Research

Clinical evaluation of the Life Support for Trauma and Transport (LSTAT™) platform

Ken Johnson[1], Frederick Pearce[2], Dwayne Westenskow[3], L Lazarre Ogden[1], Steven Farnsworth[1], Shane Peterson[4], Julia White[4] and Travis Slade[4]

[1]Assistant Professor, Department of Anesthesiology, University of Utah School of Medicine, Salt Lake City, USA
[2]Chief, Department of Resuscitative Medicine, UWH-A, Division of Military Casualty Research, Walter Reed Army Institute of Research, Silver Spring, MD, USA
[3]Professor, Departments of Biomedical Engineering and Anesthesiology, University of Utah School of Medicine, Salt Lake City, USA
[4]Research Associate, Department of Anesthesiology, University of Utah School of Medicine, Salt Lake City, USA

Correspondence: Ken B Johnson, kjohnson@remi.med.utah.edu

Received: 10 October 2001
Revisions requested: 22 November 2001
Revisions received: 13 May 2002
Accepted: 31 May 2002
Published: 10 July 2002

Critical Care 2002, **6**:439-446

This article is online at http://ccforum.com/content/6/5/439

(Print ISSN 1364-8535; Online ISSN 1466-609X)

Abstract

Introduction The Life Support for Trauma and Transport (LSTAT™) is a self-contained, stretcher-based miniature intensive care unit designed by the United States Army to provide care for critically injured patients during transport and in remote settings where resources are limited. The LSTAT contains conventional medical equipment that has been integrated into one platform and reduced in size to fit within the dimensional envelope of a North Atlantic Treaty Organization (NATO) stretcher. This study evaluated the clinical utility of the LSTAT in simulated and real clinical environments. Our hypothesis was that the LSTAT would be equivalent to conventional equipment in detecting and treating life-threatening problems.

Methods Thirty-one anesthesiologists and recovery room nurses compared the LSTAT with conventional monitors while managing four simulated critical events. The time required to reach a diagnosis and treatment was recorded for each simulation. Subsequently, 10 consenting adult patients were placed on the LSTAT after surgery for postoperative care in the recovery room. Questionnaires about aspects of LSTAT functionality were completed by nine nurses who cared for the patients placed on the LSTAT.

Results In all of the simulations, there was no clinically significant difference in the time to diagnosis or treatment between the LSTAT and conventional equipment. All clinicians reported that they were able to manage the simulated patients properly with the LSTAT. Nursing staff reported that the LSTAT provided adequate equipment to care for the patients monitored during recovery from surgery and were able to detect critical changes in vital signs in a timely manner.

Discussion Preliminary evaluation of the LSTAT in simulated and postoperative environments demonstrated that the LSTAT provided appropriate equipment to detect and manage critical events in patient care. Further work in assessing LSTAT functionality in a higher-acuity environment is warranted.

Keywords medical devices, patient simulations, transportation of patients

Introduction

Transport of critically ill patients to, between, and within hospitals can be associated with potentially adverse events [1–3]. Researchers have shown that increased vigilance, appropriate equipment, and well-trained personnel can lead to improved safety while critically ill patients are being transported [4,5]. Prior work evaluating the potential problems associated with transport of patients to intensive care units has led to the establishment of guidelines for the transport of the critically ill [6,7].

LSTAT™ = Life Support for Trauma and Transport [platform]; NATO = North Atlantic Treaty Organization; psi = pounds per square inch.

The need for safe and effective patient care en route has also been a goal of the United States military. Because initial emergency life-saving surgery and prompt, aggressive resuscitation may have to be performed under austere field conditions to render a patient transportable and since resource limitations or adverse conditions may lead to delayed evacuation or prolonged evacuation times, the United States Army has developed a new critical care transport platform called the Life Support for Trauma and Transport (LSTAT™).

Design goals for the LSTAT were solicited from medical personnel who have been deployed to combat zones, military and civilian medical personnel who transport and care for critically ill patients, and experts in military logistics with regard to medical equipment. Design goals included the following: weight limit of 120 pounds, volume not to exceed 22 × 72 × 13 inches (56 × 183 × 20 cm), battery power for up to 60 minutes, computer linkage of all the diagnostic and therapeutic equipment, capability of sending physiologic data to remote sites, and ability to generate pressurized gases for the ventilator. To meet these design constraints, the diagnostic and therapeutic equipment contained within the LSTAT had to be significantly reconfigured and miniaturized.

The purpose of this study was to evaluate how modified equipment, configured to fit within the LSTAT, may affect (1) the identification and management of life-threatening physiologic derangements, using a patient simulator, and (2) ongoing monitoring of vital signs in a recovery room setting.

Methods

Equipment

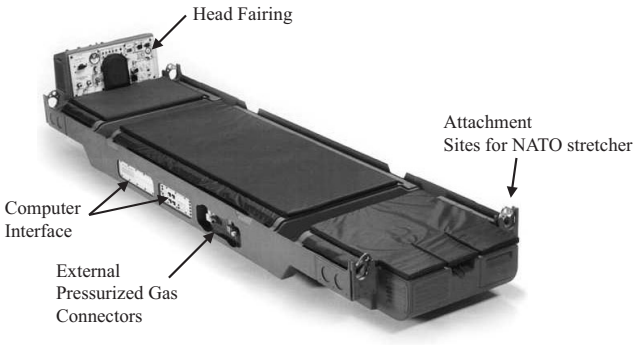
The LSTAT (model number 9602, Integrated Medical Systems, Inc, Signal Hill, CA, USA) consists of a pan and a stretcher. The pan contains commercially available equipment that has been reconfigured to fit in the 5-inch-deep (13-cm-deep) pan (Fig. 1). The pan fits beneath and is attached to a NATO stretcher and has a head fairing that extends 7 inches above the stretcher (Fig. 2). This equipment includes a transport ventilator, a 480-liter oxygen tank, a three-channel infusion pump, a defibrillator, a blood gas and blood chemistry analyzer, a suction device, a vital signs monitor, a computer, a power converter, and a battery power supply. The computer within the LSTAT continuously transmits physiologic data over a wireless network to a fixed large display called the clinical display and to a handheld notebook-computer-based display called the secondary display.

Phase I: Evaluation of the LSTAT by clinicians using a patient simulator

After internal review board approval at the University of Utah and the Army Surgeons Human Subjects Research Review Board, 25 anesthesiologists and 6 recovery room nurses served as consenting volunteer clinicians to compare the clinical utility of the LSTAT with conventional monitoring systems, using a patient simulator. Each volunteer clinician was presented with a scripted description of the study methods and equipment to be used. The study description was read verbatim by the study proctor. The study proctor was the same person for all study participants. Equipment included the LSTAT standard equipment used for physiologic monitoring (Protocol Systems Inc, Model Propaq Encore, Beaverton, OR, USA), an E cylinder filled with oxygen (holding 660 l of oxygen at 2200 psi), a semiopen ventilation circuit (Vital Signs Inc, Resuscitation Circuit Model No. 5105RV, Totowa, NJ, USA), an anesthesia machine (North American Drager, Model Narkomed AV2+, Telford, PA, USA), and a defibrillator (Hewlett Packard, model number 43110A, McMinnville, OR, USA). The anesthesia machine contained a ventilator and a suction device.

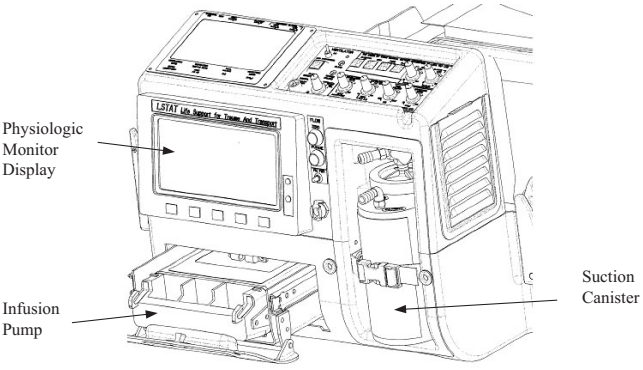
After reading the scripted instructions, each volunteer clinician was allowed to ask questions about the use of each piece of equipment. The study did not proceed until sufficient answers to all questions were given as determined by the volunteer clinician. A comparison was made of the training time

Figure 1



The United States Army's new critical care transport platform the LSTAT™ (Life Support for Trauma and Transport) pan, without a NATO stretcher.

Figure 2



The LSTAT™ (Life Support for Trauma and Transport) head fairing.

Table 1

Simulation scenarios and key therapeutic maneuvers used to compare the Life Support for Trauma and Transport (LSTAT™) with conventional monitoring equipment

Simulation scenarios	Key therapeutic maneuvers
For the anesthesia faculty and residents	
Scenario 1: Tension pneumothorax	Needle thoracostomy or a chest tube
Scenario 2: Adult respiratory distress syndrome	Positive end expiration pressure (PEEP), increase the FiO_2, consider a diuretic (furosemide), consider adjustment of ventilator settings
Scenario 3: Cardiac tamponade	Pericardiocentesis
Scenario 4: Pulseless ventricular tachycardia	Cardioversion with 360 joules
For the recovery room nursing staff	
Scenario 1: Improper ventilator settings	Adjust ventilator settings until the end tidal CO_2 is 35 mmHg
Scenario 2: Pulmonary edema	Increase the FiO_2, administer a diuretic, consider intubating
Scenario 3: Myocardial ischemia	Support airway, provide supplemental oxygen and ventilate if needed, check pulses and vital signs, call for a 12-lead ECG, consider sublingual nitroglycerin
Scenario 4: Symptomatic hypotension with occult hemorrhage	Administer intravenous fluids, send for an immediate hematocrit level, consider a blood transfusion, place the patient in the Trendelenburg position

required for volunteer clinicians to feel ready to use the LSTAT versus conventional monitors. The training time was defined as the time required by the study proctor to read the instructions plus the time required for each volunteer clinician to ask questions about its use.

After having been trained, each volunteer clinician was presented with four scenarios in turn (Table 1), using a patient simulator (Medical Education Technologies Inc, Sarasota, FL, USA). During two scenarios, the clinicians used the LSTAT and during the other two scenarios they used conventional equipment. The clinicians were randomly assigned to one of two groups. Group A used the LSTAT with scenarios 1 and 2 and conventional equipment with scenarios 3 and 4. Group B did the opposite.

Each volunteer clinician was required to state the diagnosis and the treatment needed during each scenario. Incorrect answers were ignored. If a clinician required more than 5 minutes to state the correct diagnosis or treatment, the scenario was stopped and recorded as incorrect. When the correct diagnosis was stated, the time was recorded. The time to treatment was recorded when the volunteer clinician stated the appropriate treatment and demonstrated the appropriate use of the equipment needed to implement it. The times to diagnosis and treatment with the two monitoring systems were compared using the Mann–Whitney test.

After the simulations were over, each volunteer clinician completed a survey about use of the LSTAT. The survey asked about the alarm systems, ability to detect critical changes in vital signs, and utility of the LSTAT to manage patients if no other equipment were available.

Phase II: Evaluation of the LSTAT in a routine postoperative setting

Nursing staff received a 45-minute training seminar in the use of the LSTAT, in which the system was placed on a modified wheel system (Stryker Medical, Big Wheel No. 1001, Kalamazoo, MI, USA). Ten consenting adult patients were each placed on an LSTAT in the operating room after surgery. A pulse oximeter probe, electrocardiogram leads, and blood pressure cuff were attached to the LSTAT. Each patient received supplemental oxygen via facemask. Patients were then transported to the recovery room.

The course in the recovery room was noted for all events requiring intervention (e.g. deteriorating respiratory function requiring acute management of the airway, episodes of hypotension, hypertension, arrhythmias, postoperative nausea and vomiting, and inadequate pain control) as detected by the LSTAT. Measures of performance included both the number of postoperative events requiring intervention that were detected using the LSTAT's physiologic monitors and a survey of its utility taken from recovery room nursing staff, reviewing functionality, problems, and potential problems observed during clinical use.

Results

Phase I: Evaluation of the LSTAT by clinicians using a patient simulator

Thirty-one volunteer clinicians participated in the simulator evaluation of the LSTAT. All of them had been trained in Advanced Cardiac Life Support (ACLS), 71% had up-to-date ACLS certification (recertification within the preceding 2 years), and 29% had been trained in Advanced Trauma Life Support (ATLS).

Table 2

A comparison of the time required to reach a diagnosis and proper treatment between the Life Support for Trauma and Transport (LSTAT™) and conventional monitoring equipment

Simulation scenarios		Time to diagnosis (s)	Number of clinicians unable to provide a correct diagnosis	Time to treatment (s)	Number of clinicians unable to provide a correct treatment
Scenario 1					
Tension pneumothorax	LSTAT	80 (61–154)	0/12	99 (83–195)	1/12
	CM	60 (50–107)	1/13	85 (61–111)	1/13
	P	0.3645		0.1495	
Scenario 2					
Adult respiratory distress syndrome	LSTAT	215 (66–300)	4/12	300 (248–300)	6/12
	CM	193 (137–300)	5/13	300 (156–300)	6/13
	P	0.6438		0.4464	
Scenario 3					
Cardiac tamponade	LSTAT	149 (67–300)	3/13	149 (82–300)	3/13
	CM	117 (100–273)	3/12	152 (122–280)	3/12
	P	0.8848		0.6639	
Scenario 4					
Pulseless ventricular tachycardia	LSTAT	49 (42–73)	0/13	60 (50–99)	0/13
	CM	41 (38–44)	0/12	44 (41–49)	0/12
	P	0.0317		0.0018	

Data are presented as medians and 25th to 75th interquartile ranges. CM, conventional monitors.

The time required to provide instruction to each volunteer clinician ranged from 2 to 7 minutes. They required about 1 to 2 minutes more to learn how to use the LSTAT than to use conventional monitors.

Table 2 compares conventional monitoring equipment and the LSTAT with regard to the time required to reach a diagnosis and the time required to choose an appropriate treatment for anesthesiologists. The size of the group of recovery room nurses was not large enough to merit statistical analysis and therefore only the results from the survey are reported.

In scenarios 1, 2, and 3, there was no significant difference between the LSTAT and conventional monitors in the time required to reach a diagnosis or treatment. In scenario 4 (pulseless ventricular tachycardia), the time required to make the diagnosis and treatment was shorter than with the other scenarios regardless of which equipment (LSTAT or conventional monitors and equipment) was used; 23 out of 25 anesthesiologists made the diagnosis in less than 1 minute. The time required to treat the pulseless ventricular tachycardia was less with the conventional monitors than with the LSTAT. In scenarios 1, 2, and 3, the number of anesthesiologists unable to provide a correct diagnosis or treatment within 5 minutes was evenly distributed between the conventional monitor and the LSTAT groups. In scenario 4, all anesthesiologists provided the correct diagnosis and treatment within 5 minutes.

Table 3 shows the clinicians' response to the survey regarding the clinical usefulness of the LSTAT after completing four simulations. All the participating clinicians reported that they were able to properly manage the simulated patients using the LSTAT. All participating clinicians except one who abstained reported that if no other medical equipment were available in a remote setting, they would be able to provide appropriate care using the LSTAT. All of the survey respondents indicated that it was safe to proceed to the next phase of the study, in which the LSTAT would be used in a clinical setting.

Survey questions aimed at exploring how useful the LSTAT was in managing critical events revealed that all of the participating clinicians were able to properly manage the simulated patients and 27 reported that they were able to detect critical changes in vital signs in a timely manner. Three clinicians, however, reported that they were not able to detect critical changes in vital signs because of difficulty seeing physiologic data on the display screens and the location of the displays. Several clinicians indicated that they would have liked more time to become familiar with the equipment before assuming patient care.

A majority of the clinicians reported that suction and capnography would be useful during transport and that the controls on the LSTAT were easy to operate. In addition, the survey respondents reported that the configuration of equipment, as

Table 3

Summary of survey results collected from clinician volunteers who used the Life Support for Trauma and Transport (LSTAT™) in managing critical cardiopulmonary events using a patient simulator

Simulator survey question	Yes	No	Abstained
During the simulations, did the LSTAT allow you to properly manage the patient?	31/31 (100%)	0/31 (0%)	0/31 (0%)
If no other medical equipment was available and you were called upon to resuscitate a patient with the LSTAT in a remote setting, do you feel it would be sufficient?	30/31 (97%)	0/31 (0%)	1/31 (3%)
Do you feel that it is safe to proceed to the clinical phase of this study where patients will be placed on the LSTAT?	31/31 (100%)	0/31 (0%)	0/31 (0%)
During the simulations using the LSTAT were critical changes in vital signs detected in a timely manner?	27/31 (87%)	3/31 (10%)	1/31 (3%)
Were there any limitations in the LSTAT that prevented you from detecting critical changes in vital signs and adequately addressing them?	10/31 (33%)	20/31 (67%)	0/31 (0%)
Did the visual and auditory alarms provide immediate and directed attention to the alarm condition?	20/31 (64%)	8/31 (26%)	3/31 (10%)
Would suction be useful during transport?	20/31 (64%)	3/31 (10%)	8/31 (26%)
Would capnography be useful during transport?	26/31 (83%)	2/31 (7%)	3/31 (10%)
Were the LSTAT controls accessible and easy to operate?	27/31 (87%)	3/31 (10%)	1/31 (3%)
During the simulations, did the location of the ventilator connection and physiologic monitor cables allow adequate access to the patient, controls, and displays?	27/31 (87%)	0/31 (0%)	4/31 (13%)

an intrinsic part of the stretcher, did not obstruct access to the patient. Features that were noted to be useful by respondents were the compactness of all the equipment in the LSTAT and the integration of a ventilator into the LSTAT to facilitate transport of ventilator-dependent patients.

Phase II: Evaluation of the LSTAT in a routine postoperative setting

Ten patients were monitored on the LSTAT during their recovery from surgery. Complications experienced by this patient group associated with recovery from surgery included postoperative nausea and vomiting, inadequate pain control, hypertension, hypoxia, and tachycardia. Nine nurses who cared for patients using the LSTAT in the recovery room completed surveys and the results are presented in Table 4.

All nine of the recovery room nursing staff reported that the LSTAT provided adequate equipment to properly care for patients recovering from surgery. Five of the nine reported that it was easy to operate. The remaining four reported that they would have liked a more extensive in-service training before using the LSTAT.

All those nurses who responded reported that all critical changes in vital signs were detected and addressed in a timely manner using the LSTAT. Limitations cited by the recovery room nursing staff included difficulty reading displays of vital signs on the secondary display and muted audible alarms that were difficult to hear in a recovery room environment. Three of the nine nurses reported that the large clinical display improved their ability to detect changes in vital signs and all but one reported that if no other equipment were available in a remote setting, they would be able to resuscitate a patient with the LSTAT.

During transport of recovery room patients, no critical events were reported. Two of the nurses reported that the LSTAT provided an advantage during transport within the hospital and most reported that the secondary display was useful for monitoring vital signs during transport. Three reported that if the secondary display was not available, it would be difficult to monitor vital signs during transport if the patient was placed on the LSTAT so that the head fairing containing the physiologic monitoring and ventilator displays were at the foot of the bed. All the nurses that responded reported that the maneuverability of the LSTAT was adequate to enhanced.

Overall comments by recovery room nursing staff suggested that the LSTAT would be helpful in patients with more highly acute conditions (e.g. in the intensive care unit, trauma bay, and prehospital settings) and that features that set the LSTAT apart from conventional equipment include compactness, readily available suction, capnography, defibrillator, and on-board oxygen tank. Finally, 22% of the recovery room nursing staff found the integration of the monitoring and therapeutic equipment into a stretcher for transport very useful, 67% found it to be useful, and 11% found it to be somewhat useful.

Table 4

Summary of survey results collected from recovery room nurses who used the Life Support for Trauma and Transport (LSTAT™) in managing patients recovering from surgery

Recovery room survey questionnaire	Yes	No	Abstained
LSTAT for patient care in the postanesthetic care unit			
Did the monitoring equipment in the LSTAT allow proper management of the patient?	9/9 (100%)	0/9 (0%)	0/9 (0%)
Were the LSTAT controls accessible and easy to operate?	5/9 (56%)	1/9 (44%)	0/9 (0%)
Did you find the table of vital signs useful for filling out your nursing record?	7/9 (78%)	1/9 (11%)	1/9 (11%)
Critical events			
In the recovery room, were critical changes in vital signs detected in a timely manner using the LSTAT?	7/9 (78%)	0/9 (0%)	2/9 (22%)
Were there any limitations in the LSTAT equipment that prevented you from detecting critical changes in vital signs and adequately addressing them?	3/9 (33%)	5/9 (56%)	1/9 (11%)
Were there any features of the LSTAT that improved your ability to detect critical changes in vital signs and address them?	3/9 (33%)	5/9 (56%)	1/9 (11%)
If no other medical equipment were available and you were called upon to evaluate and resuscitate a patient with the LSTAT in a remote setting, do you feel it would be sufficient?	8/9 (89%)	1/9 (11%)	0/9 (0%)
Recovery room to ambulatory surgery discharge area or hospital bed transports			
Did you notice any particular advantage of the LSTAT during intra-hospital transports?	2/9 (22%)	5/9 (56%)	2/9 (22%)
Was the location of patient connectors and lines allow for unobstructed access to the patient, controls and displays?	7/9 (78%)	2/9 (22%)	0/9 (0%)
Was the hand held display useful in monitoring vital signs during transport?	5/9 (56%)	2/9 (22%)	2/9 (22%)
Were the patient's vital signs easy to monitor during transport?	6/9 (67%)	3/9 (33%)	0/9 (0%)

Discussion

The LSTAT contains equipment typically found in an intensive care unit, integrated and miniaturized to fit beneath a transport stretcher. In addition, many of the components found within the LSTAT were reconfigured and made more rugged to meet design standards for use in military aircraft (minimize electrical emissions, withstand large changes in the ambient temperature, tolerate excessive vibration, and be insensitive to external electromagnetic interference).

With these configuration changes in mind, we examined the clinical utility of the LSTAT in simulated and real clinical environments. Our hypothesis was that when equipment typically found in an intensive care unit was condensed to fit in a small space underneath a patient stretcher, the reconfigured equipment embodied in the LSTAT would be an equivalent tool to conventional equipment in detecting and treating life-threatening problems. Our results confirmed our study hypothesis. Our most important finding is that anesthesiologists and recovery room nurses, when asked to manage simulated critical events and care for patients after surgery, were able to provide appropriate care using the LSTAT.

Phase I: Evaluation of the LSTAT by clinicians using a patient simulator

In this simulation phase of the study, the time required for clinicians to detect and treat life-threatening physiologic derangements was nearly identical using conventional equipment versus the LSTAT. In the simulations of tension pneumothorax, severe adult respiratory distress syndrome, and cardiac tamponade, the number of anesthesiologists unable to make a correct diagnosis or provide the correct treatment within 5 minutes was evenly divided between the two study groups.

In the simulation of pulseless ventricular tachycardia, the median time to diagnosis and treatment was significantly shorter using conventional monitors than using the LSTAT. Although pulseless ventricular tachycardia is a life-threatening arrhythmia and merits immediate attention, the differences between the LSTAT and conventional monitors are subtle and may not be clinically important (49 versus 41 seconds in the time to diagnosis and 60 versus 44 seconds in the time to treatment). One potential source of delay for the time to treatment was that the defibrillator used in the conventional monitoring simulation was similar to one currently used in our hospital operating rooms, whereas the defibrillator incorporated into the LSTAT is not. It is important to point out that if a defibrillator is not readily available (the defibrillator was readily available in our simulations), the time required to locate one and treat the patient could be much longer than that reported in our simulation.

In the tension pneumothorax and the adult respiratory distress scenarios, the simulated patient required mechanical ventilation. In the LSTAT group, ventilation was accomplished using the transport ventilator contained within the LSTAT. For the group using conventional monitors, ventilation was accomplished using a semiopen ventilation circuit that required manual operation. One difference reported by the volunteer clinicians was that they wanted to take the patient off the ventilator to hand ventilate the patient in order to validate their diagnosis, despite already having the peak airway pressures, delivered tidal volumes, and end tidal carbon dioxide levels readily available. This issue is not unique to the LSTAT ventilator. None of the commercially available transport ventilators has an auxiliary ventilator circuit that allows manual ventilation. Mechanical ventilation during transport of critically ill patients has been found to be advantageous over hand ventilation in meeting oxygenation and ventilation goals and in minimizing the acid–base disturbances that may lead to hemodynamic instability [1,3]. In addition, even though hand ventilation was not available during simulated transports with the LSTAT ventilator, there was no difference in the time to diagnosis or treatment for either the tension pneumothorax or the severe adult respiratory distress scenarios.

One potential criticism of the LSTAT is that it is too sophisticated and will require excessive training to teach clinicians how to use it. Our results did not validate this concern. Both recovery room nursing staff and the anesthesiologists required approximately 2 minutes more training time with the LSTAT than with conventional monitors. The overall training time never exceeded 7 minutes for the LSTAT. These results may be influenced by several factors. Because the patient transports were simulated, the volunteer clinicians may not have felt that they needed to pursue all the nuances about the LSTAT's equipment that they otherwise would have if they had been caring for a real patient. Secondly, the volunteer clinician group studied has significant experience with various types of patient monitors, ventilators, and defibrillators and may not have required as much teaching time as would other clinicians who are not as routinely involved with these items.

Phase II: Evaluation of the LSTAT in a routine postoperative setting

The LSTAT was judged by nursing staff to be adequate for the management of patients recovering from surgery. Complications experienced by the patient group were typical of complications associated with recovery from surgery. Features that set the LSTAT apart from routine monitoring of patients in the recovery room included the readily available defibrillator, availability of suction and capnography for transport, a built-in oxygen source, the fixed large clinical display of the patient's vital signs in the recovery room, and the mobile secondary display which reported the patient's vital signs for use during transport.

After having used the LSTAT in the recovery room, the nursing staff was asked to critique the use of the LSTAT in managing critical events. Data visualization and visual and auditory alarms were of primary concern both with the physiologic monitor and the ventilator. Some nurses were concerned that they would not be able to detect critical changes in vital signs because of these limitations. This problem may be the result of two conflicting design goals: the military needs (low sound and low light emissions) and the needs of the intensive care unit (visual physiologic data presentation and loud auditory signals and alarms). The screens contained within the LSTAT were selected to reduce power consumption and minimize light emission. Potential solutions to this concern include enhanced training with the LSTAT to improve clinicians' comfort with the existing data displays and alarm systems as well as exploration of alternatives for data and alarm presentation to improve the clinician's awareness of a patient's status.

Five of the nine recovery nurses reported that they did not notice any particular advantage of the LSTAT during transports within the hospital. In this phase of the study, the LSTAT was used to transport patients from the recovery room to the ambulatory surgery discharge area or to a hospital bed, a transport routinely done without any patient monitoring. Thus in less acute transport settings, it is reasonable that the LSTAT would not provide any significant advantage.

An expressed concern of some of the military product developers was that the weight of the LSTAT pan and the configuration of the LSTAT as dictated by the size constraints to fit in military aircraft would make the LSTAT awkward to use during patient care. The survey results did not support this potential concern. For example, respondents indicated that the LSTAT was easy to operate, access to the patient was not obstructed, and the LSTAT was easy to maneuver. Many respondents reported that consolidation of all the physiologic monitoring equipment and incorporation of a transport ventilator were all advantages for patient transport. After the simulator study, all respondents indicated that it was safe to proceed to the next phase of the study, in which the LSTAT would be used in a clinical setting. Furthermore, volunteer clinicians reported through their surveys that they were able to properly manage the simulated and real patients using the LSTAT. All but one clinician reported that if no other equipment were available in a remote setting, they would be able to resuscitate a patient with the LSTAT.

This report represents a preliminary evaluation of the LSTAT in a clinical setting. The goal was to validate the functionality of the LSTAT before its evaluation in more acute settings such as intensive care units, emergency departments, transports within hospitals, within medical evacuation vehicles during transport between hospitals, and eventually in remote areas where medical resources are limited or unavailable. A logical next step is to evaluate the LSTAT during the initial management of critically injured trauma patients as they

present for evaluation in an emergency room trauma bay. This might be best accomplished in a facility designed for and staffed by specialists trained in trauma patient care. The same study hypothesis might be: does equipment typically found in an intensive care unit, condensed to fit in a small space underneath a patient stretcher, serve as an equivalent tool to conventional equipment in detecting and treating life-threatening problems?

Additional questions may incoude the following: Does the LSTAT reduce the personnel and resources needed for intrahospital transport for emergency imaging (e.g. computer tomography scans or angiography studies), rapid transfer to the operating room, or transfer to the intensive care unit? Does remote monitoring of a patient during intrahospital transport improve the clinician's vigilance in detecting life-threatening problems that may develop during transport? Can personnel other than anesthesiologists and recovery room nurses learn to use the medical devices contained within the LSTAT effectively? And finally, does the integration of physiologic data, ventilator data, arterial blood gas and chemistry data, and clinical data into an optimized computer-based display help clinicians evaluate patients more efficiently and make more informed decisions when caring for patients with multiple life-threatening injuries [8–10]?

The clinical relevance of this line of investigation is a function of the prevalence of trauma in our world today and the need to provide life-saving intervention quickly after injury. Experience in major metropolitan areas where evacuation times are quick and state-of-the-art surgical and resuscitative resources and well-trained personnel are readily available has established the benefit of early surgical intervention and resuscitation on survival [11,12]. The LSTAT was designed to provide equipment for underserved areas where conventional intensive care resources may be unavailable. Thus, the LSTAT may serve as a critical resource to a highly mobile surgical team because it can be placed very near the site of injury in an effort to reduce the time from injury to life-saving intervention. The LSTAT provides the equipment necessary for appropriate postoperative care of a critically injured patient, for transport to tertiary care facilities, or for holding patients until evacuation is feasible. The LSTAT can also serve as a resource to resuscitate patients who do not require surgery but who do require intensive care.

Key messages

- Medical equipment reconfigured and miniaturized into a stretcher-based portable intensive care unit (called the Life Support for Trauma and Transport [LSTAT™]) was evaluated using a patient simulator and during patient care in a recovery room setting
- In the simulation phase of the study, volunteer clinicians compared the LSTAT with conventional monitors while managing critical events
- In the recovery room phase of the study, nurses critiqued the LSTAT while caring for patients after surgery
- In both the simulated and postoperative environments, the LSTAT provided appropriate equipment to detect and manage critical events in patient care

Competing interests

This study was supported in part by a grant from the United States Army Medical Research and Material Command. LSTAT is a trademark of the United States Army.

Acknowledgements

This study was presented in abstract form at the Annual Advanced Technology Applications in Combat Casualty Care Meeting, Fort Walton Beach, Florida, 26 September 2000.

References

1. Waydhas C, Schneck G, K Duswald: **Deterioration of respiratory function after intra-hospital transport of critically ill surgical patients.** *Intensive Care Med* 1995, **21**:784-789.
2. Smith I, Fleming S, Cernaianu A: **Mishaps during transport from the intensive care unit**. *Crit Care Med* 1990, **18**:278-281.
3. Braman S, Dunn S, Amico C, Millman R: **Complications of intrahospital transport in critically ill patients.** Ann *Intern Med* 1987, **107**:469-473.
4. Fromm RJ, Dellinger R: **Transport of critically ill patients.** *J Intensive Care Med* 1992, **7**:223-233.
5. Szem J, Hydo H, Fischer E, Kapur S, Klemperer J, Barie P: **High-risk intrahospital transport of critically ill patients: Safety and outcome of the necessary "road trip".** *Crit Care Med* 1995, **23**: 1660-1666.
6. Guidelines Committee, ACoCCM, Society of Critical Care Medicine and the Transfer Guidelines Task Force, American Association of Critical-Care Nurses: **Guidelines for the transfer of critically ill patients.** *Am J Crit Care* 1993, **2**:189-195.
7. Committee, ACoEPGA: **Guidelines for transfer of patients.** *Ann Emerg Med* 1985, **14**:1221-1222.
8. Gardner R, West B, Pryor T, Larsen K, Clemmer T, Orme JJ: **Computer-based ICU data acquisition as an aid to clinical decision-making.** *Crit Care Med* 1982, **10**:823-830.
9. Bradshaw K, Gardner R, Clemmer T, Orme J, Thomas F, West B: **Physician decision-making—Evaluation of data used in a computerized ICU.** *Int J Clin Monit Comput* 1984, **1**:89-91.
10. East T, Morris A, Wallace C, Clemmer T, Orme JJ, Weaver L, Henderson S, Sittig D: **A strategy for development of computerized critical care decision support systems.** *Int J Clin Monit Comput* 1991, **8**:263-269.
11. Jacobs L, Gabran S, Sztajnkrycer M, Robinson K, Libby M: **Helicopter air medical transport: ten year outcomes for trauma patients in New England program.** *Conn Med* 1999, **63**:677-682.
12. Kerr W, Kerns T, Bissell R: **Differences in mortality rates among trauma patients transported by helicopter and ambulance in Maryland.** *Prehospital Disaster Med* 1999, **14**:159-164.