A CRITICAL CARE HELICOPTER SYSTEM IN TRAUMA

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Civilian helicopters and emergency medical services in the United States have been in existence for approximately 15 years. The rapid growth of this type of health care delivery coupled with an increasing number of accidents has prompted professional and lay scrutiny of these programs. Although they have a demonstrated history of benefit to patients, the type and severity of injuries to patients who are eligible for helicopter transportation need further definition. The composition of the medical crews and the benefits that particular crew members bring to the patients require ongoing evaluation. Significant questions regarding the number of pilots in a helicopter and in a program remain to be answered. This article reviews the role of emergency medical air transport services in providing care to trauma patients, staff training and evaluation, and safety criteria and offers recommendations to minimize risks to patients and crews.

The role of the helicopter as a rapid means of transporting an injured patient from the scene of an incident to a trauma receiving hospital originated in the military conflict in Korea.[1] Approximately 20,000 wounded soldiers were evacuated by helicopter.[2] The concept of bringing a severely injured patient to a center that had all the necessary medical and nursing personnel and equipment to manage the patient was an important factor in reducing morbidity and mortality. Neel[3] reported that no soldier in Vietnam was more than 35 minutes away from definitive care. Helicopters evacuated more than 370,000 injured patients between 1965 and 1969 in Vietnam.

A number of important diagnostic and therapeutic advances over the last four decades have been instrumental in reducing trauma mortality. These include the introduction of antibiotics, more effective nutrition, and computerized tomography. However, reducing the time from injury to definitive care along with effective airway management and hemorrhage control are still critical factors influencing outcome in the trauma patient.[4] The helicopter with its ability to transport trained advanced life support crews to the scene and its speed of transportation has a place in the modern management of seriously ill or injured patients.

SCOPE OF THE INJURY PROBLEM

Despite the technological advances in medicine, legislative initiatives to control excess speeding and intoxicated drivers, regulations relative to passive and active motor vehicle occupant restraints, and an increasing awareness of the injury problem, trauma remains a national epidemic. Trauma or injuries are the leading causes of death for persons under the age of 44. In 1983 there were 91,000 accidental deaths and 9 million disabling injuries[5]; motor vehicle accidents accounted for 51.5% of the deaths. The cost of medical care for those injured in alcohol-related motor vehicle accidents was $434 to $483 million.[6] It is estimated that the cost of care for trauma victims was $61 billion in 1982.[7] Because trauma affects young people primarily, the number of

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years of productive life lost to the individual and the cost of prolonged disability make this a problem that requires carefully thought out solutions.

A system approach has been suggested as an optimal means of reducing morbidity and mortality from injuries. These severely injured patients require immediate assessment by trained personnel; sophisticated diagnostic radiographic evaluation, including x-rays, computerized tomography scans and angiography, and immediate anesthesia and multiple specialty availability in the operating suite.[8-18]

The military helicopter transportation system previously described was used successfully in Vietnam. The other major component that was successfully implemented involved bypassing smaller medical facilities and taking the patient directly to a tertiary care facility that had available personnel and equipment. This system of health care delivery decreased the time from injury to definitive care to 65 minutes and decreased the mortality rate to 1.7%.[19,3]

The United States did not readily apply this system of care to the civilian environment. The reason for this was documented in the National Highway Transport Safety Administration's (NHTSA) published report on medical helicopters. This report, published in 1972 and titled "Helicopters and Emergency Medical Services: NHTSA Experience to Date,"[20] documented the results of a number of helicopter demonstration projects funded by NHTSA. The report concluded that, to be effective, helicopters needed to be incorporated into a total emergency medical service (EMS) system and that design changes needed to be made to available helicopters to maximize their efficiency in the civilian environment.

The first successful hospital-based aeromedical helicopter system still in operation was implemented in Denver, Colorado, in 1973. St. Anthony's Hospital was the prototype for hospital-based critical care helicopter service. Strong physician leadership along with a major educational program to train first responders, emergency medical technicians (EMT), and law enforcement and public safety personnel to recognize those patients who would most benefit from rapid resuscitation and transportation by air led to the program at St. Anthony's Hospital. An important component in the success of this program was a dedicated EMS communication center, which facilitated communications among field personnel, flight crews, and physicians.[21] This program was the first hospital-owned and -operated aerovac system staffed with medically trained personnel; it was fully integrated into the Denver EMS system.

By mid-1986 there were 130 hospital-based aeromedical programs flying approximately 15,000 patients annually. Other nations were recognizing that the military concept of rapid helicopter evacuation of patients by trained personnel to tertiary care was viable in the civilian sector. In the West German system, for example, a patient injured on the highway can be transported to a trauma center within 15 minutes.[22,23] All West German-based trauma centers have access to hospital-based medical helicopters with advanced life support personnel abroad, including physicians.

In West Germany, the air transportation system reduced roadway mortality 25%, from 16,000 in 1970 to 12,000 in 1981.[22,23] This reduction occurred during the implementation of a system of trauma centers and helicopter stations with fully trained flight personnel, which allowed resuscitation to be initiated at the scene. Even in the face of excessive speed on West German autobahns (on which no speed limits are posted), the experiences suggest that immediate advanced life support and rapid transportation by air to a fully staffed trauma receiving center are effective in reducing mortality from trauma.

The integration of helicopters into an emergency medical service system is consistent with the national health priorities established by Congress under Public Law 9-3641. These priorities include: development of multi-institutional systems for coordinating and consolidating institutional health services (including obstetrics, pediatrics, emergency medical, intensive and coronary care, and radiation therapy); development of multi-institutional arrangements for support services; promotion of improvements in the quality of health services; and development of the capacity to provide various levels of care on a geographically integrated basis.

HISTORY OF MEDICAL AIR TRANSPORT SYSTEMS

First-Generation

The Denver system was an example of a successful first-generation system. The helicopter provided an impetus for the hospital to conduct extensive training of physicians and nurses and to improve the physical hospital environment to care for the increasing number of critically ill patients. Immediate availability of intensive care beds, well-stocked blood banks, and sophisticated diagnostic capabilities were provided. In addition, specialty physicians, including neurosurgeons, general surgeons, and anesthesiologists, were available to resuscitate and surgically intervene. This process was labor intensive and sustained significant operating costs. In the early years these costs were offset by the increased census of severely injured patients requiring sophisti-

cated, expensive technology during the inpatient stay. The charges for transporting these patients were sometimes intentionally set below the actual cost to be competitive with ground ambulance services. An additional marketing effect later became apparent. Noninjured patients with medical problems and those who required elective surgery began to select the hospital that operated the helicopter because of a perceived higher level of care and emergency management.

The medical aerovac pioneers believed this system would save lives not only because of rapid transportation but also because patients would receive comprehensive trauma care. It was the dedication and commitment of the medical and administrative staffs that contributed to the improvement in patient care, not merely the procurement of a helicopter. The helicopter was merely a vehicle that allowed the most skilled medical personnel available to access the critical patient at the accident scene or in a primary hospital and maintain the level of care while transporting the patient rapidly to a specialty care center.

The characteristics of a first-generation system are evident in the pioneer programs at Denver,[21] Houston,[24] and Jacksonville. These characteristics include: (1) use of a single-engine helicopter; (2) employment of medical crews trained in advanced life support dedicated to helicopter service; (3) integration into the EMS system; (4) service primarily to the owner hospital; (5) increase in the owner hospital's bed occupancy rates; and (6) inappropriate low service charge for the helicopter, with other inpatient-generated service revenue used to offset the losses from the helicopter component of the system. The success and visibility of the first-generation programs also made the helicopter market more intense and competitive. During the late 1970s use of helicopters for off-shore oil exploration decreased and helicopter operators became increasingly interested in providing complete aviation services to hospitals. These services included furnishing a hospital with an aircraft, pilots, and mechanics and taking full responsibility for the aviation component of the service. Diversification into the EMS market was seen as a sound business plan by major helicopter operators.

The number of hospital-based helicopter programs in the United States increased rapidly in the late 1970s and 1980s. In some areas of the country competing aeromedical transport programs developed. The mission of transporting only severely injured patients was diluted, and the medical necessity for such transports was challenged. Questions arose regarding the use of sophisticated helicopters to transport stable patients who did not require either the benefits of speed or an advanced life support crew. This problem prompted regulatory health agencies to become involved in the helicopter EMS process. As most of these programs were hospital based and the capital expenditure was substantial, a certificate of need became a prerequisite for the operation of a helicopter EMS program. This development introduced the second phase of air transport programs.

Second-Generation

In the late 1970s regulatory agencies became concerned with identifying and quantifying the actual need for medical air transport systems vis-a-vis the ability to provide improved quality of care and increased survival of patients. Quantitative evaluative processes were developed by groups in Omaha,[25] Boston, San Diego,[26] and Michigan.[27] Critics of helicopter EMS systems cited the expense of the programs as a negative factor. They also questioned the benefits of such programs, especially if ground EMS services were already in place and functioning well. Baxt and Moody[26] compared two similar groups of trauma patients, each with 150 patients. One group was treated by standard land prehospital services and the other by a rotorcraft service staffed with a physician and a nurse. They found a 52% reduction in predicted mortality for the aeromedical group, which was statistically significant. Skeptics challenged this work as not being representative of the helicopter aeromedical industry nationwide. An additional 1,273 blunt trauma patients treated and transported from the site of injury by seven different hospital-based rotorcraft EMS services in different parts of the country were studied using similar methodology. The results showed a 21% reduction in predicted mortality, which supported the original concept that helicopter EMS systems provide a significant benefit for blunt trauma patients treated at the scene of an accident.[28] The Michigan experience identified injury-specific incidence rates for trauma, burns, spinal cord injuries, and neonatal crises as prospective predictors of hospital use and showed correlation with operation of the service.[27]

The American College of Surgeons Committee on Trauma developed guidelines for a critical care air ambulance service. The needs analysis should include demographically based surveys of the incidence of serious trauma and other critical illnesses. The approximate annual incidence for serious injury, as defined by an injury severity score of greater than 15, is (500/million), severe injury requiring intensive care (250/million), severe head injury (200-250/million), and burns and spinal cord injuries (65/million). The committee also recommended that the data for a needs analysis

be specific for urban and suburban populations.[29]

Health officials were concerned with the continuing practice of charging less for emergency air transport service than the program actually cost, meaning that helicopter EMS services were designed to lose money. The rationale for this unusual business practice was that the losses incurred for operation of a helicopter EMS service would be offset by the revenue generated from the hospital fees of the severely injured patients. In general, patients transported by air stayed an average of 5.7 days in the intensive care unit, 19.3 days in the hospital, and generated $10,500 in patient charges.[30]

After evaluation of the first-generation programs, three additional characteristics were added that identified the second-generation programs.

1. A certificate of need was required prior to operation of the service.
2. Quantitative research was necessary to predict the use of the service as part of the certificate of need approval.
3. Multiple missions were implemented for patients with medical problems other than trauma, including neonatal, cardiac, and severely ill medical patients.

Third-Generation

The third-generation programs were initiated at the same time that rising hospital costs were becoming a major issue in the medical, public, and political arenas. In October 1983 the government, in an attempt to contain rapidly expanding health care costs, instituted a prospective reimbursement system for paying the hospital-generated costs of Medicare patients based on a fixed rate of return according to the patient's diagnosis-related group (DRG).[31] This legislation had a profound effect on the manner in which American health care was delivered.[32-34] The essence of this legislation was to encourage hospitals to operate in a more traditionally business-oriented fashion. If the hospital could render care for less than the sum with which it was prospectively reimbursed, the hospital could use the remaining money in ways which were beneficial to future patients. Conversely, if the care provided cost more than the hospital was reimbursed, the hospital would have to decrease its operating costs to survive. This concept was critically important in those states that implemented the DRG concept for all third-party payors, eg, Connecticut and New Jersey.

The new DRG reimbursement process had a significant effect on helicopter EMS programs. The practice of subsidizing a program that was losing money was closely scrutinized. Because first-generation helicopter programs were designed to cost more than the revenue they generated from charges, money became a major issue. The fiscal management of helicopter programs changed significantly following the introduction of cost-containment schemes and reimbursement strategies. The characteristics that differentiated third-generation programs from their predecessors were: (1) the use of twin-engine helicopters for safety, speed, and mission diversity; (2) involvement of state regulatory agencies and external oversight committees in planning and operating programs; (3) improved research strategies to test cost benefits and cost effectiveness; (4) multiple hospital involvement in transferring and receiving patients transported by air; and (5) realistic charges for the helicopter EMS service that reflected the actual costs. Such systems were implemented in Hartford, Connecticut , Boston, Massachusetts, and San Francisco, California.

PROGRAM PLANNING AND IMPLEMENTATION

Involvement of State Regulatory Agencies

Implementing a helicopter program is a major capital expenditure. Increasingly, the Connecticut Commission on Hospital and Health Care decreed that such capital expenditure required a certificate of need.[35] As this process is similar in most states, Connecticut's process for granting helicopter certificates of need will serve as an example.

The commission decided that because a medical air transport program was designed to serve the entire state, it would have to be discussed and defended before each of the health service agencies. Other interested groups with statewide purview were involved in the process. These included the Office of Emergency Medical Services of the Public Health Department, Conference of Ambulatory Care Directors, Emergency Department Directors, American College of Surgeons Committee on Trauma, Connecticut Catholic Hospital Council, and Consortium of Connecticut Hospitals. The purpose of this widespread health care provider involvement was to discuss the design, implementation, and implications of a statewide transportation service.[36] The need for such a service was quantified. The type of patient who would be served and the manner in which the service would be accessed were discussed. The medical and political implications of patient transfer from one geographic area to another were also addressed.

The financial implications to the patient and the system were of major concern. The certificate of need process required that the program be financially inde-

pendent and that the charges for the system reflect the true costs. This meant that the charge for each flight would be determined by dividing the number of flights per year into the annual operating budget. Reimbursement for aeromedical transportation was the responsibility of the patient and the insurance carrier. Extensive discussions with third-party insurance carriers had to be carried out prior to implementing the program, so that the insurance companies understood the charges, costs, and benefits of the program to the patient. Modern EMS helicopter systems require careful planning and an understanding of the potential payor mix of the patients who will be transported, as it is not ethically or morally reasonable to undertake fiscal screening prior to transporting a patient with a life-threatening emergency, especially if the flight originated from the scene of an accident.

The intense and widespread review of the proposed service that the certificate of need process generated was important as it allowed open and frank discussions of the program's costs and benefits. The process allowed comprehensive discussion and dissemination in both the medical and public arenas prior to approval by the Commission on Health and Hospital Care.

External Oversight Committees

An external oversight committee appointed by the governmental body responsible for providing emergency medical care in the state should be in place prior to program implementation. In Connecticut the Department of Health delegated this responsibility to the Office of Emergency Medical Services. The director of this service appointed a committee comprised of representatives from the medical community, including surgeons, emergency physicians, neonatologists, hospital administrators, and public safety officials, ie, the state police and ambulance services, and pilots familiar with general and helicopter aviation. The committee was charged with reviewing the planning, implementation, and ongoing evaluation of the helicopter emergency medical service.

There was considerable concern with the possible interference of patient referral lines, both from the scene and between hospitals. National guidelines generated by the American College of Surgeons Committee on Trauma for responding to the scene of an accident and transferring a patient from one hospital to another were extremely useful.[29] It is important to have regional or state committees with broad representation address these issues prior to the initiation of a helicopter emergency medical service program.

Specialized Flight Nurse Training

Modern helicopter EMS services must have well-trained and diverse flight crews that are able to function at the scene of motor vehicle accidents and other traumatic incidents, drownings, and cardiac arrests. They must also be able to handle the entire range of ill and injured patients who are transferred from one hospital to another. These include patients with multiple trauma injuries, severe burns, spinal cord injuries, cardiac and acute medical problems, and pediatric and neonatal crises.

Standards for such a diverse practice are derived from the patient's physical and psychosocial needs, resulting from the particular type of medical insult. Clinical conditions require that the staff combine knowledge of a number of disciplines. There is no national educational curriculum model to use as a guide for flight nurse preparation, thus each program has its own individual approach to training. The Hartford Hospital flight nurse education program serves as an example.

The selection process includes physiologic and psychologic testing using the criteria given in Table 1. All applicants are given a clinical psychology interview and a Rorschach projection test prior to acceptance into the training program. The 18-module program consists of 7 weeks of didactic training with 7 weeks of clinical rotations (Table 2). All modules provide the nurses with a strong foundation in physiology and the alterations in the physiology produced by illness or disease. The nurses spend a minimum of 40 hours in each of the following areas: surgical intensive care, pediatric intensive care, coronary care, neonatal intensive care, emergency department, operating room, and advanced life support ground ambulance service. Additional experience is gained in the delivery room, with the intravenous therapy team, in inhalation therapy, and in the autopsy and animal laboratories. In addition to the 532 hours of medical training, each flight nurse must become familiar with the helicopter, its equipment, and safety procedures. The flight nurses are also trained in stabilization and monitoring procedures (Table 3). Graduates of this program complete an extensive postcourse testing process including written, practical, and oral examinations.

Safety is a prime concern of the aviation team and, for this reason, flight nurses learn the methods and techniques for optimal communication in order to familiarize the medical, professional, and lay communities with the information relating to the safe landing and operation of a helicopter EMS program. Each flight nurse is assigned a specific geographic area and is responsible for commu-

TABLE 1. PHYSIOLOGIC AND PSYCHOLOGIC CRITERIA FOR SELECTING FLIGHT NURSES

Height and weight in proportion to body habitus
Musculoskeletal strength with an ability to lift 75 to 100 pounds
No history of lumbosacral or other spinal trauma or surgery
Lumbosacral spinal x-rays
Visual acuity 20/20 or correctable to 20/20 with lenses
hearing acuity 15/15 or no more than 10 dB loss in either ear
Pulmonary function testing (smokers are disqualified)
Aerobic fitness (capable of completing a stage 5 Bruce protocol treadmill stress test)
Motion sickness resistance
Personality stability

TABLE 2. EIGHTEEN-MODULE EMERGENCY MEDICAL SERVICES TRAINING PROGRAM

Emergency medical services
Thoracic and pulmonary conditions
Cardiovascular conditions
Electrocardiographic and dysrhythmia recognition
Abdominal and pelvic conditions
Central nervous system and axial conditions
Appendicular skeleton anatomy
Metabolic and endocrine conditions
Obstetrics and gynecology
Drug overdose and poisonings
Neonatology
Pediatrics
Environmental conditions
Soft tissue, maxillofacial, eye, and ear anatomy
Burns
Sequelae to trauma
Behavioral conditions
Transportation, operations, and safety

TABLE 3. STABILIZATION AND MONITORING PROCEDURES

Endotracheal and nasotracheal intubation
Cricothyroidotomy
Needle chest decompression and chest tube insertion
Venipuncture and venous cannulation (central and peripheral)
Pneumatic antishock garment use
Intravenous mediation administration
Dysrhythmia recognition
Fibrillation and synchronized cardioversion
Nasogastric intubation
Splinting of extremities and spinal immobilization
Insertion of Gardner-Wells tongs for spinal traction
Monitoring and operation of intra-aortic balloon pump and pacemakers
Neonatal transport and monitoring

nicating with and educating EMS personnel, including emergency medical technicians, fire and police personnel, and lay public, on all aspects of the program. The nurse is also responsible for critiquing each trip with the person who requested it or was present at the scene.

Staffing Patterns

Staffing for the mission varies across the United States. In general, each crew must consist of at least two persons who are able to resuscitate a severely ill or injured patient at the scene and during transport to a definitive care hospital. In hospital-based helicopter EMS systems, one member of the medical crew is a flight nurse. A second flight nurse, paramedic, emergency medical technician, or respiratory therapist may also function as part of the crew. A number of programs nationwide have a physician as an integral part of the flight crew.

Each member of the crew has clear responsibilities. The flight nurse is responsible for receiving the report from either the prehospital or hospital personnel depending on whether it is a scene to hospital or hospital to hospital transport. The nurse is responsible for performing the necessary assessment and therapeutic interventions prior to putting the patient on the aircraft. The flight nurse has the prime responsibility for medical management of the patient within the aircraft and must be completely familiar with all the medical equipment as well as all safety-related features on the aircraft. As medical missions have become more sophisticated over the past decade, flight nurses have needed to become familiar with neonatal isolettes, neonatal respirators, intra-aortic balloon pumps, respirators, and end tidal volume CO_2 monitors.

In the early 1970s helicopters were, in general, small single-engine aircraft with minimal space for sophisticated equipment and ancillary personnel. The industry has matured, and now a greater number of larger twin-engine aircraft are used. These helicopters have the ability to transport physiologically compromised patients in a safe and effective manner.

There has been an increasing need to evaluate the presence of a physician on an emergency medical ser-

vice helicopter. European systems, particularly the West Germany helicopter emergency medical service system, have functioned since their inception with specially trained emergency physicians. These physicians are responsible for intubating and performing advanced life support skills while the patient is on the aircraft. The American model more closely parallels the military concept of training nonphysicians in advanced life support technology. In most instances the flight nurse has been the advanced life support care provider. Recently, with larger aircraft and the ability to carry more personnel, physicians have become an integral part of a number of flight programs.

The purpose of the EMS physician has been to provide medical control, make treatment judgments, and perform invasive procedures. Snow et al[36] reported that a physician's presence on an EMS team was necessary 25% of the time, not necessary 39.7% of the time, and possibly necessary 34.7% of the time. A number of clinical factors were shown to be reliable predictors of the necessity for physician involvement, including shock, angina, a trauma score of 12 or lower, a score of 9 or lower on the Glasgow Coma Scale, and coma. In general, these situations involved critical and unstable patients who might rapidly deteriorate during the flight.[36,37] Rhee[38] and Carraway[39] have data supporting the presence of an experienced physician on helicopter missions. Physicians have also been reported to be useful on respiratory intensive care and neonatal transports.[40] In the Hartford experience, the physician was thought to be necessary 23% of the time.

Groups in Norfolk[41] and Lehigh Valley,[42] in Pennsylvania, have used a paramedic in association with the flight nurse, a system which has been beneficial to those patients requiring scene extrication and intervention. The Hartford group has overcome the lack of paramedic assistance by training the respiratory therapist and the flight nurse as emergency medical technicians and certifying the flight nurse as a paramedic.

Safety

Safety has emerged as the most important aspect of a helicopter emergency medical service. A number of incidents have resulted in injuries and fatalities, causing the professional and lay communities to question the operation of medical helicopter programs. Each element of a helicopter emergency medical service program must be understood to determine the areas of risk and to know what has been done and what could be done to diminish these risks.

The most common cause of an accident is pilot error. The other major cause is equipment failure. Collett[43] reported that 67% of all hospital-based helicopter accidents were attributable to pilot error. Adverse weather was responsible for 73% of fatal accidents attributed to pilot error. Poor visibility, darkness, and cloud ceilings under 500 feet accounted for all fatal pilot error accidents. Some of these risk factors are inherent to the aviation part of the program. Most hospitals contract with aviation companies, which are responsible for the pilots and the helicopters. Other risk factors are specific to the medical component of the program. The best programs have a cooperative relationship between the vendor or helicopter operator and the hospital. Helicopter operations, which include flying, maintenance, and aviation personnel management, are complex and are best managed by professionals skilled in aviation. In general, hospitals do not have this expertise.

ELEMENTS OF AVIATION RISK

Important areas of aviation risk are: pilots, mechanics, training, aircraft maintenance, weather, time of day or night, and landing sites. The pilot is the most important member of the aviation team. The number of flight hours a pilot has accumulated is one measure of experience. However, EMS flying is a unique form of aviation and requires a pilot who is comfortable with the stress of flying to unfamiliar destinations at short notice, frequently at night. The landing sites are also unconventional. The lead pilot, who is in command of all aspects of the aviation component of the program, should have 3,000 hours in helicopter flying and a minimum of one year in an EMS helicopter, 10 hours of which should be in the aircraft used in the current program. Other pilots in the program should have 2,000 hours of helicopter experience.[44]

Most EMS helicopter missions are flown in weather conditions that allow the pilot to see the ground clearly, known as visual flight rules (VFR) conditions. All pilots must be VFR qualified. The aircraft are seldom airborne in conditions that necessitate the use of instruments to reach a given destination, known as instrument flight rules (IFR) conditions. However, once or twice in a pilot's career, the pilot may have to traverse clouds or may inadvertently enter poor visual conditions (inadvertent instrument meteorologic conditions). During these times the lack of external visual landmarks may rapidly lead to disorientation. It is, therefore, recommended that the pilot be trained in the use of instruments and be IFR qualified.

Some have suggested that the safety factor could be increased by regulating the use of two IFR-qualified

pilots per flight and by flying only IFR-certified helicopters. These regulations may add a technological margin of safety, but the concerns behind them raise the more important issue of operating the aircraft in poor weather when the risks of accidents are greater. The prevailing theory is that it is unwise to fly a mission when the weather is bad enough to require IFR rules. A secondary issue is the significantly greater cost involved in equiping the aircraft, training the pilots for IFR certification, and increasing the number of pilots to allow for two pilots on each mission.

Mechanics

Helicopters are complex machines with highly advanced electronic aviation devices. Preventive maintenance is essential for safe operation. Helicopters must be inspected by a mechanic daily, and at regular intervals various parts of the engine and the avionics must be checked and replaced. The mechanic must be factory schooled and appropriately rated for the specific aircraft being used. The mechanic must be located on site, or if the program is located near an airport, a contract to perform maintenance specific to the program's aircraft must be in effect.

Parts for helicopters are expensive; some cost the program many thousands of dollars. It is, therefore, critical for the operator to be well financed and have immediate access to spare parts, minimizing the time that the aircraft is out of service for repairs. An inadequately financed program may compromise maintenance, which could lead to major equipment failures and accidents.

Weather

The single greatest contributor to helicopter accidents is poor weather. Collett[45] reported that poor weather was a factor in nearly four times as many fatal accidents as nonfatal injury-producing accidents. Limited visibility was a factor in 67% of all fatal accidents. The majority (10 of 14) of weather-related, fatal accidents occurred at night. Interestingly, 86% of these fatal accidents occurred when the aircraft was flying to its destination; 14% occurred on take off.

The frequency of EMS-related accidents, and incidents which precipitated calls for helicopter EMS responses, needs to be analyzed relative to adverse weather conditions. More accidents probably occur in adverse weather. The medical profession has a long tradition of responding immediately to medical emergencies. The important issue is to balance the medical response that will provide the best outcome for the patient with the potential risk to the responders.

The insurance industry, which bears the financial risk for the increased accident rates, may be tempted to request that the helicopter emergency medical service programs stop flying at night and in adverse weather. Such a response overlooks the obligation to respond to an emergency in the manner that gives the patient the best possible chance for a favorable outcome.[27,28]

Safety criteria were developed by the American Society of Hospital Based Emergency Air Medical Services at the Safety Congress in March 1986. The American College of Surgeons Committee on Trauma, in association with aviation experts, generated guidelines for weather minimums. The ACS recommends that for daytime operations close to the hospital, when the pilot is familiar with the geography, the ceiling should be 500 feet and horizontal visibility should be 1 mile. At night the ceiling should be 1,000 feet and visibility 1 mile. On cross-country flights at distances further from the hospital, when the pilot is not familiar with the geography, the daytime ceiling should be 1,000 feet and visibility should be 3 miles. At night the ceiling should be 2,000 feet and visibility 3 miles.[29]

These recommendations are subject to modification by the lead pilot based on the abilities of the EMS pilots and the geography over which the mission is to be conducted. The medical component of the team should not attempt to pressure the pilots to undertake a mission if the pilot has determined that to do so would be unsafe. It is considered a safe practice not to tell the pilot the medical reasons for an EMS request so that the severity or character of the request does not influence the decision to fly.

The number of hours of continuous duty a pilot must serve, the environment provided for rest, and the number of pilots in a program relative to the number of calls per month are critical factors that relate to safety. The Federal Aviation Association has developed criteria governing the number of hours of work and rest necessary for legal operation. Each pilot is required to keep a record of this work-rest status. The regulations state that a pilot must have 8 hours of uninterrupted rest during a 24-hour period. The hospital must provide a quiet suite of rooms with proper facilities so that pilots may rest when not flying.

The Safety Congress recommended a minimum of three pilots per single-pilot, certified aircraft when a program operates 24 hours a day, 365 days a year. The ACS recommendations relate to the number of flights per month (Table 4). The Helicopter Pilots Association has recommended four pilots per aircraft operational 24

TABLE 4. AMERICAN COLLEGE OF SURGEONS RECOMMENDATIONS ON NUMBER OF FLIGHTS PER MONTH

No. Flights/Month	No. Pilots/Program
30 or fewer	At least 2
30-50	Minimum of 3
50-60	Minimum of 3
60-100	Minimum of 4 or add additional aircraft

hours a day. In 1982, 36% of all programs had two pilots per program. By 1986 the number had fallen to 5%. The number of three-pilot programs rose from 52% in 1982 to 79% in 1986. The number of four-pilot programs rose from 2% in 1984 to 10% in 1986.[44]

Landing Sites

The helicopter emergency medical service system is still in its infancy, and many hospitals do not yet understand the benefits of having the ability to transport seriously ill or injured patients by helicopter. Increasingly, fully certified, illuminated landing pads with illuminated windsocks are being established at hospitals. This process need not be costly, as most hospitals have parking lots that can be converted into appropriate landing sites. Urban hospitals with less available space may require rooftop heliports with special elevator access to transport the patient.

In Connecticut, 19 hospitals have established safe, marked heliports, which have greatly increased the safety of the program. The state Helicopter Oversight Committee has served as a peer review forum at which the importance of safe landing sites can be discussed. The proceedings are available to the medical and administrative leadership in all hospitals within the state and serve as an objective, credible source of acceptable aviation standards. This forum allows the lead pilot to consult with each hospital on the safest option from an aviation standpoint.

The second type of landing site is the uncontrolled, episodic accident scene. The best available site is selected by the ground crew and marked for the pilot. The pilot observes the landing site from the air and while approaching the scene makes the final judgment on whether to land. If the site is unacceptable, the pilot selects another landing area and communicates this to the ground personnel.

A helicopter emergency medical service system must educate prehospital providers on how to establish a safe landing site, how to mark it for pilot identification, and how to behave while in the proximity of a helicopter with

TABLE 5. RECOMMENDATIONS FOR IMPLEMENTING AND ADMINISTERING AN EFFECTIVE HELICOPTER EMERGENCY MEDICAL EMERGENCY SERVICE

Implementation
- A preimplementation survey of the patient transportation needs of the proposed geographic regions should be conducted.
- A scientifically quantified needs analysis should be undertaken.

Structure
- The program should be integrated into the formal EMS system.
- The program should function under the strict medical control of the medical director or a hospital-based physician designee.

Personnel and Equipment
- Flight crew should undergo a formal training program.
- At least one crew member should be a fully trained flight nurse.
- Aircraft should be selected after the mission profile of the program has been established.
- Pilots should have EMS flying experience and specific experience with the aircraft used by the program.

Safety
- Vendors must provide a sufficient number of pilots to eliminate pilot fatigue and minimize pilot error.
- Vendors must provide frequent, recurrent aircraft-specific training.
- Hospitals must provide a suite of quiet rooms for the pilots to obtain undisturbed rest.
- Hospitals should ensure that pilots not be provided with medical information prior to the decision to undertake a flight.
- Pilots must adhere to nationally accepted weather minimums.
- The program should accept national guidelines for transporting patients by helicopter.

Evaluation
- The program should be subject to frequent objective review of its medical performance by impartial peers.
- The program must audit its performance.

blades turning. In Connecticut each flight nurse is responsible for a specific geographic area. The prehospital providers, emergency medical technicians, and fire and police personnel are contacted so that the previously outlined, safety-oriented objectives may be achieved.[46] Providers who successfully pass a written test are awarded a safety patch, which makes them identifiable by the pilot and flight crew.

PUBLIC SERVICE MEDICAL HELICOPTER SYSTEMS

A major criticism of hospital-based helicopter services has been that they are costly. The cost of the aircraft, equipment, maintenance, pilots, mechanics, and medical personnel is $1,016,000 for a single-engine helicopter; $1,142,000 for a light twin-engine helicopter; and $1,308,000 for a medium twin-engine helicopter (Table 5). The cost of these programs is passed on to patients that use them and their insurance companies.[47]

A different system of helicopter emergency medical services is the multimission public service model. These services are operated by the city or state police and are used for surveillance, search and rescue, police activities, and executive transportation as well as medical missions. The advantage is that the cost is distributed among many agencies and is usually supported by a tax base. The disadvantages are that these services have more than one objective, and training, continuing education, and medical direction of personnel are more difficult to standardize and maintain. Frequently, medical critique and feedback on the outcome of the case and the manner in which the aviation medical personnel affected the outcome is episodic and incomplete. This lack of medical direction is particularly distressing when these crews are required to perform technically demanding procedures, such as intubation of a patient with head and neck injuries. Despite these serious criticisms, the Maryland EMS system has developed a sound comprehensive trauma system using public service helicopters and personnel.[48]

RECOMMENDATIONS

Many important issues need to be addressed and questions answered when establishing helicopter emergency medical services. The problem is that although scientific principles have been applied to assessing the need for helicopter emergency medical services and the benefits that can accrue to severely injured patients, safety has not received the same scientific scrutiny. For example, numerous articles in the lay press have criticized the safety of these programs and many attribute the number of accidents to pilot fatigue. However, studies have not been conducted to show how many accidents occurred at the end of a long shift as opposed to the beginning of the shift. The question of how many pilots should staff a 24-hour, 365-day program also needs to be answered. One school of thought is that the number of pilots and amount of equipment, although important, are not the critical issues. Adherents stress training in EMS-specific aviation as being vitally important; training that includes not only the technical aspects of flying, which measure technological competence, but also judgment, which allows pilots to identify errors and approaches to problem solving.

The American Society of Hospital Based Emergency Air Medical Services, American College of Surgeons, Federal Aviation Association, and National Flight Nurse Association have all generated safety standards; however, the vendors of the services have been reluctant to standardize their safety policies relative to weather conditions and pilot selection, training, and numbers. This group needs to generate or accept already existing criteria for helicopter programs and rigorously adhere to them. Collaborative research is needed among medicine, administration, insurance, aviation vendors, the Federal Aviation Association, Department of Transportation, and National Highway Traffic Safety Administration to develop uniform national norms and standards.

The process should be activated quickly before a unilateral, ill-conceived dictum is implemented by the federal government or the insurance industry. The insurance industry may react by increasing rates to a prohibitive level or failing to insure programs that have physicians on board, which would be detrimental to the patient. The pressures for some action are significant but the patients and helicopter emergency medical service would not be well served by decisions that have not been scientifically researched. Recommendations likely to minimize the risks of a helicopter emergency medical service and result in an effective program are provided in Table 5.

Literature Cited

1. Neel SH: Helicopter evacuation in Korea. *United States Air Force Medical Journal* 1955; 6:681-702.

2. Smith AD: Medical air evacuation in Korea and its influence on the future. *Military Surgeon* 1952; 110:323-332.

3. Neel SH: Army aeromedical procedures in Vietnam: Implications in rural America. *JAMA* 1968; 204:309-313.

4. Haacker LP: Time and its effects on casualties in World War II and Vietnam. *Arch Surg* 1969; 98:39-40.

5. National Safety Council: *Accident Facts.* Emmaus PA, Rodale Pr Inc, 1982.

6. Zollinger TW, Vilardo SJ, Chan PW, et al: Assessment of medical care costs of injuries due to alcohol-related motor vehi-

cle crashes. *Journal of Safety Research* 1984; 15:77-84.

7. Muñoz E: Economic costs of trauma: United States. 1982. *J Trauma* 1984; 24:27-244.

8. Lowe DK: Patterns of death, complications and error in the management of motor vehicle accident victims: Implications for a regional system of trauma care. *J Trauma* 1983; 23:50-59.

9. McMurty RY, Nelson WR: A trauma center—What is involved? *Canadian Association of Radiologists Journal* 1983; 34:163-166.

10. Boyd DR: Trauma—A controllable disease in the 1980s. *J Trauma* 1980; 20:14-24.

11. Boyd DR: A symposium on the Illinois Trauma Program: A systems approach to the care of the critically injured. *J Trauma* 1973; 123:275-284.

12. American College of Surgeons Committee on Trauma: Hospital resources for optimal care of the injured patient. *Bulletin of the American College of Surgeons* 1979; 64:43-48.

13. American College of Surgeons Committee on Trauma: Optimal hospital resources for care of the seriously injured. *Bulletin of the American College of Surgeons* 1976; 6:15-22.

14. Detmer DE, Moylan JA: Regional categorization and quality of care in major trauma. *J Trauma* 1977; 17:592-599.

15. West JG, Trunkey DD, Lin RC: Systems of Trauma Care. A study of two counties. *Arch Surg* 1979; 114:455.

16. Thompson CT: Trauma Center Development. *Ann Emerg Med* 1981; 10:12, 662-665.

17. Freeark RJ: American Association for the Surgery of Trauma Presidential Address: The trauma center: Its hospitals, head injuries. Helicopters and Heroes. *J Trauma* 1983; 23:173-178.

18. West JG, Cales RH, Gazzargia AP: Impact of regionalization: The Orange County experience. *Arch Surg* 1983; 118:740-744.

19. Funsch HF, Nareff MJ, Watkins PP: Wings for wounded warriors. *JAMA* 1967; 200:391-398.

20. Helicopter in Emergency Medical Services: NHTSA Experience to Date. National Highway Traffic Safety Administration. US Department of Transportation publication No. 5003-00112. Dec 1972, DOT-HS80-231.

21. Cleveland HC, Bigelow DD, Dracon D, et al: A civilian air emergency device: A report of its development. Technical Aspects and Experience. *J Trauma* 1976; 16:452-463.

22. Kohn AW: Search and rescue service, in Burghardt H (ed): *Aeromedical Evacuation: Results, Analysis Developments.* A report on the First International Aeromedical Evacuation Congress. Allgemeinene Deutchen Automobil Clubs. Munich, Hauptabteilung-Verkeher 80-82, 1981.

23. Kugler G: The German Federal Republic, in Burghardt H (ed): *Aeromedical Evacuation: Results, Analysis Developments.* A report on the First International Aeromedical Evacuation Congress. Allgemeinene Deutchen Automobil Clubs. Munich, Hauptabteilung-Verkeher 76-79, 1981.

24. Duke JLH, Clarke WP: A University staffed private hospital-based air transport service. *Arch Surg* 1981; 116:703-708.

25. Providence group: *Rapid Response/Transfer Candidates for Critical Care Medical Services.* Prepared for St. Joseph Hospital, Omaha, Nebraska, March 1979.

26. Baxt WG, Moody P: The impact of a rotorcraft aeromedical emergency care service on trauma mortality. *JAMA* 1983; 249:3047-3051.

27. Rhee KJ, Burney RE, MacKenzie JR, et al: Predicting the utilization of helicopter emergency medical services: An approach based on need. *Ann Emerg Med* 1984; 13:916-923.

28. Baxt W, Cleveland H: Hospital-based rotorcraft aeromedical emergency care services and trauma mortality: A multicenter study. *Ann Emerg Med* 1985; 14:859-864.

29. Hospital and prehospital resources for optimal care of the injured patient. By the Committee on Trauma of the American College of Surgeons. *Bulletin of the American College of Surgeons* Oct 1986, pp 4-37.

30. Low KL, Low JK, Brennan R, et al: Trauma operating room in conjunction with an air ambulance system: Indications, interventions and outcomes. *J Trauma* 1982; 22:759-765.

31. Shaffer FA: DRGs: History and overview. NLN publication No. 15-34, June 1984.

32. Jacobs LM: The effect of prospective reimbursement on trauma patients. *Bulletin of the American College of Surgeons* 1985; 17-22.

33. Smits HL, Watson RE: DRGs and the future of surgical practice. *N Engl J Med* 1984; 20(31):1612-1615.

34. Jacobs L, Schwartz R: The impact of prospective reimbursement on trauma centers. *Arch Surg* 1986; 121:479-483.

35. Jacobs LM, Bennett B, Schwartz R: A medical helicopter transportation system for Connecticut. *Conn Med* 1985; 49:489-495.

36. Snow NA, Hull BS, Severns J: Physician presence on a helicopter emergency medical service: Necessary or desirable. *Aviat Space Environ Med* 1986, pp 1176-1179.

37. Snow N, Hull C, Severns J: Physician staffing on a helicopter emergency medical service. *Emergency Care Quarterly* 1986; 2:40-45.

38. Rhee KT, Burney RE, MacKenzie JR: Is the flight physician needed in helicopter emergency services? *J Trauma* 1984; 24:680.

39. Carraway RP, Brewer ME, Lewis BR: Why a physician? Aeromedical transport of the trauma victim. *J Trauma* 1984; 24:650.

40. Harless KW, Morris AT, Cengiz M: Civilian ground and air transport of adults with acute respiratory failure. *JAMA* 1978; 240:361-362.

41. Schwab CW, Peclet M, Zachowski SW, et al: The impact of an air ambulance system on an established trauma center. *J Trauma* 1985; 25:580-586.

42. Rhodes M: A retrospective study of field triage for helicopter transport. *Emergency Care Quarterly* 1986; 2:22-30.

43. Collett H: Risk management and the aeromedical helicopter. *Emergency Care Quarterly* 1986; 2:31-39.

44. Collett H: Fifth annual aircrew survey. *Hospital Aviation* October 1986, p 19.

45. Collett H: Weather related accidents. *Hospital Aviation* November 1986, p 15.

46. Gemmell CH, Magner RW, Jacobs LM: Safety within an emergency medical service helicopter program. *Emergency Care Quarterly* 1986; 2:66-73.

47. Collett H: Aeromedical program prices. *Hospital Aviation* October 1986, p 15.

48. Cowley RA, Hudson F, Scanlon E, et al: An economical and proven helicopter program for transporting the emergency critically ill and injured patient in Maryland. *J Trauma* 1973; 13:1029-1038.