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HUMAN FACTOR ASPECTS OF THE "LITTER RAK" SUPPORT SYSTEM IN AEROMEDICAL EVACUATION

RALPH W. TRIMBLE, Captain, USAF, BSC

BRYCE O. HARTMAN, Ph. D.

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas

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FOREWORD

This report was prepared in the Neuropsychiatry Branch under task No. 775504 and in support of task No. 405404. The work was accomplished during March and April 1969. The paper was submitted for publication on 20 January 1970.

This report has been reviewed and is approved.

JOSEPH M. QUASHNOCK
Colonel, USAF, MC
Commander

ABSTRACT

As part of a continuing program at the USAF School of Aerospace Medicine to evaluate aeromedical evacuation equipment, a comparative study has been made of human factor problems relating to the current litter-support system and the new Litter Rak (LR) system. Crews of novice and experienced medical technicians were timed and filmed performing various routine operations with each system. On a posttest questionnaire, all crewmembers indicated preference for the current system. Problems in the new LR system were identified as: time factors (particularly in configuration of the system); safety factors (for patients and crew); and practical difficulties (e.g., weight, and dependency of the total system on easily lost parts). Most of these deficiencies in the LR resulted from design complexity. Hence, simplicity in design and operation should be a key attribute of future litter-support systems.

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I. INTRODUCTION

The current type of litter-support (LS) system used in USAF aeromedical evacuation has been the same for over 25 years. This system holds the litters in tiers by means of metal stanchions, straps which connect to the aircraft's ceiling and floor, and metal brackets attached to the straps and to the stanchions. Hence the system is familiarly termed the "strap-and-buckle method." Some of the obviously favorable attributes of this system are ease of handling, lightness in weight, and minimum bulk. Nevertheless, various problems exist, such as: limited safety in the moving of litters during flight, limited accessibility of patients for care during flight, and questionable strength tolerances of the system. Therefore, new design concepts are under consideration.

The Lockheed Corporation of Georgia has developed one new concept in a system known as the Litter Rak (LR). It has metal arms with subsections which not only support the litter but also slide horizontally to extend the length of the arms (fig. 1). This movement capability allows aircrew members to pull the litter outward toward the aisle and away from the rest of the tier (in the same way that one pulls a drawer outward from a filing cabinet) without having to dismantle the system. The most obvious advantage of this design concept is greater patient accessibility. However, the ease of intra- or inter-tier movement of litters and the crash-worthiness of this all-metal system are also positive attributes.

The research for this report is part of a larger evaluation of Lockheed's "second generation" LR and the present LS system. Human factors involved with each system are of primary concern here. Thus, practical difficulties and time requirements for various operations are considered in addition to the questions of intra- and inter-tier movement, patient accessibility, and patient safety. Because a crewman's familiarity with the current LS system might create favorable or unfavorable prejudices and thus add to normal human factor problems, the medical technicians (constituting the crews) were assigned to groups on the basis of whether or not they already had experience with the system.

II. METHOD

Subjects

Six medical technician instructors of the USAF School of Aerospace Medicine (USAFSAM) made up two crews of three members each. Their respective experience with the current LS system ranged from 7 to 14 years.

Twelve students from the USAFSAM medical technician's school made up four crews of three members each. None of them had previous experience with the current LS system.

Test facility

The USAFSAM uses a trainer mockup of the C-141 transport for instruction purposes. This mockup was the testing facility for the present study. Components were provided from each support system to allow configuration of a double center-stanchion tier and one corresponding bulkhead tier. Other material included the litters and bandages necessary to complete the following procedures.

FIGURE 1

Photograph of the Litter Rak system, with slide-out capability illustrated, as used in the C-141 aircraft.

Procedures

The two crews of technicians already familiar with the current system were labeled Experienced group A (E-A) and Experienced group B (E-B). Each crew was familiarized with the LR. Then, with each support system, the crews conducted three trials, each of which involved the following five operations:

1. Configuration of a double center-stanchion tier and one bulkhead tier facing the double tier (thus providing space for 11 litters).

2. Enplaning one "patient" and three empty litters on the center-stanchion tier facing the bulkhead tier, and enplaning one patient and two empty litters on the bulkhead tier. The center-stanchion patient was placed in the third-from-bottom position in his tier (except in a few cases, when he was placed in the second-from-bottom position); the bulkhead patient was placed in the middle position of his tier.

3. Reinforcing a bandage placed on the knee away from the aisle for each patient.

4. Deplaning the patients and litters.

5. Deconfiguration of the LR system.

For the LR trials, an additional operation of moving a patient from the top position of the center stanchion to the bottom position was originally planned but proved to be unfeasible (as explained in the report section on "Results"). The crewmembers were allowed short rests between each of the operations. Trials with the LR system were counterbalanced with those with the LS system in order to minimize possible systematic effects (such as fatigue) on the crew.

The four crews of technician students lacking experience with the current LS system were labeled: Inexperienced groups A (I-A), B (I-B), C (I-C) and D (I-D). Each of these crews was familiarized with the LR and with the current LS system. Then, for each system, the respective crews conducted the three trials (already described)—but with the following differences:

During Trial I, each inexperienced crewmember was personally instructed and guided through his activities by an experienced member.

During Trial II, an experienced crewmember was present both to answer the crew's questions and to point out errors to the crew.

During Trial III, the inexperienced crewmembers were "on their own."

The following types of observations and measurements were made throughout the study:

The time required to complete each of the operations for any given trial was recorded to the nearest second.

The operations were filmed for subsequent review and documentation of positive and negative features of each system.

Crewmembers filled out a questionnaire (table I) designed to elicit their reactions to the two support systems.

III. RESULTS

Type of litter-support system and crew-experience level (in terms of the current LS system) were the two main factors considered

TABLE I

QUESTIONNAIRE

Litter Support and Suspension System

	Current buckle/strap system	Litter-Rak system
1. Which system was easiest to learn how to use?	____	____
2. After learning, which was easiest to use with regard to:		
a. Assembly	____	____
b. Patient loading	____	____
c. Patient handling	____	____
d. Patient unloading	____	____
e. Disassembly	____	____
3. All factors considered, which system do you prefer? Why?	____	____
4. What learning difficulties did you encounter with:		
a. Present system?		
b. Litter-Rak system?		
5. Cite favorable and/or unfavorable features of each system:		
a. Present system favorable?		
b. Present system unfavorable?		
c. Litter-Rak favorable?		
d. Litter-Rak unfavorable?		

in the study. Trial III operation times and responses to the seven comparison questions (items 1, 2a, 2b, 2c, 2d, 2e, and 3) of the crew questionnaire (table I) were the quantities analyzed.

An analysis of variance on repeated measurements revealed no crew-experience effects at the .05 level of significance for Trial III operation times. Of the two support systems, however, the LR required a significantly longer time for configuration, reinforcing bandages, and deconfiguration operations (all P's $< .01$). In table II are provided the mean differences between the systems, and standard deviations of the differences for the Trial III operations.

The replies to the seven items in the crew questionnaire (table I) are summarized in table III according to the frequency of responses in favor of the two systems and the probabilities of obtaining these frequencies—assuming either type of response to be equally likely. As shown in table III, the only item which did not yield a significant preference for the current system was concerned with patient handling (item 2c). On the question of patient enplaning (2b), crew preferences for the current system were significant at the .05 level; on all remaining questions, crew preferences were significant at the .01 level. Particularly noteworthy was the unanimous agreement, in favor of the current system, where crewmembers were asked to consider all factors of each system and list an overall preference.

TABLE II

Trial III operations

Operation	$\bar{d}$* (min.)	S.D. (Difference)
Configuration	1.46	0.43
Enplaning	0.27	0.68
Reinforcing bandages	0.40	0.18
Deplaning	−0.03	0.28
Deconfiguration	1.03	0.52

*$\bar{d}$ = Litter Rak mean time minus the current LS system mean time.

No statistical analyses were made for the short-answer items of the crew questionnaire, but the repeatedly cited favorable and unfavorable attributes of each system were noted. The LR was often viewed favorably for its patient accessibility, one of its important design features. The LR is often viewed unfavorably, however, for its weight, bulkiness, complexity (e.g., places and functions of various pins, and placement of the support arms), its limited aisle space, the tendencies of pins and other equipment to bind or otherwise malfunction, the ease with which crucial parts (e.g., pins) could become lost, and the frequency of injuries to the technicians' hands.

The current LS system, on the other hand, was often viewed favorably for its light weight, simplicity, and accompanying speed and ease in configuration and deconfiguration. The LS system was viewed unfavorably, however, for the difficulties in alignment of the brackets and in keeping the straps out of the way during the enplaning and deplaning processes. Most important, the strength tolerances of the straps were questioned.

Numerous film shots were taken throughout the study. Two reels were later edited in order to serve as visual references and thus increase the meaning of this report, point out

TABLE III

Subjects' preferences as reflected by questionnaire items

Questionnaire No. and item	Litter Rak	Current system	Probability level
1. Easiest to learn*	1	16	$<.01$
2a. Configuration*	2	15	$<.01$
b. Enplaning	4	14	$<.05$
c. Patient handling	9	9	N.S.†
d. Deplaning	3	15	$<.01$
e. Deconfiguration*	2	15	$<.01$
3. All factors considered	0	18	$<.01$

*One subject mis-marked, causing the total number of preferences to be 17 rather than 18 for that item.

†N.S. = $P > .05$.

various problems with the LR, and increase the likelihood of improvements in future litter-support systems. These films are available for review through the School of Aerospace Medicine (SMED). The first reel shows the Trial III operations for both systems as performed by group I-B, the most proficient of all the crews tested. The second reel illustrates the slide-out feature of the LR and nine actual or potential problems of the LR system in its present stage: i.e.,

1. The bolt securing the support cable to the center stanchion interferes with the progress of the support arm along the runway of the center stanchion.

2. The center-stanchion spring pins prevent the support arms from entering the stanchion runways.

3. The various pins tend to bind or malfunction.

4. The pins may be disconnected from the rest of the components because of broken lanyards.

5. Aisle space is inadequate for enplaning or deplaning patients, or safe intra-tier movement of patients.

6. Deplaning patients from the third center tier presents difficulties.

7. Hand injuries to technicians are frequent.

8. Potential head injury to technicians is a hazard.

9. Litter is insecure in LR bindings.

IV. DISCUSSION

The lack of significant differences caused by the crewmembers' previous experience with the current system would suggest that few, if any, unique human factor problems have to be overcome *as a function of that experience.* If this conclusion is valid, implementation of a new system like the LR need not be complicated by problems (e.g., variations of instructions, assignments, distribution of the system, or alterations of the system) arising from the technicians' previous experiences.

During Trial III operations, where crews were most proficient with each system, the contrast in time demands by the two systems (for configuration, reinforcement of bandages, and deconfiguration) was statistically significant and in favor of the current system. While, under routine conditions, the small time differences required for reinforcement of bandages and for deconfiguration might be inconsequential, the configuration time differences might be more important (e.g., in combat zones). The configuration time differences obtained in the present test situation involved only 11 litters. One could extrapolate from this difference (i.e., 1.46 min.) and suggest that, to provide spaces for 60 litters in a field situation, the crew would need at least 7.96 minutes longer to configure an LR than an LS system. Even longer time-periods might be necessary, since the slowing effects of fatigue would also be greater for the crew with the heavier and more complicated LR equipment. Moreover, the chances of time-consuming errors with equipment (or even some injuries—already more likely with the LR) would mount with this increased time and fatigue. In a combat zone, where time demands are often greater, the additional time required to configure an LR could be a disadvantage. Thus the mechanically simpler LS system is suggested as more desirable for use in combat zones.

According to questionnaire responses (table III), the crews consistently preferred the current system over the LR system. (The only nonsignificant results were on the question of patient handling.) Therefore it is recommended that any implementation of the LR system be accompanied by a solid justification to the crewmembers, so that biases in favor of the current system can be forestalled.

Also in relation to the item on patient handling, the number of minutes required for reinforcement of bandages was less with the LS than with the LR system. Neither of these findings provides much encouragement for the use of the LR system. Several additional points should be considered, however. First, because of demands of the test situation, no attempt was made to test all of the tier positions or to sample the wide range of cases which medical crewmembers encounter. Second, speed was of primary concern in this study; but, in field situations, movement capabilities for exacting work and comfort for both patients and crewmembers are also very important. Hence field testing would be the more appropriate method of answering the item on patient handling and accessibility.

One feature of the LR's slide-out design is the possibility of easy inter- and intra-tier movement. In this study, however, because of the limited aisle space in the C-141 when both the bulkhead and center-stanchion tiers have been configured, the patients and litters had to be tilted to attain such movement. Patient safety and comfort were thus compromised. Because a wider range of inter- and intra-tier movement would greatly increase the flexibility of patient placement onboard (e.g., nurses could more easily place patients according to medical problem rather than destination, and arrange space for unexpected additional patients), it is recommended that further engineering attempts be made to redesign the support arms in order to afford more aisle space. This improvement will likewise be necessary for the safety of patients in the enplaning and deplaning procedures.

The problem of narrow aisles, caused by use of the LR system, resulted not only in the risk of patients being dropped but also in considerable abuse to the technicians' hands. The film and the questionnaire responses indicate the need for a number of procedures or design changes to reduce such hazards. As for procedures, some subjects had to strain to unload patients from the third-from-bottom position on the center-stanchion because of the nature of the support arms. To reduce the risk of dropping the patient from this position or from the top bulkhead tier, four (rather than two) crewmembers should assist in placing each patient. Another potential danger, as shown in the film, is that of head injury from falling support arms during the LR installation and dismantling. Such dangers should be eliminated.

In brief, the need to remedy the following seven problem areas is apparent:

1. With the present LR bindings, a person can grasp any part of the litter pole away from the aisle and jerk the pole loose from the bindings. Therefore a reasonable assumption is that a similar effect could be caused by the gravitational force of a patient during rough flight conditions.

2. The bolt, which secures the cable to the center stanchion, is presently placed so that it can block the path of support arms as they slide up or down the stanchion's runways. This problem wastes time, irritates personnel, and contributes to wear and tear on the equipment.

3. After considerable use, the spring pins near the tops of the center stanchions protrude enough to block the entry of the support arms into the center-stanchion runways. The result is delay in the configuration operation

4. The frequent complaints, regarding the complexity of the apparatus and the number of pins, suggest a general need for simplification.

5. The frequent pin binds indicate need for improved machining of the pins and the holes into which they are to fit.

6. The hand cuts (suffered by technicians) indicate need for improved machining of various edges.

7. Many pin lanyards broke during the study. In a field situation, such breaks could lead to lost pins which, in turn, could render whole components unusable. Although a decrease in pin binds would partially solve the problem, the need for a more adequate lanyard is indicated.

The problems revealed by this in-house study lead to the conclusion that the *present* LR system is unacceptable for use in the C-141 aircraft. On the other hand, these problems do not seem unsurmountable. If they are successfully resolved, then the limitations of the LR probably will not outweigh the potential value. Therefore, at least from the standpoint of "Category II" (critical in-house evaluation) testing, further development of the LR system would seem worthy of encouragement.

There is constant pressure from the field to improve litter-support equipment. Because stanchions and horizontal arms are characteristic of most proposals on this subject, a review of the problems reported in this paper should be helpful in evaluating other design concepts for litter-support equipment.

Probably the most important result of this study is a general conclusion: Litter-support systems should be simple in design and operation—even at the expense of eliminating some advantageous, but probably secondary, capabilities.

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Ralph W. Trimble, Captain, USAF, BSC
Bryce O. Hartman, Ph. D.

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