading a carry chair, but when the task was checked in the HTA data it was found that correct protocol for this loading system had not been followed. The carry chair was lifted into the ambulance, whereas the protocol stated that the patient should be transferred onto the easi-loader stretcher outside the ambulance and then loaded on the stretcher. Assisting a walking patient off an ambulance was the least complex using the tail lift, with only 1.6 links compared with 2.7 for both of the other systems using the side step egress.

An HTA was developed for each observed loading and unloading task resulting in 170 HTA datasets. These were combined into 23 generic task summaries with the design and operational issues compiled into tables. There were many more issues observed with the tail lift than with the easi-loader and ramp and winch. Issues identified with the ramp and winch related to manual handling and posture, equipment misuse and vehicle layout. The easi-loader analysis highlighted issues of manual handling, force exertion and posture. Although the tail lift did not have manual handling problems, a number of other issues were identified, including posture, control location, equipment misuse, user equipment interface intolerance and user error.

To compare the three systems, the results from the observational data were triangulated and compiled into both a table and visual diagrams (fig 4) displaying which factors affected which systems, and which data analysis technique had identified them.

### Questionnaire

The national ranking questionnaire received 134 questionnaires from ambulance services and manufacturers. As the questionnaire was distributed electronically, the total distribution and therefore the percentage return rate are not known. In all, 59% of respondents were operational staff and regular users of the equipment. The questionnaire data were analysed by calculating the average ranked score (table 1).

Basic operational and safety design issues such as stretcher/control location and obstacles were omitted from the questionnaire. Control location was an issue for each system—for example, the winch, air suspension and ramp controls were not colocated.

Patient and operator safety, and manual handling were ranked as the most important factors for loading and unloading patients, followed by system design with respect to mechanical/electrical reliability.

### Postural analysis

A total of 662 postures were analysed and the average REBA scores were calculated.[22] The easi-loader was in action category 3 (score of 8.1, action necessary soon), whereas the other systems (tail lift score of 5.8, ramp/winch score of 5.7) were in REBA action category 2 (medium risk, action necessary).

## DISCUSSION

The most important operational factor was patient and operator safety. The tail lift was found to perform best for this factor, with fewest identified problems. The ramp/winch had finger traps and the stretcher was observed to be jerked (or bounced) over the vehicle/ramp interface, due to a difference in floor height, resulting in an unsafe and uncomfortable ride for patients. Some of the ramps did not have full-length side barriers to prevent stretchers slipping off, although the wedge ramp was protected at the top.

The easi-loader stretcher had the most problems for patient and operator safety. Difficulties with the operation of the stretcher legs were both reported and observed with the legs occasionally failing to lock in place.

Staff reported manual handling risks for all systems, with more for the ramp/winch and easi-loader than the tail lift. Manual handling issues relating to the tail lift stemmed from the weight of the stretcher rather than the loading system. Observations of the ramp/winch recorded that the winch was not used on any occasion for loading or unloading tasks. All three systems reported mechanical/electrical faults, but these were often attributed to the incremental design process (in particular for the tail lift) with each new version being an improvement on the previous model.

Time can be crucial when transferring a patient to hospital, so the system must operate at speed if required. The easi-loader was the fastest system to operate, followed by the tail lift, with the ramp/winch the slowest. The safety precautions for the tail lift added task complexity and time to the tasks—for example, staff were observed to step into the vehicle without deploying the steps, resulting in a step height >75 cm.

Road camber affected all of the systems, although the ramp/winch and tail lift systems were less affected than the easi-loader. On an uneven surface, neither the ramp nor the tail lift platform lie flat against the ground. For the easi-loader a camber can increase the catastrophic risk of the legs failing to

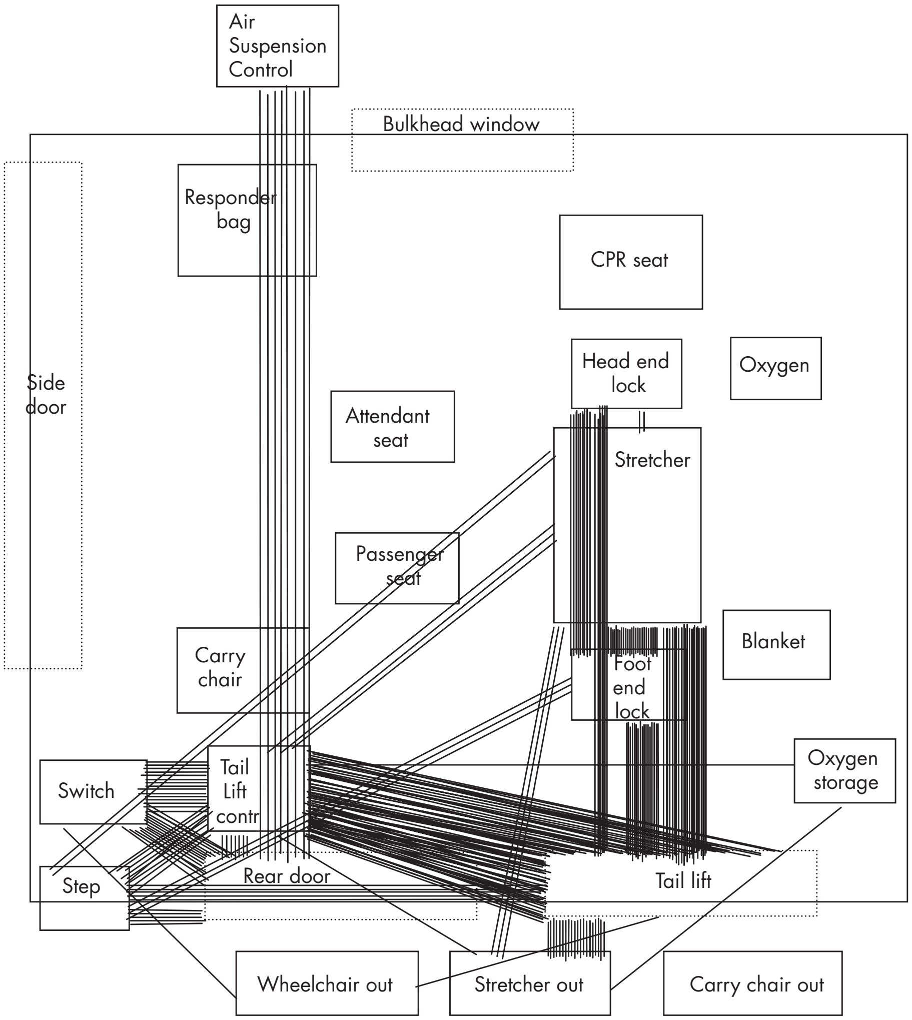


**Figure 3** Link analysis of stretcher loading with the tail lift (each line represents an interaction/link between the two components).

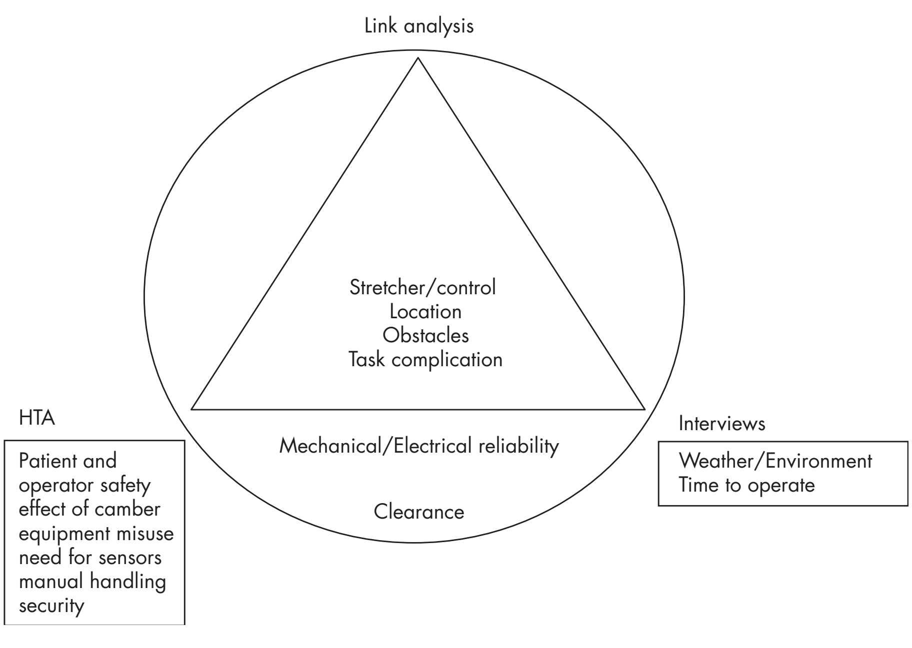


**Figure 4** Triangulation results for the tail lift (triangle, three methods; semicircles, two methods; and boxes, one method).

**Table 1** Ranking results

| Factor | Average ranked score | Ranked position |
|---|---|---|
| Patient and operator safety | 1.7 | 1 |
| Manual handling | 3 | 2 |
| Mechanical/electrical reliability | 4.9 | 3 |
| Time to operate | 5.4 | 4 |
| Carry chair access | 5.4 | 4 |
| Vehicle layout | 5.7 | 6 |
| Task complication | 6.1 | 7 |
| Weather/environment | 8 | 8 |
| Clearance | 8.1 | 9 |
| Effect of camber | 8.3 | 10 |
| Security | 8.8 | 11 |
| Infection control | 8.8 | 11 |
| Equipment misuse | 9 | 13 |
| Need for sensors | 11 | 14 |

lock and staff compensate for this by lifting the stretcher, to allow the legs to rotate through their full arc, increasing the manual handling risk.

The design of the interface between the ambulance and loading system is affected by both the weather and security issues. For example, vehicles with the tail lift and easi-loader systems are both left open after unloading the stretcher as the loading systems protrude from the vehicle preventing the back doors from being locked. The doors in the ramp/winch system can be closed when the ramp is deployed so the unattended ambulance is secure. Better security solutions must be considered.

For unloading, it was found that a large percentage of patients were transported on a stretcher, whereas they had been loaded on either a carry chair or stretcher, depending on health status and their location when the crew arrived. This suggests that the ambulance loading system needs to facilitate loading of all types of mobility equipment. Easi-loaders have no facility to load carry chairs, and although the ramp can be used to load a chair, the winch cannot be applied. Because of the position of the stretcher and the carry chair inside the ramp and winch vehicle there is limited space for wheelchair access. The tail lift is the only system that can be used to load all types of mobility equipment and so reduces manual handling.

The results from the postural analysis data found that the tail lift and ramp/winch posed a medium risk to staff (REBA action category 2) whereas the easi-loader had a high risk (REBA action category 3). The 2 s data sampling for the postural analysis allowed detailed analysis and the identification of high risk subtasks. It was recommended that some of these could be omitted from the tail lift task, by automating the subtasks carried out for patient safety measures—for example, opening out the back step to the vehicle, and raising and lowering the support hand rails. Further improvements could include a lower tail-gate height, alternative tail lift designs to deal with the task complexity and postural issues, and a substitute rear door to deal with security issues when the tail lift is lowered.

This study has found that automotive technology has reduced manual handling and reduced the risk of musculoskeletal injury to ambulance staff. This suggests that the advancements made in recent years to protect patients and staff have been successful.[1]

The British standards have supported the phasing out of easi-loader stretchers in the UK.[3 4] This study supports this initiative by finding that it posed a greater risk of injury to staff and patients. Ambulance services in the UK have been moving towards automated systems such as the ramp and winch and tail lift, but this is a slow process, with 42% of services still using easi-loaders in 2003. The tail lift loading system was found to eliminate lifting and considerably reduce manual handling in loading and unloading from the ambulance and is recommended for future ambulances in the UK.[22]

Further research is needed on the design of stretchers and carry chairs due to concerns raised about the equipment weight and compatibility.

## CONCLUSION

Both the field and simulation studies identified the tail lift as the preferred ambulance loading system. The tail lift reduces manual handling activities and provides the option to load stretchers, carry chairs, wheelchairs and walking patients. There is scope for improving the design by automating subtasks, lowering the tail gate height, improving security and simplifying operational designs.

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