NATIONAL EMS RESEARCH AGENDA

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ABSTRACT

Now, more than ever before, the spirit of the emergency services professional is recognized by people everywhere. Individuals from every walk of life comprehend the reality of the job these professionals do each day. Placing the safety of others above their own is their acknowledged responsibility. Rescue and treatment of ill and injured patients is their purpose as well as their gratification. The men and women who provide prehospital care are well aware of the unpredictable nature of emergency medical service (EMS). Prehospital care is given when and where it is needed: in urban settings with vertical challenges and gridlock; in rural settings with limited access; in confined spaces; within entrapments; or simply in the street, exposed to the elements. Despite the challenges, EMS professionals rise to the occasion to do their best with the resources available.

Despite more than 30 years of dedicated service by thousands of emergency medical service professionals, academic researchers, and public policy makers, the nation's EMS system is treating victims of illness and injury with little or no evidence that the care they provide is optimal. A national investment in the EMS research infrastructure is necessary to overcome obstacles currently impeding the accumulation of essential evidence of the effectiveness of EMS practice. Funding is required to train new researchers and to help them establish their careers. Financial backing is needed to support the development of effective prehospital treatments for the diseases that drive the design of the EMS system, including injury and sudden cardiac arrest. Innovative strategies to make EMS research easier to accomplish in emergency situations must be implemented. Researchers must have access to patient outcome information in order to evaluate and improve prehospital care. New biomedical and technical advances must be evaluated using scientific methodology. Research is the key to maintaining focus on improving the overall health of the community in a competitive and cost conscious health care market. Most importantly, research is essential to ensure that the best possible patient care is provided in the prehospital setting.

The bravery and dedication of EMS professionals cannot be underestimated. Images of firefighters, EMS personnel and others going into danger, while others are evacuating will remain burned in our collective consciousness. These professionals deserve the benefit of research to assist them in providing the best possible care in the challenging circumstances they encounter.

With this document, we are seeking support for elevating the science of EMS and prehospital care to the next level. It is essential that we examine innovative ways to deliver prehospital care. Strategies to protect the safety of both the patient and the public safety worker must be devised and tested. There are many questions that remain to be asked, many practices to be evaluated, and many procedures to be improved. Research is the key to obtaining the answers.

DEDICATION

During the writing of this document, we were devastated by the premature death of two colleagues who unselfishly gave of their energy, enthusiasm, time and wisdom to work toward improving emergency medical care, trauma care and health care access. The loss of their knowledge, friendship and concern for others leaves a void in the EMS community. In the spirit with which they made their contributions to this discipline, we dedicate this document to *Scott Frame, MD,* and *Keith Neely, PhD*. Their contributions as members of the writing team for the National EMS Research Agenda are treasured, and we remember them fondly.

PREFACE

This document, commissioned by the National Highway Traffic Safety Administration and the Maternal and Child Health Bureau, describes the history and current status of EMS research. Within its pages, impediments to the growth of scientific investigation in the field are identified; and strategies are suggested for improving the quality and quantity of EMS research with the goal of providing a scientific foundation upon which to base current and future prehospital care. We describe a culture of EMS that has been slow to respond to, recognize, and utilize the potential that exists in technology and science today. The time for major advancement in the science and practice of EMS is here. Emergency Medical Service providers must be able to deliver state of the art care based on sound scientific knowledge. A number of us, our families, or our friends will at some point turn to local EMS providers for assistance; and we expect that they will provide us with the best care possible.

It is our intent that this document be used by policy makers, EMS professionals and administrators, academicians, and interested members of the public as a rationale for the allocation of resources to EMS research. We envision a not-too-distant future in which funding is available to enable collaboration between EMS professionals and academicians, support multi-center research, facilitate the development of new researchers, support the effective use of data from national databases, integrate education and training regarding research into EMS practice, and to promote the evaluation of important treatments in an efficient and highly productive manner.

It is time for change, time to make a difference, and time to limit injury and suffering within our capacity to do so. This document is intended to provide direction for the steps that must be taken to improve prehospital care for all Americans.

DEFINITION OF EMS FOR THIS DOCUMENT

Emergency medical service is widely regarded as including the full spectrum of emergency care from recognition of the emergency, telephone access of the system, provision of prehospital care, through definitive care in the hospital. It often also includes medical response to disasters, planning for and provision of medical coverage at mass gatherings, and interfacility transfers of patients. However, for the purposes of this document, the definition of EMS is limited to the more traditional, colloquial meaning: prehospital health care for patients with real or perceived emergencies from the time point of emergency telephone access until arrival and transfer of care to the hospital.

FEDERAL AGENCIES CAN HELP ADVANCE EMS RESEARCH

We call on federal agencies for their assistance in implementing the recommendations in the National EMS Research Agenda to enhance EMS research. A variety of federal agencies have supported EMS operations and research in the past and most continue to do so now. We hope that agencies such as the National Highway Traffic Safety Administration (NHTSA), the Agency for Healthcare Research and Quality (AHRQ), the Centers for Disease Control (CDC), the Health Research and Services Administration (HRSA), the National Fire Academy, the Department of Defense, and the National Institutes of Health (NIH) will continue to support EMS research by providing funding for educational programs, supporting the development of Centers of Excellence, and by acknowledging their commitment to EMS research through the inclusion of

EMS related research opportunities among their requests for proposals to solve health problems for Americans.

EXECUTIVE SUMMARY

Imagine if you will, the public outcry that would ensue if a jumbo jet filled with passengers crashed every day in the United States. Regrettably, Americans no longer need to imagine images of disasters that result in the tragic loss of lives. However, each day, *more* people die of sudden cardiac arrest than would fill a Boeing 747.[1] The most effective way to improve the odds of survival for sudden cardiac arrest is rapid defibrillation in the prehospital setting. As high quality Emergency Medical Services (EMS) developed during the 1970s, cardiac arrest survival rates increased from near nothing to about 20% in a few progressive cities.[2] However, essentially no additional progress in survival from cardiac arrest has occurred since 1980.[3] For children, the odds of survival remain abysmal. Less than 2% of children with prehospital cardiac arrest survive to leave the hospital.[4]

Trauma systems developed during the 1970s to address the inadequacy of care for victims of traffic crashes. EMS began to transport patients directly to regional trauma centers, often bypassing closer community hospitals. With the establishment of these regional trauma centers the odds of survival from motor vehicle crashes improved.[5] This reduction in mortality from injury illustrates the value of having EMS professionals who understand how to use the emergency care resources available in each community.

The vast majority of patients cared for by EMS, however, are not victims of cardiac arrest or major injury. They have illnesses or injuries that are not life threatening yet require access to medical care. EMS spends about five billion dollars each year, most of which is used for the provision of care to patients without life threatening conditions. Essentially no research has been performed to evaluate the effectiveness of EMS care for this group of patients.

Progress in prehospital emergency patient care is needed. There is not enough high quality EMS-related research to drive improvements in patient outcome and that vast amounts of money are being spent for patient care with little rigorous evaluation of the effectiveness of that care. Methodologically sound research must be incorporated into all facets of the EMS system. This document, *The National EMS Research Agenda*, discusses the reasons why EMS research is important and emphasizes that the responsibility for examining EMS practice lies with all stakeholders in EMS.

Performance of high quality EMS research is hindered by five impediments: 1.) A paucity of highly skilled researchers; 2.) Inadequate funding; 3.) Failure of EMS professionals to understand the importance of conducting EMS research and translating the findings into clinical practice; 4.) A lack of integrated information systems that provide for meaningful linkage with patient outcomes; 5.) Logistical problems in obtaining informed consent. However, these barriers can be overcome.

Develop Researchers

High quality research will not occur unless there are individuals with the training and experience to accurately answer important questions. Currently, there are few expert researchers with an interest in EMS-related problems who have an understanding of the special challenges of conducting research in the EMS setting. Researchers with a wide variety of backgrounds including physicians, nurses, EMS professionals, public health experts, and scientists from other disciplines need to be encouraged to perform EMS research.

Recommendation 1.

A large cadre of career EMS investigators should be developed and supported in the initial stages of their careers. Highly structured training programs with content directed toward EMS research methodologies should be developed.

- Fellowship training programs capable of producing at least five EMS researchers per year are needed. Federal agencies are potential funding sources for these fellowships. Ideally, fellowship programs should be at least two years in length and should produce individuals with training and expertise in both research methods and funding acquisition. A doctoral degree (PhD, MD, etc.) should be a prerequisite for entry into the training programs. Program funding that includes institutional overhead and provides funds to ensure that research projects can be accomplished during the fellowship is essential. Individual training grants specifically targeted to EMS specific topics and system evaluation should be available.

Facilitate Collaboration

Effective EMS research necessitates creating working relationships between EMS researchers and social scientists, economists, health services researchers, epidemiologists, operations experts, clinical scientists, basic scientists, and researchers from other disciplines. Building these relationships requires a dedicated and committed core research group with access to reliable funding sources.

Recommendation 2.

Centers of Excellence should be created to facilitate EMS research. These Centers will bring together experienced investigators, institutional expertise, and resources such as budgetary and information systems support. Centers will develop and maintain strong working relationships with local and regional EMS providers. As the focal point of these resources, Centers of Excellence will be the catalyst for collaboration between EMS systems and investigators. Such an environment will enable quality research to flourish.

- One or more federal agencies should encourage the submission of proposals to develop at least five EMS Centers of Excellence. Each successful applicant should be funded for five years and be evaluated for renewal in a competitive application process. At least $1M should be devoted to development of research programs and infrastructure at each Center every year. Each Center should be located within an academic institution with ties to fellowship programs, career faculty researchers, multidisciplinary expertise, training programs, and other resources necessary to create research infrastructure.

- One or more federal agencies should issue requests for proposals for at least two regional EMS research centers. The centers will organize and manage multi-system studies. The centers will form a network to facilitate access to data. Each center should operate on a five-year funding cycle with a competitive renewal process at the end of each five-year phase.

Establish a Reliable Funding Stream

The absence of funding for major EMS research represents a huge obstacle to improving the health of the public. Researchers cannot perform research without financial support. Most research accomplished to date within EMS has been conducted on shoestring budgets using volunteer labor, surplus supplies, and in kind contributions from hospitals, medical schools, and EMS agencies.

Researchers also need dedicated time to perform EMS research. Since investigators frequently have competing roles in their work, they are pressured by their institutions to spend time on projects with the best reimbursement. Institutions will release investigators from other responsibilities to concentrate on EMS research if there are incentives and advantages for the organization. Despite the lack of a concerted and focused effort, the advances in EMS that have occurred historically are remarkable. However, failing to intentionally plan for and fund EMS research will likely delay discoveries that have the potential to save untold numbers of lives.

Additional annual funding in an amount equal to 1% of the annual expenditures on EMS systems should be allocated for research into the effectiveness of those systems. This would mean approximately $50 million would be available for research each year.

Recommendation 3.

Federal agencies that sponsor research should acknowledge their commitment to EMS research.

- The federal government should increase its commitment and support of EMS research.
- A joint announcement, similar to that issued for EMS Research concerning children (PS-01-044), should be issued to provide opportunities for conducting EMS research under the sponsorship of a group of Federal agencies and to broadly describe the areas in which research is warranted. Each sponsoring agency should delineate and prioritize specific areas of interest and provide detailed information regarding application upon request.
- The number of fully federally funded controlled clinical trials conducted in the EMS setting should increase by 25% each year for five years beginning in FY 2003.

Establish Alternative Funding Sources

The federal government should not be the only organization funding EMS research. Charitable foundations often offer unique and flexible funding, some of which should be dedicated to EMS research. State EMS lead agencies traditionally have not performed EMS research, but they should develop a serious commitment to improve patient care based upon evidence generated by high quality research. Ideally, state agencies should collaborate with at least one academic institution with expertise in EMS research. This collaboration will give state regulators, provider agencies, and EMS professionals access to individuals with expertise regarding grant applications and local research related issues. This academic collaborator should also offer guidance to the state lead agency on EMS research policies.

Recommendation 4.

States, corporations, and charitable foundations should be encouraged to support EMS research.

- State lead EMS agencies should promote prehospital research and facilitate the development of relationships and resources necessary for such studies.
- Corporations and charitable foundations should provide funds for EMS related research.

Recognize The Need for EMS Research

In most fields of human endeavor, there is a significant time delay from a new discovery until the new methods are integrated into practice. EMS has a similar delay in implementation of research results. This delay can negatively impact patient care by perpetuating erroneous or ineffective practices and by inhibiting timely implementation of new effective treatments.

The problem of translating research into practice is especially difficult in EMS. Most EMS professionals are not trained to critically evaluate new treatments and so they do not possess the skills to decide whether evidence truly supports their use. Therefore, EMS agencies should employ physicians with the expertise to evaluate new treatments and with the ability to develop and improve patient care protocols based on scientific findings. These physicians should work to educate EMS providers about the scientific process of linking research findings to clinical care. This relationship will provide an environment in which EMS personnel will be able to adopt new protocols with an understanding of how decisions were made. The culture within EMS needs to change to promote research and demand evidence before implementing new system modifications, medications, or drug therapies.

Recommendation 5.

The efforts of EMS professionals, delivery systems, academic centers, and public policy makers should be organized to support and apply the results of research.

- NHTSA should adopt a curriculum for EMS educators that teaches critical review of the scientific literature.
- The National Fire Academy should continue to offer courses that convey the importance of EMS research and detail specific strategies by which fire services can facilitate EMS research.
- Federal agencies should adopt or develop a curriculum for EMS administrative officers that will instill the importance of evidence-based decision-making, reduction of medical errors, and introspection into the culture of EMS organizations.
- Appropriate research principles should be included in the core content of EMS education of first responders, EMT-Basics, EMT-Intermediates, and EMT-Paramedics.
- National and state accrediting agencies for EMS educational programs should require that familiarity with the scientific literature be an essential component of EMS education programs.
- Academic institutions should develop training pathways for EMS professionals interested in pursuing a research career.
- EMS agencies should contribute to the research process by agreeing to collaborate with academic institutions. Collaboration should include assistance with field data collection and patient enrollment in research studies.

View Research as Necessary for the Improvement of Patient Care

EMS organizations and agencies of the federal government have an obligation to promote the development of a culture within EMS organizations that values and supports research.

Recommendation 6.

EMS professionals of all levels should hold themselves to higher standards of requiring evidence before implementing new procedures, devices, or drugs.

Create Reliable Information Systems

EMS care delivery is unusual in that the patients are only under EMS care for a short time and may not be known by name. The lack of accurate patient identification presents a major challenge for the investigator wishing to measure outcomes. In addition because of the fragmented nature of

the EMS delivery system, a given EMS agency may care for only a limited number of critically ill patients annually. Thus, the use of standardized data collection, data linkage, and reporting mechanisms are critical to allow patient outcomes to be compiled and meaningfully evaluated.

Recommendation 7.

There should be standardized data collection methods at local, regional, state, and national levels. These data must be devoid of information that allows individual patient identification. All EMS provider agencies should adopt the Uniform Prehospital Data Elements for data collection.

- NHTSA should sponsor a process to revise the Uniform Prehospital Data Elements at least every ten years.
- State lead EMS agencies should require all EMS organizations in their jurisdictions to collect and submit to the state the Uniform Prehospital Data Elements at a minimum, and states should report that information to a national EMS data repository.
- Federal agencies should promote the development and maintenance of a national EMS data repository to facilitate comparison of EMS system designs on the effectiveness of care delivery and improving patient safety.

Enhance Ethical Approaches to Research

In many emergency situations, time is inadequate to allow a critically ill patient or a surrogate decision maker to appropriately consider the risks and benefits of participating in a research study. There are two sets of regulations (Department of Health & Human Services and Food and Drug Administration) concerning the waiver of informed consent for medical research. These two sets of regulations have created some confusion among EMS researchers. Their implementation has exposed a fundamental problem associated with conducting research with subjects who cannot provide consent: There is a direct and irrevocable tension between protecting the rights of research subjects and the ability to investigate and improve the care rendered to future patients. The current federal regulations on research in emergency situations may have the unintended consequence of ensuring that EMS professionals will provide care that has not been scientifically validated. . New interventions to treat critical illness will continue to be introduced into the EMS environment, but difficulty in complying with the requirements of the consent regulations may impede the ability of EMS researchers to ensure that they have been studied appropriately first.

Recommendation 8.

The Food and Drug Administration (FDA) and the Office for Human Research Protections (OHRP) should work with EMS research stakeholders to evaluate the current requirements for exception from informed consent in emergency situations and to identify those requirements that are serious impediments to conducting EMS research. The FDA, OHRP, and EMS research stakeholders should work together to develop and propose EMS-specific consent strategies as well as appropriate revisions to the existing regulations to reduce the impediments to research while continuing to adequately protect research subjects.

- There should be a national conference that brings together a large variety of EMS research stakeholders and regulators to recommend improvements to the emergency exception to informed consent procedures.

- Based on the recommendations of the FDA and OHRP, Congress should amend the laws governing exception from informed consent for emergency research to reduce the regulatory burden and facilitate research while continuing to protect the rights of research subjects.
- There should be educational programs that explain the consent process and recommend strategies by which EMS researchers can fulfill the requirements.
- Educational programs that describe the difficulties in obtaining consent in the EMS environment, explain the emergency exception from consent process, and promote acceptance by and consistency among Institutional Review Board (IRBs) should be made available to IRB members and administrators.

Conclusion

A national investment in EMS research infrastructure is necessary to overcome the obstacles currently impeding EMS research. Funding is needed to train new researchers and to establish their careers. Increased financial support is necessary to develop effective prehospital treatment for the diseases that drive the design of the EMS system, including injury and sudden cardiac arrest. Innovative strategies to make EMS research easier to accomplish in emergency situations must be legitimized and implemented. Researchers must have access to patient outcome information so that the impact of prehospital patient care can be evaluated and improved. Incorporating standard scientific methodology into the evaluation of biomedical and technical advances in prehospital care is crucial. Research is the key to maintaining an appropriate focus on improving the overall health of the community in a competitive and cost conscious health care market. Most importantly, research is essential to ensure that the best possible patient care is provided in the prehospital setting.

INTRODUCTION

Medicine is primarily concerned with preventing and curing disease and relieving suffering. The Emergency Medical Service (EMS) is important part of the health care system, especially for people who suffer sudden and unexpected emergencies. In most communities, EMS is regarded as a public good. There are myriad approaches to offering EMS: it may be provided by the fire department, by another agency within the local government, by private entities that provide care within a local geographic area, by volunteer organizations, or by any number of other configurations.

Emergency medical service is often regarded as including the full spectrum of emergency care from recognition of the emergency condition, requesting emergency medical aid, provision of prehospital care, through definitive care in the hospital. It may also include medical response to disasters, planning for and providing medical coverage at mass gatherings, and interfacility transfer of patients. However, for the purposes of this document, the examination of EMS is limited to the more traditional, colloquial definition: prehospital emergency care from the time of the request for medical aid until arrival at and transfer of care to the hospital.

EMS care is provided by a variety of personnel, both paid and volunteer, who are trained at various levels of sophistication including first responders, EMT-Basic, EMT-Intermediate, and EMT-Paramedic. Basic level providers, trained in as little as 110 hours, provide services such as first aid, cardiopulmonary resuscitation, and patient stabilization. At the other end of the training spectrum, paramedics, who have acquired up to thousands of hours of training, bring highly sophisticated medical interventions that require critical thinking, such as endotracheal intubation and intravenous medication administration, to patients in the prehospital setting. EMS agencies often employ physicians with the expertise to evaluate new treatments and with the ability to develop and improve protocols based on scientific findings.[6]

EMS Impact

While precise numbers are not available, EMS treats and transports approximately 25 to 30 million patients per year. As an important point of entry into the healthcare system, EMS is in a unique position to impact those patients. It is logical to assume that prehospital intervention positively affects patient outcome, but this influence is difficult to quantify. For example, early defibrillation to victims of sudden cardiac arrest,[7] administration of nitroglycerin to patients with chest pain,[8;9] and prehospital administration of fibrinolytic therapy to patients with myocardial infarction[10] measurably saves lives. On the other hand, seemingly logical interventions such as the pneumatic anti-shock garment[11] and endotracheal intubation of children[12] may in fact cause harm. That so few EMS interventions have been subjected to outcome studies illustrates the lack of evidence for most prehospital therapies. More research is necessary to provide the evidence upon which EMS practices can be based.

Misperceptions about EMS on the part of the public abound. In one study, fifteen percent of the patients in a hospital emergency department thought that paramedics were physicians.[13] The entertainment media routinely depict cardiopulmonary resuscitation as resulting in good patient outcome, likely leading to unrealistic expectations among the lay public.[14] Most members of the public believe that the use of warning lights and sirens saves clinically significant time in ambulance response and transport to the hospital, although several studies have suggested otherwise.[15;16] No one has published an evaluation of the public's perception of the importance of EMS research or the impact of research (or the lack thereof) on EMS practices.

Is EMS Cost-effective?

EMS systems are expensive to operate. The true economic burden of EMS is widely distributed and therefore well hidden from view. In the Medicare program alone, more than $2.5 billion is spent for patient transportation. It is estimated that $5 billion is spent on EMS in the United States each year. More detail on the costs of the EMS system is available in the document describing the Negotiated Rule Making process on EMS reimbursement sponsored by the Health Care Financing Administration on the Internet at www.hcfa.gov/medicare/comstate.htm.[17] The incremental costs and benefits of different levels of EMS care are poorly quantified[18] and remain the subjects of ongoing studies.[19;20]

Need for Outcome Measurement

Why are such large sums of money spent on a system with seemingly little evidence of efficacy?[21] One reason is that efficacy information is difficult to define and obtain. Part of the problem lies in the uncertainty of how to measure patient outcome. An obvious outcome measure is mortality or lives saved. While seemingly easy to define, there is uncertainty over determining when a "save" occurs. Is it a "save" if a patient requiring CPR is admitted to the intensive care unit but dies after three days? Is it a "save" if that same patient dies in six months but was able to spend five of those months at home with his family?

Mortality is often not a good measure of patient impact because it is an infrequent outcome in many disorders. Evaluation of an infrequent outcome requires either large numbers of patients, long periods of time, or sometimes both. EMS currently lacks the resources for these large research efforts. Disability, relief of suffering, utilization of health services, and costs may be better measures of outcome but are often even more complex to define and obtain. For example, attempting to answer a question such as, "what is the relative benefit of transporting a patient with a femur fracture to the hospital in the back of an ambulance with a leg splint versus by taxicab with no treatment?" can be challenging as one begins to define "benefit."

Accurately measuring outcome is made more challenging by the fact that the patient is delivered by EMS directly to a more comprehensive part of the health care system. Definitive care is seldom delivered in the field, but significant supportive care may take place there. Attribution of ultimate patient outcome to prehospital events is therefore confounded by the impact of interventions received by the patient later in the continuum of care. Measuring the impact of EMS patient care is further complicated by the concentration of specialized medical services such as major trauma care and tertiary pediatrics in a few experienced hospitals. When treating patients with problems such as major trauma, efficient transport to the optimal facility may be the most important prehospital intervention.[22]

Organized Research Effort Needed

A well-organized EMS research effort is clearly needed to dramatically increase the evidence upon which prehospital patient care is based. "Public and private organizations responsible for EMS structures, processes and/or outcomes must collaborate to establish a national EMS research agenda. They should determine general research goals and assist with development of research funding sources."[23]

The authors of this document discussed the utility of creating a list of specific research topics that would be of value in EMS. However, there are compelling arguments against creating such a list. Individual investigators or research teams rather than committees usually generate the best new ideas. In addition, because of the rapid pace of change in the medical sciences, lists are usually

out of date by the time they are published. The writing team agreed that valuable research topics would certainly include the following:

- Ensuring proper and effective patient care.
- Improving the quality of EMS care and systems.
- Improving patient safety by reducing errors.
- Analysis of the cost-effectiveness of systems and interventions.
- Measuring the direct, indirect, and marginal costs of emergency medical services.
- Providing information about the clinical aspects of emergency care, systems configuration and operation.
- Encouraging effective injury prevention strategies and other public health measures.
- Expanding the appropriate use of medical informatics in EMS.
- Developing valid tools and methods for measuring the quality of EMS care and systems.
- Learning effective ways to provide professional education, training, and retraining that will maximize skill acquisition and retention and improve practice patterns and patient outcomes.
- Determining effective methods of public education that effect positive behavioral changes in the areas of injury prevention, basic emergency care skills, and the use of EMS systems.

EMS systems must justify their role in the health care process. They must prove that the care and transportation they provide is necessary and delivered in an effective and economical manner. These mandates can only be achieved by true integration of the research process into the system. Research will lead to the development of more effective treatments, strategies for resource management that benefit the EMS system, and ultimately to improved patient care.

HISTORY OF EMS RESEARCH

Modern EMS systems developed following the 1966 publication of a National Academy of Sciences paper entitled *Accidental Death and Disability: The Neglected Disease of Modern Society*[24] and the work of J.F. Pantridge extending emergency cardiac care to the prehospital setting in the United Kingdom.[25] Dr. Pantridge's program in Northern Ireland inspired the pioneering efforts of physicians such as Eugene Nagel in Miami and Leonard Cobb in Seattle to extend emergency cardiac care to the patient's home.[26;27]

Federal Involvement in EMS Begins

Accidental Death and Disability called for improving prehospital trauma care.[24] As a result, Congress passed the Highway Safety Act in 1966, which established the National Highway Traffic Safety Administration (NHTSA) within the Department of Transportation. Because motor vehicle crash injuries constituted a substantial proportion of the EMS patient load, NHTSA was charged with improving EMS systems by administering grants for ambulance purchases, communications systems, and training programs, and with supporting other traffic related system improvements. NHTSA furthered its role in the advancement of prehospital care by developing national standard curricula for the education of EMS personnel and by lending its foresight, leadership, and commitment to the development of EMS systems.

In 1973, Congress enacted the EMS Systems Act (Public Law 93-154). This Act provided funding for the development of regional EMS systems and authorized a program of research in emergency techniques, methods, devices and delivery. The National Center for Health Services Research (NCHSR), predecessor to the Agency for Healthcare Research and Quality (AHRQ), was responsible for administering this applied research effort. Between 1974 and 1981, the NCHSR supported approximately 50 EMS demonstration projects.

In 1984, Congress established the federal EMS for Children (EMSC) program as a demonstration grant co-sponsored by NHTSA and housed in the Maternal Child Health Bureau. The Institute of Medicine issued a 1993 report on EMS for children that identified several priority areas, including a call for additional data collection, evaluation and research.[28] Since the report was issued, the EMSC program has played a valuable part in advancing the cause of EMS research and in establishing directions for the future of EMS for children. In addition to providing funding and leading EMS initiatives, the program has developed a consensus document of research priorities, including identifying appropriate outcomes.[29]

In January 2001, seven federal agencies participated on an interagency program announcement, PA-01-044, titled Emergency Medical Services for Children Research. The topics to be studied include asthma, traumatic brain injury, and violence prevention. HRSA's other federal partners in this effort (besides the Agency for Healthcare Research and Quality) were the National Institute for Occupational Safety and Health at the Centers for Disease Control and Prevention, as well as the National Heart, Lung and Blood Institute, National Institute for Child Health and Human Development, National Institute on Drug Abuse, National Institute of Mental Health, and the National Institute of Nursing Research, all from the National Institutes of Health.

Other EMSC initiatives providing funding for EMS research include the support of the development of a National EMS Database jointly with NHTSA, awards to promote pediatric patient safety research in EMS, and the EMSC Network Development Demonstration Project (NDDP) Cooperative Agreement Grant (CDA#93.127L). The $1.8 million NDDP grant is being supported by the EMSC program in collaboration with the Division of the Research, Training and

Education of the Maternal and Child Health Bureau. NDDP will support the best proposals to create research networks for performing high quality collaborative research on EMSC topics. Each research node will collect data from participating EDs in its area in order to get answers to pediatric emergency care research questions which were previously difficult to obtain.

Beginning of EMS Research

During the late 1960's, a growing number of EMS organizations around the world recognized that their ambulance services required advancement.[30-34] Improvements in these systems were generally implemented without undergoing unbiased evaluation. For example, in 1966 an editorial in the *British Medical Journal* suggested that patients were dying of suffocation because ambulance service personnel were inadequately trained in airway management.[30] EMS systems responded by introducing airway interventions formerly reserved for the hospital emergency department directly into the field setting. The prevailing attitude was that if an intervention was useful and effective in the hospital then it would be similarly useful in the prehospital environment.

However, study results from one particular environment do not necessarily translate successfully to other environments and may not apply to other populations. Studies of efficacy (i.e., does something work under ideal conditions) do not necessarily indicate effectiveness (i.e., does it work in the real world). Interventions that work in the emergency department might not work in the ambulance, interventions that work in an ambulance might not work in a helicopter, and interventions that work in a moderately busy suburban EMS system may not work in an overburdened urban system. While it makes intuitive sense to take the emergency department to the patient, the compressed time frame for patient evaluation, the lack of many medical technologies such as x-rays, and the limited training of EMS professionals sometimes alter the risk-benefit ratio.[35]

The earliest scientific analyses of EMS practices were limited in scope and methodology. Only three EMS-related randomized, controlled clinical trials were published before 1980.[36-38] The remaining published studies were observational, descriptive, or retrospective in nature. Many studies were designed simply to demonstrate that certain hospital interventions, such as inserting a peripheral intravenous line or performing defibrillation, could be extended to the prehospital environment.[25;39] Often the results indicated that the intervention could be applied in the field but gave no clue as to whether the patient benefited. For example, the early studies of the pneumatic anti-shock garment (PASG) and the esophageal obturator airway (EOA) observed physiologic responses such as increased blood pressure but did not evaluate the relationship of the physiologic changes to patient outcome.[40;41]

The science of EMS has been criticized for providing insufficient evidence to support many of its practices. In 1989, Ronald Stewart advised that EMS must begin to prove itself through research.[42] Nearly a decade later, Michael Callaham repeated the sentiment and observed, "It is possible to document exactly how much scientific support there is for the efficacy of our present scope of EMS practice, and it is impressively deficient."[21]

Progress towards a scientific foundation for EMS practices is slow, in part due to the inherent difficulties in performing research in the field, but also because of the lack of research infrastructure in EMS systems and the absence of funded researchers working in this field. Thousands of people dedicated to improving prehospital care including physicians from a variety of specialties, EMS providers, allied health professionals, public leaders, and even the lay public have been working both individually and through myriad professional organizations toward creating that scientific basis. Most research accomplished to date within EMS has been conducted

on shoestring budgets using volunteer labor, surplus supplies, and in kind contributions from hospitals, medical schools, and EMS agencies.

A Case Study In EMS Research

The experience with the pneumatic anti-shock garment (PASG) is illustrative of the early research experience in EMS. Many EMS physicians promoted its use in a wide variety of medical and surgical conditions with little evaluation of its effectiveness,[43;44] while others were less convinced of its value.[45] PASG use became widespread, with many jurisdictions requiring them as minimal equipment for ambulances at an expense of several thousand dollars per vehicle. Several years after gaining acceptance as a standard item to be stocked on ambulances, a single, randomized clinical trial found that application of the PASG to victims of truncal penetrating trauma in an urban environment actually worsened patient outcome.[46] In the wake of that study, the popular sentiment rapidly shifted to renounce the use of the PASG. Yet, a comprehensive review of the literature established that some patients might in fact benefit from use of the PASG.[11] This is but one example in which misinformation and the lack of scientific knowledge about optimal patient care has confused clinicians and left them floundering to provide the best care without the guidance of good science.

Decisions about the effectiveness of any intervention must be based upon reliable evidence. This requires that there be enough studies to provide sufficient information upon which, among other things, effectiveness and generalizability of the intervention can be determined. Due to the paucity of available research, EMS decision makers have been forced to make judgments based upon limited evidence. Two current issues in which this problem is readily apparent are pediatric airway management, where one controlled trial has questioned the efficacy of endotracheal intubation;[12] and the use of amiodarone for cardiac arrest, where another randomized controlled trial has suggested a positive effect.[47] While both of these studies are examples of methodologically sound research and add to the overall understanding of their respective issues, additional high quality investigations are needed.

THE PRESENT STATE OF EMS RESEARCH

Appeals for Advancement

EMS research is still in an early stage of maturation. A concerted effort to improve the scant scientific knowledge that serves as the basis for EMS practice is now mandatory.[23;48] There has been a strong plea for improving the science within the field.[49] The leaders of the *Future of Emergency Medicine Research* conference, sponsored by the Emergency Medicine Foundation, the Society for Academic Emergency Medicine, and the Association for Academic Chairs of Emergency Medicine, emphasized the need for individual and program commitment to the process of advancing research in emergency medicine. The conference report called for the necessary resources to enhance emergency medicine research through training, academia, funding, national support, multi-center research and development of new outcome measures.[50]

The Society for Academic Emergency Medicine EMS Task Force published a paper in 1999 entitled *EMS Systems: Foundations for the Future*, which called for the specialty of emergency medicine to foster the continued development of EMS administration, education, and research.[48] The report pointed out, "The benefits of prehospital care never have been demonstrated scientifically in many medical and surgical conditions. The time has come to prove the value of field care and determine the most cost-effective and medically sound treatments."[51]

Peer Review Journals

Several peer-review medical journals devoted to EMS are now in publication including *Prehospital Emergency Care* and *Prehospital and Disaster Medicine*. In addition, general emergency medicine journals, including *Annals of Emergency Medicine*, now contain sections devoted to EMS research. There are also subspecialty journals within emergency medicine, such as *Pediatric Emergency Care* and the *Air Medical Journal*, that publish material related to EMS and effectively reach an audience involved in at least some aspect of prehospital care of patients. The emergence of these journals holds an important position in the history of EMS. Their existence shows that EMS research is valuable to the readers of those publications.

Methodological Constraints and Concerns

Although the science of EMS has advanced, many concerns remain. Most of the problems are not very different than issues with which other fields of medicine have struggled. For example, there are not enough controlled clinical trials of new treatments for patient problems encountered by EMS professionals.

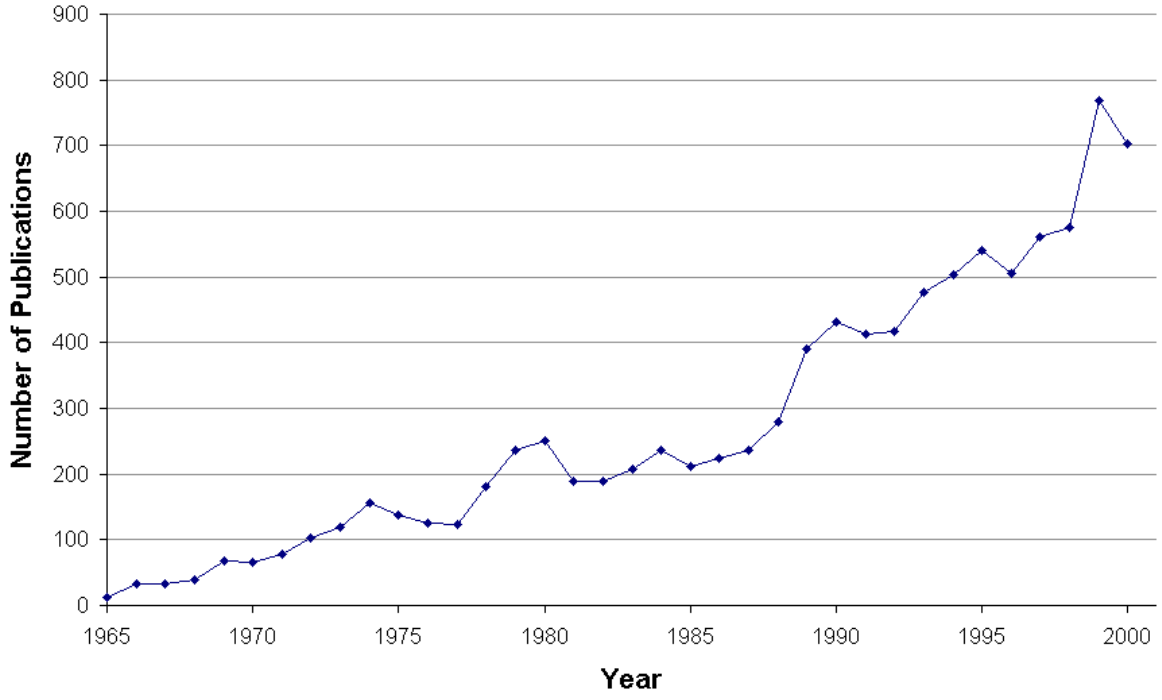
One methodological concern in EMS research is that the best outcome measures for various study questions are not clear.[51] While survival may be an appropriate outcome measurement for sudden cardiac arrest, it would not be a meaningful outcome measurement for studies of minor trauma or respiratory distress because almost all patients will survive independent of any EMS intervention. Further, appropriate measurements of pediatric patient outcomes are sometimes different from those that are commonly used for adults.[29]

Current Literature in EMS

Several reviewers have evaluated the quality and quantity of EMS research over the last 30 years. Figure 1 shows an appraisal of the number of EMS related manuscripts published each year since 1965. The data in the figure are the result of an extensive search of multiple National Library of Medicine (NLM) research databases including MEDLINE and CINAHL. Although the number of EMS publications is not vast, the volume has been increasing steadily over the years at a respectable rate. Since 1970, the quantity of published EMS literature increased at a rate of

approximately 200 articles per decade. The increase is likely due to increased awareness of the need for study in this area and also the appearance of several new journals dedicated to the specialty. If this growth rate remains constant, about 900 articles will be published in the year 2010.

Figure 1: EMS Literature Growth Over Time



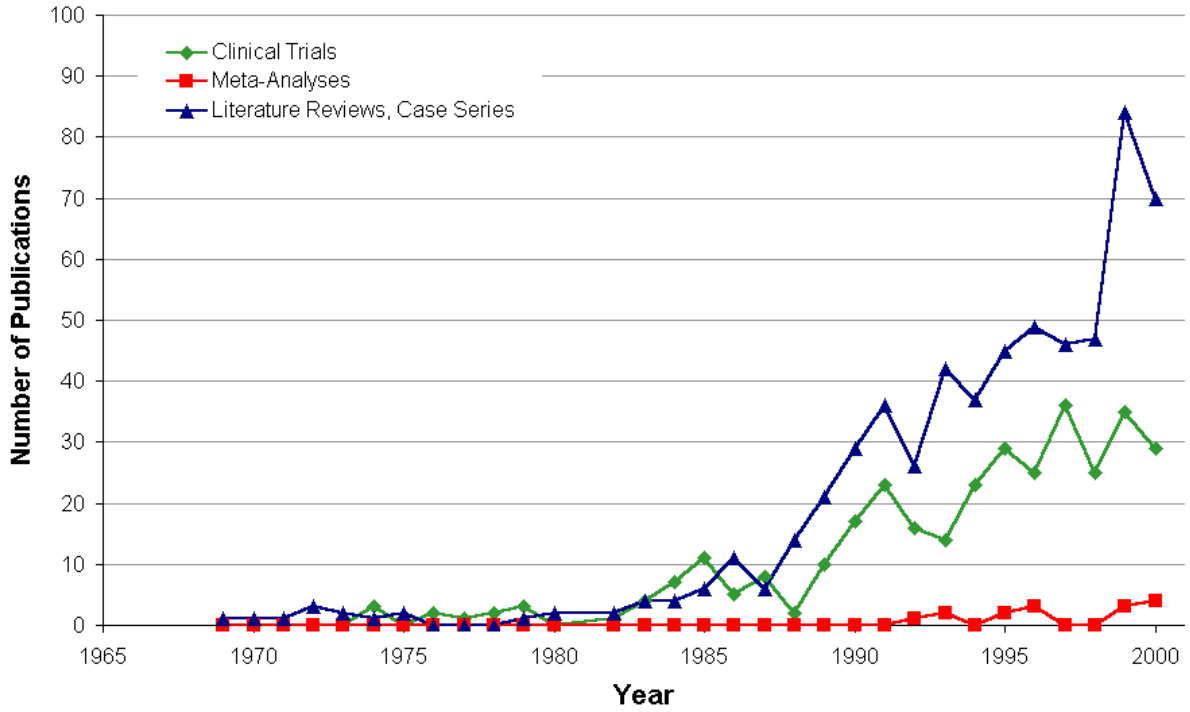
There have been many pleas to increase the number of clinical trials,[52;53] and some have made eloquent points about the dangers inherent in the existence of so few methodologically sound studies.[21] Concern for the lack of scientific support for many pre-hospital interventions, lack of uniform reporting methods, monitoring of outcomes and adverse effects invokes the need for reexamination of EMS practice.[48;54;55]

While randomized controlled trials may be the gold standard for clinical studies, they are not appropriate for every question. For example, randomized trials are not appropriate for studies of harm, prognosis, or diagnostic devices.[56;57] Randomized controlled trials can also be more challenging to implement in systems and educational settings. Indeed, very little educational research utilizes randomized-controlled designs.[58]

Although the body of published EMS literature is growing steadily, there is much concern about the substance of the material. In a recent review of the EMS literature published between 1985 and 1994, the most frequently used study design was the case series, which accounted for 44 percent of the publications. The majority of EMS studies published during that ten-year period (53%) were retrospective in nature.[55]

Figure 2 shows the results of an analysis conducted for the National EMS Research Agenda project in which the NLM designated study type was used to classify the 9,232 identified EMS related citations published between 1966 and 2000. These categorizations are estimates, as not all studies included a design designation. Despite this limitation in the analysis, it remains apparent that the overwhelming majority of the published EMS literature is not research reports but rather

Figure 2. EMS Literature by Study Type



historical articles, editorials, consensus development pieces, biographies, monographs, or guidelines. Of those study types recognized as "research", reviews (n=593; 6% of total) reigned over clinical trials (n=331; 4%) and meta-analyses (n=15; 0.1%). Evaluated on the basis of the strength of the study design, the majority of EMS studies published in peer-reviewed journals use unpersuasive methodology. The bulk of the published research can be characterized by its overwhelming propensity to use simple descriptive methods and retrospective techniques.

With the understanding that randomized clinical trials may not always be the most appropriate design for scientific validation of prehospital treatments or system changes, the number of randomized trials conducted has been used as a surrogate marker for the level of sophistication in research. With this limitation in mind, the proportion of randomized trials out of all the clinical investigations published in EMS has been reported to range between 1%[21], 5%[59]and 15%.[55] As a point of reference, the proportion of randomized trials published in the entire specialty of emergency medicine has not changed much over the years, increasing from 10% in 1983, to 12% in 1989, and reaching 15% by 1997.[60] This proportion is thought to be similar to the proportion of randomized trials estimated to exist in published internal medicine literatures.[61] Appendix F of this document lists published randomized or pseudo-randomized clinical trials conducted in the EMS setting from 1966 through 2000 that could be identified by the writing team.

Research Domains

There are three domains within the spectrum of EMS research: clinical, systems, and educational. Clinical research involves the study of direct patient care activities. Systems research explores the effects of varying EMS system designs and operational methods on resource utilization. Educational research examines the appropriate methods for preparing prehospital care providers.

While each domain can be approached independently, researchers must recognize the interactions between the three areas. Teaching a paramedic to apply a splint ultimately translates into a patient care practice: immobilizing a fracture. Determining the appropriate clinical use of narcotics for pain management ultimately becomes a systems issue: securing and tracking controlled substances.

Clinical Research

To date, investigators with little formal research training and minimal funding or other resources have contributed the substance of the literature in prehospital emergency care. Thus, most published research addresses the most austere questions involving single clinical interventions or health issues. Answers to major EMS issues such as cost-effectiveness, resource utilization, efficacy of field therapies, and injury prevention are conspicuous by their absence from the literature. In addition, as in other areas of medicine, there is little research demonstrating effective methods to improve patient safety in EMS by reducing medical errors.

Despite the absence of evidence for the efficacy of almost all field interventions, progress is occurring in several areas. The Ontario Prehospital Advanced Life Support (OPALS) Study is the largest prehospital study ever conducted. It is enrolling more than 25,000 cardiac arrest, trauma, and critically ill patients over an 8-year period (1994-2002). The OPALS study uses a rigorous controlled methodology and a large sample size, and it is designed to measure the benefit in survival and morbidity that results from the introduction of prehospital ALS programs to communities of different sizes.[19;20;62] While prehospital clinical studies of that magnitude have not been completed in the United States, some complex, well designed studies have been successfully implemented and completed. A clinical trial of the use of high dose epinephrine[63]and the pediatric intubation study from Los Angeles[12] are notable examples.

Systems Research

In 1995, a systems analysis framework was suggested in order to accurately study the complex and interrelated questions that characterize EMS.[64] Systems analysis research models are more commonly employed in disciplines such as engineering, economics, and epidemiology where they are used to evaluate complex questions, often involving computer simulation and mathematical models such as nonlinear or multivariate analysis.[65;66] In the publication, *EMS Systems: Foundations For The Future*, members of the SAEM EMS Task Force reviewed the unique aspects of systems-based questions and suggested a shift from the traditional EMS quality assurance model to one based on improving overall system performance.[48]

An example of systems research is the investigation that showed providing defibrillators to police officers to augment EMS response to sudden cardiac arrest improved survival to hospital discharge.[67;68] Another example demonstrated that pain is routinely under-treated in patients with extremity fractures.[69] Although partially a clinical issue, certain components of the EMS system, such as the level of training for the caregivers and the procedures for replenishing medication supplies, contributed significantly to the problem. Researchers should approach EMS as a system of care, rather than as an isolated process.

Education

There have been a handful of studies designed to analyze the suitability of the curricula and training practices to the actual provision of services by EMTs.[70-74] There seems to be very little in the way of actual evaluation of the relationship between curricula, educational methods and practice. For example, the core competencies expected of paramedics vary widely across the country, suggesting a lack of agreement on the appropriate set of skills for an entry-level paramedic.

An example of educational research is the analysis to determine whether the advanced airway training module in the EMT-Basic National Standard Curriculum assured competency in performing endotracheal intubation, a complex skill. Two investigations found that most EMT-Basic level providers did not achieve skill competency when asked to perform endotracheal intubation on actual patients in the field.[75;76]

OVERCOMING THE BARRIERS TO EMS RESEARCH

There are two primary barriers that have inhibited the development of a strong research program in EMS. They are a paucity of well-trained researchers with an interest in EMS research and a lack of reliable funding sources to support research. There are also three identifiable secondary barriers to EMS research. They are: a lack of recognizing the need for evidence-based practice; standardizing, accessing and sharing data; and complying with the current established ethical requirements for human research.

To some extent, there is a chicken and egg phenomenon at work within the two primary barriers to developing a comprehensive EMS research program. For example, funding agencies understandably prefer to place their funds with researchers who have a track record of proven productivity. However, since there are not many proven researchers with interests in EMS problems, few funds flow into EMS-related research. On the other hand, academic institutions are reluctant to support the professional development of new, EMS-focused researchers because they cannot identify likely funding sources with a history of supporting EMS research.

Primary Barriers: Developing Researchers

As a discipline of medicine, EMS needs to develop a larger cadre of experienced investigators. Novice investigators need formal research training and the opportunity to work with experienced mentors. EMS researchers must collaborate with social scientists, economists, health services researchers, epidemiologists, operations researchers, and other clinical scientists to increase the expertise available for, to generate novel hypotheses in, and to improve the quality of investigations.

Researchers affiliated with medical schools and large teaching hospitals perform most EMS studies because those institutions have the necessary research infrastructure. They offer Institutional Review Board review as well as assistance with obtaining grants and negotiating contracts. They have large libraries with many resources. Statisticians, epidemiologists, methodologists, database managers, and software engineers are available for consultation. Emergency physicians, cardiologists, surgeons, pediatricians, and other specialists who have interests in specific areas of EMS are available for collaboration. Opportunities exist for EMS researchers to collaborate with other disciplines and with industry in many different areas of scientific evaluation. Public health initiatives, injury prevention, development of new technologies, and health economics are examples of areas in which such opportunities exist. Prospective EMS researchers who do not have easy access to the traditional academic research setting may be able to establish relationships with public agencies or private corporations and build their research careers through those venues.

Most EMS researchers have little or no formal training in research methodology.[23] Many colleges and universities have programs that could provide training to interested EMS professionals. For example, graduate degree programs in research and public health are widely available and could easily be tailored to meet the needs of students with specific EMS interests. . One good model of such training programs is the Robert Wood Johnson Foundation Clinical Scholars Program. There are examples of successful collaboration between academic institutions and EMS agencies to provide EMS fellowship training to interested physicians. The Society for Academic Emergency Medicine and the Medtronic Physio-Control Corporation have supported an EMS fellowship program since 1990, and most graduates of that program have pursued careers in EMS research. Still, these training opportunities are limited in their availability.

Recommendation 1.

A large cadre of career EMS investigators should be developed and supported in the initial stages of their careers. Highly structured training programs with content directed toward EMS research methodologies should be developed.

- Fellowship training programs capable of producing at least five EMS researchers per year are needed. Federal agencies are potential funding sources for these fellowships. Ideally, fellowship programs should be at least two years in length and should produce individuals with training and expertise in both research methods and funding acquisition. A doctoral degree (PhD, MD, etc.) should be a prerequisite for entry into the training programs. Program funding that includes institutional overhead and provides funds to ensure that research projects can be accomplished during the fellowship is essential. Individual training grants specifically targeted to EMS specific topics and system evaluation should be available.

Strong consideration should also be given to developing a few centers of excellence in EMS related research. These centers would use their financial resources to build the necessary infrastructure to successfully complete EMS related research. That infrastructure would necessarily include experienced investigators, information systems support, strong links with the local and regional EMS providers, and training opportunities for novice investigators.

Protected time for faculty engaged in research is not adequate in most academic Departments of Emergency Medicine and degree granting institutions offering EMS provider education. Protected time is necessary to ensure research productivity. Developing faculty requires making an investment in them. Academic departments need to invest in EMS research by supporting adequate release time for researchers, and senior faculty should invest in EMS research by serving as mentors to novice researchers. EMS centers of excellence would provide support for release time to permit faculty to engage in research.

Several important EMS problems have a relatively low frequency of events. This is true for clinical, systems and education issues. These questions will need to be addressed using a multi-center collaborative approach. While a number of such trials have been completed in recent years, these efforts need to be expanded.[77] It would be useful to develop one or more EMS research coordinating centers to pull together the resources necessary to organize and manage multi-center clinical trials.

Recommendation 2.

Centers of Excellence should be created to facilitate EMS research. These Centers will bring together experienced investigators, institutional expertise, and resources such as budgetary and information systems support. Centers will develop and maintain strong working relationships with local and regional EMS providers. As the focal point of these resources, Centers of Excellence will be the catalyst for collaboration between EMS systems and investigators. Such an environment will enable quality research to flourish.

- One or more federal agencies should encourage the submission of proposals to develop at least five EMS Centers of Excellence. Each successful applicant should be funded for five years and be evaluated for renewal in a competitive application process. At least $1M should be devoted to development of research programs and infrastructure at each Center every year. Each Center should be located within an academic institution with ties to

fellowship programs, career faculty researchers, multidisciplinary expertise, training programs, and other resources necessary to create research infrastructure.

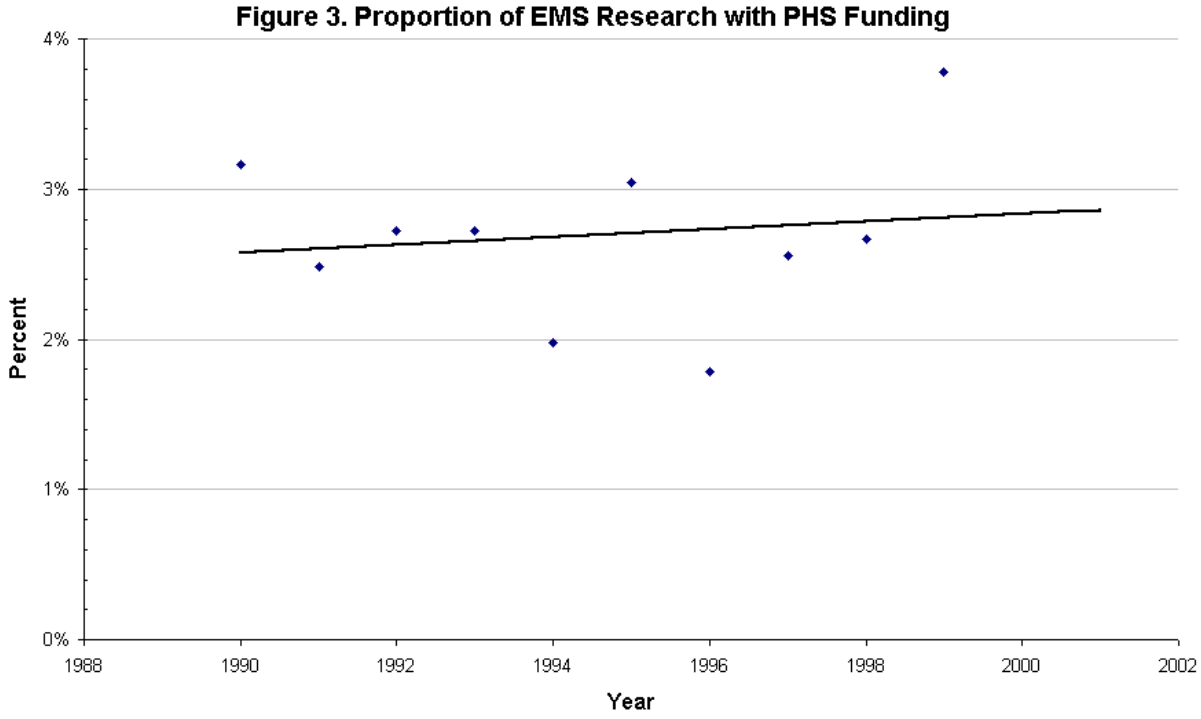
- One or more federal agencies should issue requests for proposals for at least two regional EMS research centers. The centers will organize and manage multi-system studies. The centers will form a network to facilitate access to data. Each center should operate on a five-year funding cycle with a competitive renewal process at the end of each five-year phase.

As a unique body of knowledge is developed, EMS will become recognized as a medical subspecialty. Credentialing within the subspecialty will carry with it an obligation to advance the knowledge base of EMS. An increasing numbers of researchers will be drawn into the field, and academic institutions will develop the necessary infrastructure to support their activities. The resultant interactions between faculty, colleagues, fellows, and students will create a milieu resulting in an increased number of people with excellent EMS research skills. As these academic programs develop they will attract new researchers who will want to obtain advanced training and advanced degrees in research. The research produced by these well-trained EMS researchers will contribute to the continued growth of the subspecialty.

Primary Barriers: Funding

Improved monetary compensation for EMS research would help motivate researchers to look at EMS issues. Additional training grants would be useful to encourage the development of experts in both EMS research and a number of areas related to emergency medical systems, such as injury prevention, health services research, and operations management. As the number of well-trained researchers increases, a reliable stream of funding will be needed to support their activities. That stream of funding will necessarily come from a variety of sources. Public funds along with corporate and foundation support will all be needed.

A strong argument can be made that the government should fund the majority of the research into the effectiveness of EMS since EMS is largely paid for with taxpayer monies and since there is almost certainly a pay off in terms of improved efficiency and effectiveness of care. Of the 794 papers identified as likely related to EMS published in 1999 and cited on PubMed, only 30 (3.8%) had at least some support from the United States Public Health Service (PHS). Indeed, 1999 was a record year for PHS support of published EMS research (Figure 3).



Other areas of medicine appear to get more governmental research support than EMS. For example, in 1999 there were 5862 articles with a MeSH heading of breast neoplasms; 892 (15.2%) were PHS supported. There were 1468 articles cited in PubMed in 1999 with a MeSH heading of acquired immunodeficiency syndrome. Of those, 209 (14.2%) were at least partially supported by the PHS. There were 3003 articles with a MeSH heading of myocardial infarction, and 230 (7.7%) of them were PHS supported.

Two diseases with a large impact on both the general health of the public and the design of EMS systems are sudden cardiac arrest and major traumatic injuries. In 1999, there were 13,430 articles with a MeSH heading of heart arrest, of which 828 (6.1%) were PHS supported. There were 4776 articles with a MeSH heading of multiple trauma, and only 86 (1.8%) of those were PHS supported. It is clear that the amount of current funding is inadequate to support real progress in reducing the morbidity and mortality from both of these diseases that kill a large number of Americans each year. The NIH has begun to recognize this fact and held the PULSE Conference in June 2000 to explore ways to increase the funding devoted to attacking the problem of sudden cardiac arrest. A similar initiative is needed to increase funding for research on treatment of injury.

Recommendation 3.

Federal agencies that sponsor research should acknowledge their commitment to EMS research.

- The federal government should increase its commitment and support of EMS research.
- A joint announcement, similar to that issued for EMS Research concerning children (PS-01-044), should be issued to provide opportunities for conducting EMS research under the sponsorship of a group of Federal agencies and to broadly describe the areas in which research is warranted. Each sponsoring agency should delineate and prioritize specific areas of interest and provide detailed information regarding application upon request.

- The number of fully federally funded controlled clinical trials conducted in the EMS setting should increase by 25% each year for five years beginning in FY 2003.

EMS researchers must also begin to compete for funding that is not specifically earmarked for prehospital care. Because EMS has the potential to provide services to individuals experiencing almost every disease process, the pool of appropriate funding sources may be quite large.

The federal government should not be the only organization funding EMS research. Charitable foundations often offer unique and flexible funding, some of which should be dedicated to EMS research. State EMS lead agencies traditionally have not performed EMS research, but they should develop a serious commitment to improve patient care based upon evidence generated by high quality research. Ideally, they should collaborate with at least one academic institution with expertise in EMS research. This collaboration will give state regulators, provider agencies, and EMS professionals access to individuals with expertise regarding grant applications and local research related issues. This academic collaborator should also offer guidance to the state lead agency on EMS research policies.

Recommendation 4.

States, corporations, and charitable foundations should be encouraged to support EMS research.

- State lead EMS agencies should promote prehospital research and facilitate the development of relationships and resources necessary for such studies.
- Corporations and charitable foundations should provide funds for EMS related research.

To successfully compete for both public and private funding, whether earmarked for EMS or not, it will be important for the specialty of EMS to develop a cadre of qualified peer reviewers for granting agencies. As more researchers with EMS backgrounds gain experience with major granting agencies, they will be selected as peer reviewers. This will help facilitate EMS research in the long run as these qualified reviewers will be able to educate other members of grant application review committees about the importance of EMS research programs. A full description of the process of peer review is available on the NIH web site at http://www.drg.nih.gov/review/peerrev.htm.

Secondary Barriers: Recognizing the Need for EMS Research

Although it may not be similar in magnitude to the other barriers to EMS research, the lack of appreciation for the importance of EMS research can be detected throughout all aspects of the EMS system. There is a common belief that EMS research is not important as a basis for system evaluation and improvement. This belief is detrimental to efforts to improve the system based on scientific evaluation.

Recommendation 5.

The efforts of EMS professionals, delivery systems, academic centers, and public policy makers should be organized to support and apply the results of research.

- NHTSA should adopt a curriculum for EMS educators that teaches critical review of the scientific literature.
- The National Fire Academy should continue to offer courses that convey the importance of EMS research and detail specific strategies by which fire services can facilitate EMS research.

- Federal agencies should adopt or develop a curriculum for EMS administrative officers that will instill the importance of evidence-based decision-making, reduction of medical errors, and introspection into the culture of EMS organizations.
- Appropriate research principles should be included in the core content of EMS education of first responders, EMT-Basics, EMT-Intermediates, and EMT-Paramedics.
- National and state accrediting agencies for EMS educational programs should require that familiarity with the scientific literature be an essential component of EMS education programs.
- Academic institutions should develop training pathways for EMS professionals interested in pursuing a research career.
- EMS agencies should contribute to the research process by agreeing to collaborate with academic institutions. Collaboration should include assistance with field data collection and patient enrollment in research studies.

The Culture of EMS

The misunderstanding within the EMS community of the importance of research is multi-factorial. EMS professionals often view research as an academic exercise with little applicability to patient care. EMS administrators have difficulty understanding the links between research and system operations. EMS education programs frequently do not emphasize the role of research in shaping EMS practices, perhaps because instructors themselves do not understand the significance of research. The general public and most policy makers have little understanding about the actual services provided by EMS agencies, and thus they are also unlikely to recognize the need for research to improve those services.

An organized effort on the part of EMS professionals, delivery systems, education centers and public policy makers is needed to take advantage of the available EMS research opportunities and to support research endeavors for the benefit of the public. Adoption of a new mindset must be followed by specific actions designed to encourage the integration of research into the framework of EMS. Providers must see practical applications of the concepts gleaned from field research. EMS administrators must support research if the use of evidence based decision making is to become integrated throughout the system. EMS educational programs must show students the need for collecting and analyzing data in order to provide a scientific basis for EMS patient care. Finally, regulatory agencies must encourage collaboration, use of technology for data capture, linkage with outcomes and analysis, and self-evaluation as means to improve EMS systems.

EMS Systems

EMS agencies need to provide appropriate mechanisms for interested individuals to use their research skills. EMS systems must also commit to collaborating with academic centers. Academic collaboration is a crucial link in creating a process that can translate research into improvements in patient care and system efficiency. In essence, society needs the EMS equivalent of the teaching hospital: the teaching EMS system. Unfortunately, there are few, if any, incentives for participating in such an arrangement.

EMS Education

Insufficient academic commitment to EMS research has also been identified as an important impediment to progress in the development of a body of scientific knowledge necessary for the support of EMS practices.[23] Those educational institutions that chose to offer EMS training programs must integrate research into the process of developing entry-level EMS professionals.

Successful integration requires using scientific evidence as the basis for education and fulfilling the traditional academic role of contributing to the evidence base.

The amount of education about research principles currently provided to EMS professionals is limited at best. Education about EMS research is virtually non-existent in most EMT-Basic programs. Although research methodology is part of the National Standard Curriculum for EMT-Paramedics, most EMS educational institutions provide little time for it in their training programs. Some degree granting paramedic education programs do include a research component in their curricula, and a few require students to complete a research project prior to completion of the program.

Educational programs are not teaching research principles because many EMS educators are not knowledgeable about the process of research and therefore are unable to teach others. There are few resources available to assist EMS educators in teaching this material. Two national efforts aimed at improving the research education of prehospital providers are the EMS research workshops offered by National Association of EMS Physicians and the Prehospital Care Research Forum. These entry level one or two day courses are offered at national EMS conferences or by themselves for interested sponsoring organizations.

Education programs for EMS providers must keep pace with the evolving basis for clinical practice. The curricula developed by the U.S. Department of Transportation National Highway Traffic Safety Administration which provide the basis for education of first responders, EMT-Basics, EMT-Intermediates, and EMT-Paramedics should be revised to include improved objectives regarding research principles. These objectives must emphasize the need to teach the importance of research as well as the principles involved in conducting EMS-related research, and should become a part of the routine education of EMS field providers and managers. The objective is not to develop every EMS provider into an EMS researcher but to help all personnel understand the need for research to enable them to be supportive.[23] These educational efforts should provide a working understanding of the research process and not simply encourage memorization of methodological criteria and statistical terminology.

Exposure to the scientific literature should also be an essential component of EMS education programs. The curricula should include an introduction to the critical appraisal of scientific articles and methods for asking and answering clinical questions. The curricula should also introduce the student to the methods that practicing health care professionals use to update their knowledge and practice patterns, including routine reading of scientific journals.

EMS education systems must be compatible with an academically based approach to EMS education that parallels the education process of other allied health professions. These concepts have been addressed in the EMS Education Agenda. Academic institutions that sponsor EMS education programs must make a commitment to supporting EMS research.

The process of teaching a novice EMS professional, including skill and knowledge acquisition and retention, has not been adequately studied. EMS educators in traditional academic settings are uniquely positioned to evaluate both the content of EMS curricula adequacy and the effectiveness of teaching techniques.

The Public and Policy Makers

Public policy makers must also participate in the cultural changes necessary to establish an evidence base for EMS practices. State lead EMS agencies should support statutory changes that encourage evidence based prehospital care. They should promote public health services research

and facilitate the development of relationships and resources necessary for such studies.[23] States need to adopt standardized data collection strategies and use technology to link prehospital patient care information with outcome data.

State lead agencies must move away from a role focused on regulating the processes of delivering care and evolve into agencies providing insightful leadership and technical assistance. One way to accomplish this is by participating in the evaluation of patient and system outcomes. One example of how a regulatory body can evolve is the Joint Commission on Accreditation of Healthcare Organizations. That organization is changing its focus from process regulation to outcomes measurement. These changes are controversial, and they are not easy to implement. However, they ought to lead to significant improvements in patient outcomes.[78]

Finally, as competition for health care dollars increases, individual, corporate, or governmental purchasers of health care services are interested in documentation of the effectiveness of the system and the impact of EMS on public health. The public's knowledge of EMS-related issues, including funding, level of care provided, equipment, system expectations and standards must be increased. These issues should become key factors driving EMS research.

EMS Professionals

Individual providers need to embrace research as the basis for prehospital practices, and at least some of those providers should become active participants in the research process. EMS agencies should encourage and support participation of their employees in these endeavors. A research career track should be developed for those EMS professionals who have the desire to participate in research, and systems can actively work to support researchers by creating research-related positions. Likewise a commitment to supporting the research process should be an integral part of the responsibilities identified in the medical director's job description.

Recommendation 6.

EMS professionals of all levels should hold themselves to higher standards of requiring evidence before implementing new procedures, devices, or drugs.

Secondary Barriers: Information Systems

There are a number of problems in storage and retrieval of information that impede EMS research. These include differing data definitions, inadequate hardware and software infrastructure, database linkages, and statistical implications of large databases.[79]

Recommendation 7.

There should be standardized data collection methods at local, regional, state, and national levels. These data must be devoid of information that allows individual patient identification. All EMS provider agencies should adopt the Uniform Prehospital Data Elements for data collection.

- NHTSA should sponsor a process to revise the Uniform Prehospital Data Elements at least every ten years.
- State lead EMS agencies should require all EMS organizations in their jurisdictions to collect and submit to the state the Uniform Prehospital Data Elements at a minimum, and states should report that information to a national EMS data repository.
- Federal agencies should promote the development and maintenance of a national EMS data repository to facilitate comparison of EMS system designs on the effectiveness of care delivery and improving patient safety.

Data Definitions

An EMS researcher may need to obtain information from a number of different EMS agencies and hospitals. This makes research more difficult because different organizations will often use the same terms in different ways. In technical terms, they are using different data definitions.

An example may help to make this clear. A researcher who is interested in the care of victims of motor vehicle crashes would like to know the total time interval from the occurrence of a crash until the driver arrived at the hospital. This researcher wishes to compare patients in suburban areas with those in rural areas. Since the time of the crash is not recorded automatically, the researcher decides to use the time that the first person called 911 as a surrogate marker for the time of the crash. In one community, the computer aided dispatch system saves the time at which a call begins to ring at the public safety answering point and labels that data point as the "911 call time". In another community, the computer aided dispatch system records the time at which the call is answered by the EMS dispatcher after the call was transferred from an operator at the public safety answering point. That agency also uses the label "911 call time". A researcher who did not know the specific mechanisms for collecting and labeling data used by these two EMS agencies could be easily misled into thinking that both agencies were recording the same event, when in fact these are two distinct time points.

Clinical research activities have been enhanced by efforts to standardize prehospital data acquisition. Standardized templates and definitions for the reporting of prehospital cardiac arrest data have been developed.[80] Similar reporting standards have been developed for pediatric cardiac arrest[81] and trauma data.[82]

There are two major federally sponsored data definitions that describe data points that could be collected on each patient encounter. These are the Uniform Prehospital Data Elements developed by NHTSA[83] and the Data Elements for Emergency Department Systems (DEEDS) developed by the Centers for Disease Control.[84] The development of the Uniform Prehospital Data Elements and Definitions in 1993 was a crucial step to structure evidence about the efficacy of prehospital care.[83] Sadly, few EMS systems have adopted these criteria; and most agencies are still unable to link prehospital data with outcome information. Only 25 states require EMS provider agencies to use most or all of these data elements. The DEEDS document was developed by the Centers for Disease Control to address the same data labeling issues for emergency department encounters.[84] Despite evidence that these data-standardization tools may not be used to their full potential, their existence is encouraging.[85]

Widespread use of both the DEEDS data definitions and the Uniform Prehospital Data Elements would enhance EMS research. The challenge is in convincing EMS agencies to embrace a new system. While administrators may benefit from the ability to advance the quality improvement process and perform system benchmarking, implementation of these systems is costly. At this time, there is not a compelling advantage to using the newer systems for those actually providing care to patients.

Hardware and Software Infrastructure

The computer revolution is happening in medicine. The Health Insurance Portability and Accountability Act of 1996 (HIPAA) will prompt a massive investment in electronic documentation. The regulations implementing HIPAA require additional security measures for medical record information, including medical records held by EMS agencies. Research review is permitted under these regulations, but HIPAA imposes new requirements in addition to existing privacy regulations. See the Code of Federal Regulations 164.514(i) for additional information.

Most EMS agencies and emergency departments still use paper records with multiple copies. Paper records present many problems for researchers. Both the originals and the copies are often illegible. Some of the time points recorded, which may be considered as hard data by researchers, are actually estimates by the caregivers.[86] If a patient is transferred between hospitals, the paper records may not make the trip with the patient.

Electronic medical record systems are being developed for use in emergency medicine and EMS. However, the design of these products will unquestionably affect the quality of the data. If the products are cumbersome to use, then the health care providers operating them may provide incomplete data in order to simply achieve their immediate goal of completing the data entry process.[87] As the process of product development continues, software designers will likely incorporate standardized data definitions like the DEEDS data dictionary and the Uniform Prehospital Data Elements. So, as less documentation is done on paper and more is automated, the use of these established data definitions will increase and the ability of EMS researchers to abstract patient data will be enhanced.

Data Set Linkages

EMS systems should track patient outcomes into the hospital and beyond. One method for obtaining patient outcome data in EMS is to link together large databases that describe different stages of the continuum of patient care. For example, a statewide EMS database might be linked with a financial dataset that describes inpatient hospital charges, and that database may in turn be linked to a death registry. In theory, such linkages allow researchers to follow a patient from the prehospital phase, through hospitalization, and after discharge. In fact, such linkages are challenging to create. The patient's name is often stripped out of datasets to preserve confidentiality and other identifying information, such as the patient's home address, may be missing because those providing care did not have it at the time the records were created. To tackle this problem, enterprising researchers developed a technique called probabilistic matching.[88] The probabilistic system is often able to match 95% or more of records in different databases.[89] EMS investigations have used this technique, including examination of the impact of EMS on children with special needs[90] and linking hospital trauma registry data with prehospital records.[91]

In addition to the technical challenges posed by incomplete data, the best outcome variables may not be recorded in available data sets. Since medical records and database structures are designed independent of specific research questions, key information is often incomplete or simply altogether absent. One temptation is to use the information that is present in the database in an attempt to get as close to the answer as possible. The problem is that this approach can give results that are not meaningful because the most appropriate outcome variables have not been measured.

Another problem is that elements of the health care system may be reluctant to share information. Maintaining patient confidentiality is a major issue. For example, matching a zip code and date of birth in a large database can uniquely identify about 15% of subjects. Some privacy advocates maintain that if a researcher can use a data set to violate the privacy of even one person, then the data should not be collected.

Patient privacy is an important issue in EMS research. Recently the Department of Health and Human Services has developed recommendations to protect against the disclosure of identifiable patient information. The impact of these new privacy regulations on the linking of patient data and its availability for research purposes remains to be seen. These rules may become an additional obstacle to the effective evaluation of prehospital interventions; or they may establish a level of

privacy protection that adequately alleviates concerns among the public, thus facilitating advances in clinical research.

One potential solution to the problem of maintaining patient confidentiality is to assign a longitudinal patient identifier. For example, in the State of Washington, trauma patients are given a bracelet with a unique identifying number that remains with the patient throughout the process of care. That number is kept with the medical record but the patient's name and address is not maintained at the state level, thus preserving confidentiality since the unique number but not patient identifying data moves from the hospital or EMS agency to the state.

Another important regulatory issue that needs to be considered by researchers is a proposed change in the freedom of information law that would allow requests for access to raw research data collected for federally funded research projects. This proposal has several implications. For one, the confidentiality of the study subjects might be compromised. There is also a potential problem with protection of the raw research data from a legal discovery process. If EMS systems and health care providers are going to undertake serious evaluations of their practices in order to improve the care they provide to their patients, they must be assured that the information gathered in that process won't subsequently be used to support litigation against them.[92] One possible solution to this problem would be the availability of a "federal certificate of confidentiality" issued by the Office of Management and Budget.

It is useful to link outside data, like law enforcement records about motor vehicle crashes, to EMS and hospital data. [93] It is also sometimes helpful to link to payment data sets, such as those used in the medical expenditure panel study or the payment databases of health insurance plans. These linkages also raise confidentiality concerns that must be addressed by EMS researchers.

Statistical Implications of Large Databases

Since there are only one or two large datasets of EMS patients in any state, there are important statistical implications. As more questions are asked, it is increasingly likely that a result will be positive based upon chance alone and not a real difference. Since there is not a second dataset with which to validate the results, it becomes impossible to tell which positive results are meaningful and which are statistical flukes. When EMS researchers conduct studies involving large state-based data sets, they will need to validate those studies by repeating them in other states or at a different time.

Secondary Barriers: Ethical Concerns

Principles

Adhering to ethical research principles results in higher quality research, ensures that all individuals are respected, and protects vulnerable people. The ethics of conducting research in the EMS environment are sometimes complicated by time urgency and decreased patient competency.[94] Despite these challenges, EMS related research has to follow the same basic ethical guidelines as any other human subjects research.

The Federal government has assumed the lead role in protecting the rights of human research subjects. The Office of the Inspector General of the Department of Health and Human Services (HHS) recently published a report on the status of protecting the rights of research subject. The Office of Human Research Protections (OHRP) is charged with assuring compliance with ethical guidelines. Grant reviewers, funding agency staff, clinicians, journal editors, and other researchers all share in the responsibility to protect human subjects.

EMS researchers must fulfill all of the requirements for human research delineated at the federal, state, local, and institutional level. Federal regulations have been developed with hospital and outpatient based clinical research in mind. As a result, researchers may often view these requirements as impediments to conducting prehospital research. While burdensome to the researcher, the process of ethical review often will result in an improved research plan because of the structure provided by the process and by suggestions from the reviewers.

Informed Consent

One particular concern expressed by EMS researchers is the requirement to obtain written informed consent. Two ethical principles underlying informed consent are that it is free from coercion and that the prospective research subject has time to contemplate whether or not to participate. It may be, particularly in emergency research where therapy has to be initiated in minutes, that neither principle is true. [95]

In the mid-1990's, the FDA and HHS agreed that there needed to be a method for allowing emergency resuscitation research to occur even when the subject was unable to give consent. Two sets of federal rules were modified within the Department of Health and Human Services regulating obtaining informed consent for medical research. The "General Requirements for Informed Consent" (45 CFR 46.116) are administered by the Office for Human Research Protections (OHRP) and include provisions for the waiver of consent in certain circumstances.

New regulations providing for "Exception from Informed Consent Requirement for Emergency Research" (21 CFR 50.24) were developed for activities regulated by the Food and Drug Administration (FDA).[96] The FDA regulations, CFR 21 Part 50, section 50.24, specify the requirements for exception from informed consent for emergency research. The FDA recently released a draft document providing guidance for implementing the rules.

These regulations have created some confusion among EMS researchers. Their implementation has exposed a fundamental problem associated with conducting research with subjects who cannot provide consent: There is a direct and irrevocable tension between the standards of protecting the rights of research subjects and the ability to investigate and improve the care rendered to future patients.

The current federal regulations on research in emergency situations may have the unintended consequence of ensuring that EMS professionals will continue to provide care that has not been properly evaluated. New interventions to treat critical illness will continue to be introduced into the EMS environment, but difficulty in complying with the requirements of the consent regulations may impede the ability of EMS researchers to ensure that they have been studied appropriately first.

Recommendation 8.

The Food and Drug Administration (FDA) and the Office for Human Research Protections (OHRP) should work with EMS research stakeholders to evaluate the current requirements for exception from informed consent in emergency situations and to identify those requirements that are serious impediments to conducting EMS research. The FDA, OHRP, and EMS research stakeholders should work together to develop and propose EMS-specific consent strategies as well as appropriate revisions to the existing regulations to reduce the impediments to research while continuing to adequately protect research subjects.

- There should be a national conference that brings together a large variety of EMS research stakeholders and regulators to recommend improvements to the emergency exception to informed consent procedures.
- Based on the recommendations of the FDA and OHRP, Congress should amend the laws governing exception from informed consent for emergency research to reduce the regulatory burden and facilitate research while continuing to protect the rights of research subjects.
- There should be educational programs that explain the consent process and recommend strategies by which EMS researchers can fulfill the requirements.
- Educational programs that describe the difficulties in obtaining consent in the EMS environment, explain the emergency exception from consent process, and promote acceptance by and consistency among Institutional Review Board (IRBs) should be made available to IRB members and administrators.

In those circumstances in which waiver of the written consent requirement is not appropriate, other strategies for streamlining the consent process might be possible. The consent form does not necessarily need to be a multi-page document and using a shorter form may facilitate giving information to the patient. Some researchers have had success with a two-step process in which a structured verbal consent is obtained in the field followed by written consent once the patient arrives at the emergency department.[97;98]

It is important to note that some patients, such as those in coma, will never be able to give informed consent. Further, those patients who may be able to give informed consent may still be unduly influenced by the emergent nature of their condition.[95] EMS researchers must work with their IRBs to develop consent mechanisms that account for these issues and protect these patients while not unfairly excluding them from the research process and the potential benefits of those efforts.

Many areas of prehospital care in need of research involve patients who are competent and not in extremis. Obtaining consent from such patients is comparable to obtaining consent from patients in any other clinical setting. One difference is that the process of obtaining consent from an EMS patient may take place in a public environment and therefore those enrolling the patient in research must take steps to protect confidential patient information.

Certain research populations may continue to be underrepresented in research studies due to real or perceived impediments in obtaining informed consent. These excluded groups can include children, domestic violence victims, sexual assault victims, illiterate and non-English speaking patients, elderly people, potentially pregnant women, mentally or behaviorally challenged individuals, and the drug or alcohol impaired. EMS systems care for a disproportionate share of these patients.[99] Investigators and institutional review boards should consider this concern when determining the consent requirements for any study and take steps to avoid the inappropriate exclusion of such subjects. Federal policies on the inclusion of women, minorities and children as research subjects are detailed in appendix D.

IRBs and EMS Research

Some institutional review boards are unfamiliar with the scope of prehospital emergency medical care and thus may have difficulty understanding the issues associated with conducting research in that environment. The prospective EMS investigator needs to become familiar with the local IRB guidelines and process. Through positive interactions with the IRB, a researcher can help

educate the members about EMS issues; and, together, the researcher and the IRB can develop study or consent methodologies that meet the needs of the investigator while fulfilling current legal requirements.

One possible concern that might be raised by an IRB is that study enrollment will delay patient transport. It is incumbent upon the investigator to determine the risks associated with such a delay. For most prehospital patients, those risks are minimal. The researcher may have to overcome preconceptions among IRB members that all patients who call EMS need rapid response and transport.

An IRB might also express concern about altering the existing standard of care for a prehospital study. Yet, little that is considered "standard care" has ever been rigorously evaluated in the prehospital setting. It is considered ethical to alter or remove a non-evidence-based pattern of care in order to evaluate prehospital practices, so long as such studies are designed to minimize the risks to subjects. Two notable examples of this practice are the study of pneumatic anti-shock garments in which the garments, long part of standard care for trauma patients, were removed from ambulances as part of a study evaluating their efficacy [46] and the pediatric intubation study in which children were allocated to receive either bag-valve-mask ventilation or endotracheal intubation.[12]

Concerns about altering standard of care can be addressed, at least in part, through the use of data and safety monitoring boards.[100] Such entities are set up as part of the study design and review the data at predetermined interim periods to assess for any untoward affects of the study. This can be accomplished without breaking the blinding scheme and without giving the researchers any indication of the study results. If it appears that a study is resulting in unacceptable risks to patients, the data and safety monitoring board can stop it. The concept of such boards is not new; their use by EMS researchers is simply one technique that might be successful for addressing IRB concerns.

Valuing Individual Autonomy

Current ethical guidelines, as written, value individual autonomy over other competing values. At the same time, the only way to ensure public and government support for research activities is to ensure the safety of all research subjects. In overcoming the barriers to EMS research posed by ethical constraints, EMS researchers must follow the federal law while at the same time championing rational revision of the regulations. Reaching this goal will require consensus among regulators, researchers, clinicians and the general public.

Sources for complete information about ethical standards and IRB requirements are listed in appendix C of this document.

SUMMARY

The National EMS Research Agenda makes the following recommendations:

1. A large cadre of career EMS investigators should be developed and supported in the initial stages of their careers. Highly structured training programs with content directed toward EMS research methodologies should be developed.
2. Centers of Excellence should be created to facilitate EMS research. These Centers will bring together experienced investigators, institutional expertise and resources such as budgetary and information systems support. Centers will develop and maintain strong working relationships with local and regional EMS providers. As the focal point of these resources, Centers of Excellence will be the catalyst for collaboration between EMS systems and investigators. Such an environment will enable collaborative research to flourish.
3. Federal agencies that sponsor research should acknowledge their commitment to EMS research.
4. States, corporations, and charitable foundations should be encouraged to support EMS research.
5. The efforts of EMS professionals, delivery systems, academic centers, and public policy makers should be organized to support and apply the results of research.
6. EMS professionals of all levels should hold themselves to higher standards of requiring evidence before implementing new procedures, devices, or drugs.
7. There should be standardized data collection methods at local, regional, state, and national levels. These data must be devoid of information that allows individual patient identification. All EMS provider agencies should adopt the Uniform Prehospital Data Elements for data collection.
8. The Food and Drug Administration (FDA) and the Office for Human Research Protections (OHRP) should work with EMS research stakeholders to evaluate the current requirements for exception from informed consent in emergency situations and to identify those requirements that are serious impediments to conducting EMS research. The FDA, OHRP, and EMS research stakeholders should work together to develop and propose EMS-specific consent strategies as well as appropriate revisions to the existing regulations to reduce the impediments to research while continuing to adequately protect research subjects.

An investment in EMS research infrastructure is necessary to overcome the obstacles currently impeding EMS research. Funding is needed to train new researchers and to establish their careers. Increased financial support is necessary to develop effective prehospital treatment for the diseases that drive the design of the EMS system, including injury and sudden cardiac arrest. Innovative strategies to make EMS research easier to accomplish in emergency situations must be legitimized and implemented. Researchers must have access to patient outcome information so that the impact of prehospital patient care can be evaluated and improved. Incorporating standard scientific methodology into the evaluation of biomedical and technical advances in prehospital care is crucial. Research is the key to maintaining an appropriate focus on improving the overall health of

the community in a competitive and cost conscious health care market. Most importantly, research is essential to ensure that the best possible patient care is provided in the prehospital setting.

APPENDIX A: THE NATIONAL EMS RESEARCH AGENDA WRITING TEAM

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	Elinor Walker	Agency for Healthcare Research and Quality

APPENDIX B: ORGANIZATIONS INVITED TO PARTICIPATE IN THE NATIONAL REVIEW TEAM

Organization	Representative	Web Site
Committee on Accreditation of Educational Programs for the EMS Professions (CoAEMSP, formerly the JRCEMT-P)	James M. Atkins, MD	www.coaemsp.org
Prehospital Care Research Forum (PCRF)	Elizabeth Criss, RN, CEN, MAEd	www.pcrf.mednet.ucla.edu
American College of Osteopathic Emergency Physicians (ACOEP)	John W. Becher, DO, FACOEP	www.acoep.org
Health Resources and Services Administration/ Maternal and Child Health Bureau/Emergency Medical Services for Children (HRSA/MCHB/EMSC)	Cindy Doyle, RN, MA	www.mchb.hrsa.gov www.ems-c.org
American College of Surgeons/Committee on Trauma (ACS/COT)	Scott Frame, MD, FACS (dec.)	www.facs.org
National Association of EMS Quality Professionals (NAEMSQP)	Todd Hatley, MBA, MHA, REMT-P	www.naemsqp.org
National Association of EMS Physicians (NAEMSP)	Richard Hunt, MD, FACEP	www.naemsp.org
American College of Emergency Physicians (ACEP)	Alan Katz, MD, FACEP	www.acep.org
National Volunteer Fire Council (NVFC)	Kenneth R. Knipper, EMT-B	www.nvfc.org
American Ambulance Association (AAA)	Kurt Krumperman, EMT-P	www.the-aaa.org
American Academy of Pediatrics (AAP)	Nate Kuppermann, MD, MPH	www.aap.org

American Public Health Association (APHA)	Richard Levinson, MD, DrPH	www.apha.org
National Association of State EMS Directors (NASEMSD)	Kevin McGinnis	www.nasemsd.org
International Association of Fire Fighters (IAFF)	Lori Moore, MPH, EMT-P	www.iaff.org
Society for Academic Emergency Medicine (SAEM)	Robert O'Connor, MD	www.saem.org
Association of Air Medical Services (AAMS)	Jeff Plant, MD, FRCP	www.aams.org
American Academy of Orthopaedic Surgeons (AAOS)	Andrew Pollak, MD, FAAOS	www.aaos.org
Emergency Nurses Association (ENA)	Kathy Robinson, RN	www.ena.org
National Association of EMS Educators (NAEMSE)	Judith A. Ruple, PhD, RN, NREMT-P	www.naemse.org
National Association of EMT's (NAEMT)	Jay Scott, BS, NREMT-P	www.naemt.org
International Association of Fire Chiefs (IAFC)	Chief John Sinclair, EMT-P	www.iafc.org
American Academy of Family Physicians (AAFP)	Jeffrey Susman, MD	www.aafp.org
National Registry of EMT's (NREMT)	Howard Werman, MD	www.nremt.org
Air Medical Physicians Association (AMPA)	Kenneth Williams, MD, FACEP	www.ampa.org
National Council of State EMS Training Coordinators (NCSEMSTC)	Don Wood	www.sni.net/ncsemstc

APPENDIX C: ETHICAL STANDARDS AND IRB REQUIREMENTS

- Complete information about ethical standards and IRB requirements can be found at both the National Academies of Science IRB home page and the U.S. Department of Health and Human Services' (DHHS) Office of Human Research Protections (OHRP) website (http://ohrp.osophs.dhhs.gov/). That website also has links to sites with additional information.
- The Federal Policy for the Protection of Human Subjects (45 CFR 46) is available at http://ohrp.osophs.dhhs.gov/humansubjects/guidance/45cfr46.htm
- Food and Drug Administration Requirements for Human Research, including Requirements for Exemption from Informed Consent for Emergency Research (21 CFR 50) is available here: http://www.access.gpo.gov/nara/cfr/waisidx_00/21cfr50_00.html. The Belmont Report, which was an important basis for the development of ethical research standards in the U.S., can be found at http://ohrp.osophs.dhhs.gov/humansubjects/guidance/belmont.htm. A tutorial on ethical requirements for research that was designed for employees of the NIH but available to anyone is available here: http://ohsr.od.nih.gov/
- The National Association of EMS Physicians website contains information on ethical challenges in emergency medical services at http://www.naemsp.org/sw/Resources/EthicalChlng.html
- Suggested Reading: Mahon NE, Yarcheski A: Ethical concerns in research with adolescents. Journal of Pediatric Nursing 1988; 3(5): 341-344.

APPENDIX D

Inclusion Of Women And Minorities In Research Study Populations Involving Human Subjects

- It is the policy of Federal agencies that women and members of minority groups and their sub-populations must be included in all Federal agency-supported research projects involving human subjects, unless clear and compelling rationale and justification is provided that inclusion is inappropriate with respect to the health of the subjects or the purpose of the research. This policy results from the NIH Revitalization Act of 1993 (Section 492B of Public law 103-43).

- All investigators proposing research involving human subjects should read the "NIH Guidelines on the Inclusion of Women and Minorities as Subjects in Clinical Research" which have been published in the Federal Register of March 28, 1994 (FR 59 14508-14513), and in the NIH Guide for Grants and Contracts, Vol. 23, No. 11, March 18, 1994 available on the web at the following URL address: http://grants.nih.gov/grants/notic-files/not94-100.html. To the extent possible, AHRQ requires adherence to these NIH Guidelines.

Inclusion Of Children As Participants In Research Involving Human Subjects

- It is the policy of NIH that children (i.e., individuals under the age of 21) must be included in all human subjects research, conducted or supported by the NIH, unless there are scientific and ethical reasons not to include them. This policy applies to all initial (Type 1) applications submitted for receipt dates after October 1, 1998.

- All investigators proposing research involving human subjects should read the "NIH Policy and Guidelines on the Inclusion of Children as Participants in Research Involving Human Subjects" that was published in the NIH Guide for Grants and Contracts, March 6, 1998, and is available at the following address: http://grants.nih.gov/grants/guide/notice-files/not98-024.html.

APPENDIX E: BIBLIOGRAPHIC LIST OF INTERNET LINKS

Page	Name	Website	Description of Site Linked
3,4	EMS Agenda for the Future [23]	www.nhtsa.dot.gov/people/injury/ems/agenda/emsman.html	Link to *National Highway Traffic Safety Administration* site and posted copy of the EMS Agenda for the Future.
4	EMS Agenda for the Future Implementation Guide [101]	www.nhtsa.dot.gov/people/injury/ems/agenda/index.html	Link to the *National Highway Traffic Safety Administration* site and posted copy of the EMS Agenda for the Future Implementation Guide.
4	Technology Assessment and Practice Guidelines Forum [102]	odp.od.nih.gov/consensus/about/process.htm	*Guidelines for the Planning and Management of NIH Consensus Development Conferences.* This site provides guidelines for organizing major conferences that produce consensus statements on important and controversial topics in medicine.
5	Research Agenda Home	www.ResearchAgenda.org	Web site with pertinent information relating to the National EMS Research Agenda Project
6	Breaking the Scientific Bottleneck	www.aamc.org/newsroom/clinres	*The Association of American Medical Colleges* Research Statement: Breaking the Scientific Bottleneck. Clinical Research: A National Call to Action
9	Negotiated Rule Making [17]	www.hcfa.gov/medicare/comstate.htm	Document (2-14-2000) regarding Medicare expenditures for ambulance services. *Health Care Financing Administration. Department of Health and Human Services*
12	National Academy of Sciences [24]	www4.nationalacademies.org/nas/nashome.nsf/	Link to *National Academy of Sciences'* web site. For reference to paper entitled *Accidental Death and Disability: The Neglected Disease of Modern Society.*
13	Agency for Healthcare Research and Quality	www.ahrq.gov	Link to *Agency for Healthcare Research and Quality* web site. The AHRQ provides evidence-based information on health care outcomes, quality and cost, use and access.
23	Uniform Prehospital Data Elements and Definitions. [83]	www.nhtsa.dot.gov/people/injury/ems/pub/def.zip	Link to the *National Highway Traffic Safety Administration's* web site and electronic copy of the data elements (criteria written to facilitate standardization of prehospital data).
23	Privacy regulations	aspe.hhs.gov/adminsimp	*Health and Human Services* web site. Privacy rules here: aspe.hhs.gov/admnsimp/bannerps.htm final rule (Federal Register) Dec 28, 2000.
26, 40	EMS Education Agenda For The Future: A Systems Approach [48;54]	www.nhtsa.dot.gov/people/injury/ems/EdAgenda/final/index.html	*National Highway Traffic Safety Administration's* web site and link to the *EMS Education Agenda for the Future* Document
33	Robert Wood Johnson Foundation Clinical Scholars Program	www.rwjf.org/library/clin2000.htm	The Robert Wood Johnson Foundation Homepage. Describes the mission of the RWJ foundation and the direction toward which their philanthropic grant making efforts are aimed.
35	PULSE conference	www.nhlbi.nih.gov/meetings/pulse/index.htm	Proceedings of June 2000conference. "NHLBI Workshop on Post-Resuscitation and Initial Utility in Life Saving Efforts" (PULSE). The goal of the workshop was to provide novel research recommendations in the area of cardiopulmonary resuscitation.

Page	Name	Website	Description of Site Linked
39	Curricula	www.nhtsa.dot.gov/people/injury/ems/nsc.htm	The Curricula developed by *the U.S. Department of Transportation National Highway Traffic Safety Administration*
	First Responders, EMT-Basics, EMT-Intermediates, EMT-Paramedics.	www.nhtsa.dot.gov/people/injury/ems/pub/emtbnsc.pdf	Individual content for each of the EMT levels.
41	Outcomes measurement [78]	www.jcaho.org/perfmeas/nextevol.html	Facts about ORYX: The Next Evolution in Accreditation. In February 1997, the Joint Commission announced the health care organization requirements for the ORYX initiative, which integrates outcomes and other performance measurement data into the accreditation process.
43	Prehospital Uniform Data Elements	www.nhtsa.dot.gov/people/injury/ems/pub/def.zip	Link to the *National Highway Traffic Safety Administration's* web site and electronic copy of the Prehospital uniform data elements (criteria written to facilitate standardization of prehospital data).
43	DEEDS [84]	www.cdc.gov/ncipc/pub-res/deedspage.htm	Data Elements for Emergency Department Systems.
41	The NIH web site	www.drg.nih.gov/review/peerrev.htm	Link to *NIH* Web Site and discussion of the peer review process used to evaluate grant proposals. "A Straightforward Description of What Happens to Your Research Project Grant Application (R01/R21) After it is Received for Peer Review"
43	Regulations implementing CFR 164.514(i)	www.hhs.gov/ocr/hipaa	HIPAA will require additional security of medical record information including medical records held by EMS agencies.
		www.hhs.gov/ocr/regtext.html	Research review is permitted under these regulations, but additional requirements are added to previously existing regulations. See CFR 164.514(i)
48	Belmont Report	www.dhhs.gov/progorg/oei/reports/a447.pdf	Text of the report "Protecting the Rights of Research Subjects"
	Office of Human Research Protections	ohrp.osophs.dhhs.gov	Link to the Department of Health and Human Services home page.
49	CFR 21 Part 50, section 50.24	www.fda.gov/opacom/morechoices/fed996.html	Section of the Federal Register document containing the legislation concerning the process required for exception from informed consent for emergency research.
	Exception to informed consent implementation guide draft document	www.fda.gov/ora/compliance_ref/bimo/err_guide.htm	Draft document released by the FDA

APPENDIX F: PUBLISHED EMS RANDOMIZED CLINICAL TRIALS

The following table is a listing of major randomized or pseudo-randomized clinical trials completed in the prehospital setting. It is a modification of a table by Brazier et al.,[59] that is available on the Internet at http://www.rcsi.ie/library/prehospital_care.html.

Trial	Patients	Setting	N	Intervention	Main Result
Valentine 1974 [36]	Adults younger than 70 with high suspicion for acute myocardial infarction	Multicenter, Australia	269	Physician intramuscular injection of (a) lidocaine or (b) placebo	During first two hours after injection, 5% absolute reduction in mortality ($p<0.04$)
Hampton 1978 [37]	Adult patients without motor-vehicle trauma	Nottingham, England	3340	(a) Transport by mobile coronary care unit or (b) routine transport	2% absolute reduction in mortality from heart attacks (NS)
Diederich 1979 [38]	Acute myocardial infarction patients younger than 70	Lubeck, Germany		Intramuscular injection of (a) lidocaine or (b) placebo	Mortality lower in lidocaine group.
Mahoney 1983 [103]	Cardiac arrest patients older than 20	Minneapolis, Minnesota, USA	136	(a) Pneumatic antishock garments or (b) usual care	Survival to hospital discharge was 9% in (a) and 4% in (b) (NS).
Mateer 1984 [104]	Cardiac arrest patients	Milwaukee, Wisconsin, USA	140	After endotracheal intubation either (a) interposed abdominal compression CPR (IAC-CPR) or (b) standard CPR is begun	4% absolute increase in patients admitted to ED with a pulse (NS)
Olson 1984 [105]	Ventricular fibrillation persisting after initial shocks	Milwaukee, Wisconsin, USA	92	(a) Bretylium and then, if VF persists, lidocaine or (b) lidocaine and then, if VF persists, bretylium	Survival to hospital discharge was 5% in bretylium first group vs 10% in lidocaine first group (NS)
Paris 1984 [106]	Cardiac arrest patients with pulseless idioventricular rhythm	Pittsburgh, Pennsylvania, USA	86	(a) Dexamethasone 100 mg or (b) saline placebo	No long term survivors in either group
Stueven 1984 [107]	Witnessed non-traumatic adult cardiac arrest patients with asystole and not responding to epinephrine, bicarbonate, or atropine	Milwaukee, Wisconsin, USA	32	(a) Calcium chloride or (b) saline placebo	No long term survivors in either group
Bickell 1985 [108]	Injured patients with hypotension	Houston, Texas, USA	68	(a) Pneumatic antishock garments or (b) usual care	No difference in presenting emergency department trauma score

Trial	Patients	Setting	N	Intervention	Main Result
Mateer 1985 [109]	Same as Mateer 1984 [104]	Milwaukee, Wisconsin, USA	291	After endotracheal intubation either (a) interposed abdominal compression CPR (IAC-CPR) or (b) standard CPR is begun	3% absolute decrease in patients admitted to ED with a pulse (NS)
Silfvast 1985 [110]	Patients with cardiac arrest	Helsinki, Finland	65	(a) Phenylephrine 1 mg or (b) epinephrine 0.5 mg intravenously	3% absolute increase in patients with "successful" resuscitation (NS)
Stueven 1985a [111]	Cardiac arrest patients with asystole as in Stueven 1984 [107]	Milwaukee, Wisconsin, USA	73	(a) Calcium chloride or (b) saline placebo	No long term survivors in either group
Stueven 1985b [112]	Cardiac arrest patients with electromechanical dissociation who did not respond to epinephrine and bicarbonate	Milwaukee, Wisconsin, USA	90	(a) Calcium chloride or (b) saline placebo	16% of patients receiving calcium were admitted to the emergency department with a pulse vs 5% of controls. Only one patient was a long term survivor.
Goldenberg 1986 [113]	Cardiac arrest patients	St. Paul, Minnesota, USA	175	Airway managed with either (a) esophageal gastric tube airway (EGTA) or (b) endotracheal intubation (ETI)	Training in use of EGTA cost less than ETI. Survival to hospital discharge 12.9% vs 11.1%.
Hargarten 1986 [114]	Stable patients with chest pain	Milwaukee, Wisconsin, USA	446	(a) Lidocaine or (b) usual care	1.4% absolute decrease in hospital mortality (NS). Four patients with sudden death in each group (NS).
Mattox 1986 [115]	Injured patients with systolic BP < 90mm Hg	Houston, Texas, USA	352	(a) Pneumatic antishock garments or (b) usual care	No difference in mortality (NS).
Baxt 1987 [116]	Trauma patients requiring resuscitation transported by helicopter	San Diego, California, USA	545	Helicopter staffed by (a) flight nurse and paramedic or (b) flight nurse and physician	Mortality of patients treated by flight nurse / physician team was lower than that of patients treated by flight nurse / paramedic ($p<0.05$), and lower than predicted by TRISS ($p<0.05$)
Bickell 1987 [117]	Victims of gunshot or stab wounds to anterior abdomen with a systolic BP <90mm Hg	Houston, Texas, USA	201	(a) Pneumatic antishock garments or (b) usual care	8.8% absolute **increase** in mortality at hospital discharge (NS)
Castaigne 1987 [118]	Patients seen within three hours of symptoms suggesting AMI who had a qualifying ECG	Val de Marne, France	25	Administration by non-cardiologist staffed mobile care unit of (a) anisoylated plasminogen streptokinase activator complex (APSAC) or (b) placebo	Thrombolytic drug treatment started 56 minutes sooner after onset of pain in mobile care unit group than in control group.

Trial	Patients	Setting	N	Intervention	Main Result
Cummins 1987 [119]	Patients in cardiac arrest	Seattle, Washington, USA	321	Use by EMT of (a) automated external defibrillator (AED) or (b) standard defibrillator	7% absolute reduction in mortality at hospital discharge (NS). Time from power on to first shock 0.9 minutes faster in AED group.
Hedges 1987 [120]	Patients in asystole or with hemodynamically significant bradycardia	Thurston County, Washington, USA	202	(a) Prehospital transcutaneous cardiac pacing or (b) usual care	1.9% absolute reduction in mortality at hospital discharge (NS)
Hoffman 1987 [121]	Patients whose chief complaint was dyspnea and who had a presumed diagnosis of cardiogenic pulmonary edema	Los Angeles County, USA	57	Administration by paramedic of (a) sl nitroglycerin and iv furosemide, or (b) iv morphine and furosemide, or (c) all three, or (d) iv morphine and sl nitroglycerin	No difference at hospital discharge.
Barthell 1988 [122]	Patients in asystole or with hemodynamically significant bradycardia	Milwaukee, Wisconsin, USA	239	(a) External cardiac pacing device or (b) usual care	2.4% absolute reduction in mortality at hospital discharge (NS)
DuBoise-Rande 1989 [123] Castaigne 1989 [124]	Patients seen within three hours of symptoms who had a qualifying ECG	Val de Marne, France	93	(a) Administration of APSAC by anaesthesiologist staffed mobile care unit or (b) inhospital treatment	0.3% (NS) reduction in mortality in the prehospital group at hospital discharge.
Krischer 1989 [125]	Adults with non-traumatic out of hospital cardiac arrest	Florida, USA	702	(a) Simultaneous compression-ventilation (SC-V) CPR or (b) standard CPR	6.8% increase in mortality ($p<0.01$) at hospital discharge
Mattox 1989 [46]	Injured patients with systolic BP < 90mm Hg	Houston, Texas, USA	911	(a) Pneumatic antishock garment or (b) usual care	6% absolute **increase** in mortality at hospital discharge ($p=0.05$)
Olson 1989 [126]	Pulseless, nonbreathing patients with initial cardiac rhythm of ventricular fibrillation	Milwaukee, USA	102	Administration by paramedic of repeated iv doses of (a) epinephrine or (b) methoxamine	11.8% (NS) at hospital discharge
Barbash 1990 [127]	AMI patients seen within four hours of symptoms who had a qualifying ECG and confirmed for inclusion by remote physician	Israel	87	(a) Administration of recombinant tissue-type plasminogen activator (rt-PA) by physician and paramedic staffed mobile coronary care unit or (b) inhospital treatment	4.5% (NS) reduction in mortality in (a) at 60 days.

Trial	Patients	Setting	N	Intervention	Main Result
Hargarten 1990 [128]	Patients seen with symptoms suggestive of AMI and confirmed for inclusion by remote physician after ECG review	Milwaukee, USA	1,427	Administration by paramedic of (a) iv lidocaine bolus and infusion or (b) placebo	1.5% increase in mortality (NS) at hospital discharge
Karagounis 1990 [129]	Patients clinically suspected of having an AMI	Salt Lake City, Utah, USA	71	(a) Prehospital cellular transmission of 12-lead ECG or (b) no prehospital ECG	In-field ECG caused negligible delays in on-scene and transport time
Roine 1990 [130]	Patients resuscitated from ventricular fibrillation	Helsinki, Finland	155	(a) Initiation of IV nimodipine 10 mcg/kg with 24 hour infusion or (b) placebo by physician staffed advance life support unit	4% reduction in mortality at one year in nimodipine group (NS)
Schofer 1990 [131] Mathey 1990 [132]	AMI patients seen within four hours of symptoms who had a qualifying ECG	Hamburg, Germany	78	(a) Administration of iv urokinase by physician and emergency medical technician staffed mobile coronary care unit or (b) inhospital treatment	2.8% (NS) reduction in mortality in (a) at hospital discharge.
Mattox 1991 [133]	Trauma patients with systolic BP <90mm Hg	Multicenter, USA	359	Administration of (a) 7.5% NaCl with 6% Dextran or (b) lactated Ringers	Absolute reduction in mortality of 3.3% (NS); 7.5% NaCl/Dextran significantly increased BP ($p<0.05$)
Risenfors 1991 [134]	AMI patients seen within 2.75 hours of symptoms	Göteborg, Sweden	101	Administration by cardiologist staffed mobile coronary care unit of (a) rt-PA or (b) placebo	8.7% (NS) reduction in mortality in (a) at hospital discharge
Vassar 1991 [135]	Trauma patients transported by helicopter with systolic BP <100mm Hg	Sacramento California, USA	166	Administration of (a) 7.5% NaCl with 4.2% Dextran or (b) lactated Ringers	Absolute reduction in mortality of 4.8% (NS); 7.5% NaCl/Dextran significantly increased BP ($p<0.05$)
Berntsen 1992 [136]	Patients seen within six hours of symptoms suggestive of AMI	Norway	204	Administration by general practitioner of (a) IV bolus and IM injection of lidocaine or (b) placebo	4.8% (NS) at hospital discharge; 0.9% (NS) absolute reduction in ventricular fibrillation
Brown 1992 [137]	Adult cardiac arrest patients	Multicenter, USA	1280	Administration by paramedic of (a) high dose epinephrine or (b) standard dose epinephrine	1% absolute reduction in mortality at hospital discharge (NS).

Trial	Patients	Setting	N	Intervention	Main Result
Callaham 1992 [138]	Nontraumatic cardiac arrest patients	San Francisco, USA	816	Administration by paramedic of (a) high dose epinephrine or (b) high dose epinephrine bitartrate or (c) standard dose epinephrine	No difference at hospital discharge
GREAT Group 1992 [139]	Patients with acute myocardial infarction seen at home by general practioners within 4 hours of symptom onset	Grampian region, Scotland	311	(a) APSAC 30 units at home and placebo in hospital or (b) placebo at home and APSAC 30 units in hospital	7.6% absolute reduction in 3 month mortality for group with thrombolysis started at home (95% confidence interval 14.7% to 0.4%).
Kereiakes 1992 [140]	Patients with AMI confirmed by serial ECGs and enzyme analysis	Cincinnati, Ohio, USA	22	(a) Prehospital cellular transmission of 12-lead ECG or (b) no prehospital ECG	Significant reduction in hospital delay to initiation of thrombolytic therapy ($p<0.005$)
Karpov 1992 [141]	Patients with suspected AMI	Russia	200	(a) Prehospital administration of iv streptokinase and heparin by cardiologist or (b) inhospital administration or (c) usual care	6% (NS) reduction in mortality for (a) vs. (b) at 30 days; 10% ($p<0.05$) for (a) vs. (c) at 30 days
McAleer 1992 [142]	AMI patients seen within six hours of symptoms who had a qualifying ECG	Enniskillen, Northern Ireland	145	(a) Administration of iv streptokinase by physician staffed mobile coronary care unit or (b) inhospital treatment	21.5% ($p<0.05$) reduction in mortality in (a) at two years
Stiell 1992 [143]	Patients with cardiac arrest	Ottawa, Ontario, Canada	335	Administration of (a) high-dose epinephrine or (b) standard dose epinephrine	2% absolute increase in mortality at hospital discharge (NS)
Bertini 1993 [144]	Patients seen within six hours of symptoms suggestive of AMI who had a qualifying ECG	Florence, Italy	60	Administration by cardiologist and paramedic staffed mobile coronary care unit of (a) lidocaine bolus and infusion or (b) placebo	4.1% (NS) at hospital discharge; 15.2% ($p<0.05$) absolute reduction in ventricular fibrillation
EMIP Group 1993 [145] Boissel 1995 [146]	Patients seen within six hours of symptoms who had a qualifying ECG	Europe and Canada	5,469	Administration by emergency medical personnel of (a) iv anistreplase or (b) placebo	1.4% (NS) reduction in mortality in (a) at 30 days
Longstreth 1993 [147]	Cardiac arrest patients	Seattle, Washington, USA	748	Administration of intravenous maintenance solutions containing either (a) 5% dextrose in water (D5W) or (b) half normal saline	1.8% reduction in mortality in the D5W group at hospital discharge (NS)

Trial	Patients	Setting	N	Intervention	Main Result
Vassar 1993 [148]	Trauma patients transported by helicopter, with systolic BP <90 mm Hg	Multicenter, USA	194	Administration of (a) lactated Ringers or (b) 7.5% NaCl or (c) 7.5% NaCl with 6% Dextran or (d) 7.5%NaCl with 12% Dextran	Mortality in the 7.5% NaCl group was significantly lower than predicted by TRISS ($p<0.001$); adding Dextran made no difference.
Vassar 1993 [149]	Trauma patients with systolic BP <90 mm Hg	Sacramento California, USA	258	Administration of (a) normal saline or (b) 7.5% NaCl or (c) 7.5% NaCl with 6% Dextran	Mortality in the 7.5% NaCl group was significantly lower than predicted by TRISS ($p<0.025$); adding Dextran made no difference.
Weaver 1993 [150]	Patients seen within six hours of symptoms who had a qualifying ECG and confirmed for inclusion by remote physician	Seattle, Washington, USA	360	(a) Administration of aspirin and alteplase by paramedic or (b) inhospital treatment	2.4% (NS) reduction in mortality in (a) at 30 days
Bickell 1994 [151]	Adults with penetrating torso injuries and systolic BP < 90mm Hg	Houston, Texas, USA	598	(a) Immediate fluid resuscitation in field or (b) delayed fluid resuscitation in operating suite	8% absolute reduction in mortality at hospital discharge for the group receiving delayed fluid resuscitation (OR 0.70, 95% confidence interval 0.50 – 0.99, P = 0.04)
Ellinger 1994 [152]	Patients in cardiac arrest	Mannheim, Germany	56	(a) Active compression decompression CPR (ACD-CPR) or (b) standard CPR	1.8% increase in mortality in ACD-CPR group at hospital discharge (NS).
EMIP-BB Group 1994 [153]	Patients seen within two hours of symptoms suggestive of AMI who had a qualifying ECG	Lyon, France	77	Administration by emergency medical personnel of (a) IV atenolol or (b) placebo	0.7% difference in mortality at hospital discharge (NS)
Rhee 1994 [154]	Injured adults with GCS <8 transported by helicopter	Sacramento, California, USA	77	Performance by flight nurses of (a) nasotracheal intubation or (b) neuromuscular blockade-assisted oral intubation	No difference in success rate; nasotracheal intubation required significantly less time to perform ($p<0.01$)
Staudinger 1994 [155]	Out of hospital cardiac arrests	Valparaiso, USA	80	Intubation with (a) 'Combitube' combined endotracheal and esophageal obturator airway adjunct or (b) standard endotracheal tube	0.5% absolute reduction in mortality at hospital discharge (NS)

Trial	Patients	Setting	N	Intervention	Main Result
Choux 1995 [156]	Prehospital cardiac arrest patients	Paris, France	536	(a) High-dose epinephrine or (b) standard dose epinephrine	3.6% increase in admission to hospital in (a) and 3.7% increase in survival at 6 months in (a) (NS).
Dybvik 1995 [157] Dybvik 1996 [158]	Adult cardiac arrest patients with asystole or ventricular fibrillation persisting after one shock	Oslo, Norway	502	(a) 250 ml of sodium bicarbonate-trometamol-phosphate mixture with buffering capacity 500 mmol/l or (b) 250 ml of 0.9% saline	4% **decrease** in survival to hospital discharge in buffer therapy group (NS).
Quadrel 1995 [159]	Known adult asthmatics with wheeze	New Jersey, USA	154	Administration by paramedic of (a) sc epinephrine, or (b) nebulized metaproterenol or (c) sc epinephrine and nebulized metaproterenol	Nebulized metaproterenol is as effective as sc epinephrine; the combination of the two drugs offered no additional benefit
Schwab 1995 [160]	Normothermic adult victims of out-of- hospital, nontraumatic cardiac arrest on whom CPR was performed by first responders	San Francisco and Fresno, California, USA	860	First responders did either (a) active compression-decompression CPR (ACD-CPR) or (b) standard CPR	1% decrease in survival to hospital discharge in ACD-CPR group (NS).
Weiss 1995 [161]	Patients transported by paramedical ambulance service	New Orleans, Louisiana, USA	182	(a) Tympanic membrane thermometry or (b) usual care	Acceptable correlation with gold standard
Zehner 1995 [98]	Adults with respiratory distress	Syracuse, New York, USA	83	Paramedics administered either (a) albuterol aerosol and saline injection or (b) saline aerosol and terbutaline injection	Albuterol group had greater improvement in respiratory distress score by hospital arrival.
Brouwer 1996 [162]	As in Weaver [150]	Seattle, USA	360	As in Weaver [150]	2% increase in mortality (NS) at two years.
Luiz 1996 [163]	Out of hospital cardiac arrests	Mannheim, Germany	56	(a) Active compression-decompression (ACD) or (b) standard CPR	1.8% increase in mortality (NS) at hospital discharge
Mauer D 1996 [164]	Out of hospital cardiac arrest patients	Mainz, Germany	220	(a) Active compression-decompression CPR (ACD-CPR) or (b) standard CPR	2% decrease in mortality (NS) at hospital discharge
Sayre 1996 [165]	Helicopter transported and intubated patients with a head injury	Cincinnati, Ohio, USA	41	Administration by emergency physician of (a) iv 20% mannitol or (b) 0.9% saline	No change in systolic BP over a 2-hour period
Stiell 1996 [166]	Out of hospital cardiac arrests	Ontario, Canada	1,011	(a) ACD or (b) standard CPR	1.7% (NS) absolute reduction in mortality in (a) at 1 hour; 0.9% (NS) at hospital discharge

Trial	Patients	Setting	N	Intervention	Main Result
Lindner 1997 [167]	Cardiac arrest patients in ventricular fibrillation unresponsive to defibrillation	Ulm, Germany	40	(a) epinephrine or (b) vasopressin	At 24 hours, 40% absolute reduction in mortality (P < 0.02); at hospital discharge, 25% absolute reduction in mortality (NS).
Mader 1997 [168]	Nontraumatic, asystolic cardiac arrest patients	Springfield, Massachusetts, USA	22	(a) aminophylline or (b) placebo	Half of aminophylline patients had organized rhythm compared with none of the placebo patients (P=0.02).
Plaisance 1997 [169]	Out of hospital cardiac arrests confirmed by ECG	France	512	(a) ACD or (b) standard CPR	12.4% (p<0.005) absolute reduction in mortality (a) at 24 hours; 3.2% (NS) at 1 month
Rosen 1997 [170]	Male combative patients	Denver, Colorado, USA	46	Administration by paramedics of (a) IV droperidol or (b) placebo	Patients significantly less agitated (p<0.001) after 10 minutes
Rumball 1997 [171]	Patients requiring advanced airway management	Canada	470	Three different airway management techniques – pharyngeal tracheal lumen airway (PTL); combitube (Combi), and laryngeal mask airway (LMA)	Successful insertion and ventilation: Combi, 86%; PTL, 82%; LMA, 73% (p = 0.048)
Gueugniaud 1998 [172]	Adult cardiac arrest patients	Multicenter, Europe	3327	(a) High dose epinephrine or (b) standard dose epinephrine	0.5% absolute increase in mortality at hospital discharge (NS).
Gardtman 1999 [173]	Suspected acute myocardial infarction patients with ongoing chest pain	Göteborg, Sweden	262	Morphine 5 mg IV followed by (a) metoprolol 5 mg IV x 3 with 2 minute intervals or (b) placebo IV x 3	Arbitrary 10 point chest pain score decreased by 3 units in (a) and 2.6 units in (b) (NS).
Kudenchuk 1999 [174]	Cardiac arrest patients with ventricular fibrillation not responding to three shocks	Seattle, Washington, USA	504	(a) IV amiodarone or (b) placebo	10% absolute decrease in mortality at hospital admission (P=0.03); no difference at hospital discharge (NS).
Mader 1999 [175]	Nontraumatic, asystolic cardiac arrest	Springfield, Massachusetts, USA	82	(a) aminophylline or (b) placebo	7% increase in return of spontaneous circulation (NS).
Plaisance 1999 [77]	Cardiac arrest patients	Paris and Thionville, France	750	(a) ACD-CPR or (b) standard CPR	4% absolute decrease in mortality at hospital discharge (P=0.01) and 3% absolute decrease in mortality at one year (P=0.03).
Skogvoll 1999 [176]	Cardiac arrest patients of presumed cardiac origin	Trondheim, Norway	302	(a) ACD-CPR or (b) standard CPR	1% absolute decrease in mortality at hospital discharge (NS).

Trial	Patients	Setting	N	Intervention	Main Result
Gausche 2000 [12]	Pediatric patients ≤ 12 years of age or 40 kg bodyweight requiring prehospital airway management	Los Angeles and Orange Counties, California, USA	830	Scope of paramedic practice alternates between (a) bag-mask ventilation with endotracheal intubation (ETI) or (b) bag-mask ventilation alone	Absolute mortality in ETI group was 4% higher than bag-mask ventilation alone group (NS).
Plaisance 2000 [177]	Nontraumatic cardiac arrest patients	Paris, France	21	(a) ACD-CPR with an impedance threshold valve or (b) ACD-CPR	Maximal end-tidal CO_2, coronary perfusion pressure, and diastolic blood pressure were all higher in group (a) ($P<0.01$).
Schneider 2000 [178]	Ventricular fibrillation patients with an AED used	Multicenter, Europe	115	(a) AED using 150 j biphasic waveform or (b) 200 j to 260 j monophasic waveform	98% defibrillated in first three shocks using biphasic waveform vs 69% using monophasic waveform ($P<0.0001$).
Turner 2000 [179]	Adult trauma patients	Multicenter, England	1309	(a) IV fluids started at scene or (b) no prehospital IV fluids	Absolute mortality was 0.4% lower in the group not getting prehospital IV fluids (NS).

REFERENCE LIST

1. Murphy S. National Center for Health Statistics, Centers for Disease Control and Prevention, editors: *Deaths: Final Data for 1998*. Public Health Service 2000. Volume 48, Number 11 :1-106. http://www.cdc.gov/nchs/releases/00news/finaldeath98.htm.

2. Eisenberg MS, Bergner L, Hallstrom A. Out-of-hospital cardiac arrest: improved survival with paramedic services. *Lancet* 1980; 1(8172):812-815.

3. Becker LB, Smith DW, Rhodes KV. Incidence of cardiac arrest: a neglected factor in evaluating survival rates. *Ann Emerg Med* 1993; 22(1):86-91.

4. Young KD, Seidel JS. Pediatric cardiopulmonary resuscitation: a collective review [see comments]. *Ann Emerg Med* 1999; 33(2):195-205.

5. Mullins RJ, Mann NC. Population-based research assessing the effectiveness of trauma systems [see comments]. *J Trauma* 1999; 47(3 Suppl):S59-S66.

6. Alonso-Serra H, Blanton D, O'Connor RE. Physician medical direction in EMS. National Association of EMS Physicians. *Prehosp Emerg Care* 1998; 2(2):153-157.

7. Weaver WD, Hill D, Fahrenbruch CE, Copass MK, Martin JS, Cobb LA et al. Use of the automatic external defibrillator in the management of out-of- hospital cardiac arrest. *N Engl J Med* 1988; 319(11):661-666.

8. Wuerz RC, Meador SA. Effects of prehospital medications on mortality and length of stay in congestive heart failure. *Ann Emerg Med* 1992; 21(6):669-674.

9. Bertini G, Giglioli C, Biggeri A, Margheri M, Simonetti I, Sica ML et al. Intravenous nitrates in the prehospital management of acute pulmonary edema [see comments]. *Ann Emerg Med* 1997; 30(4):493-499.

10. Morrison LJ, Verbeek PR, McDonald AC, Sawadsky BV, Cook DJ. Mortality and prehospital thrombolysis for acute myocardial infarction: A meta-analysis. *JAMA* 2000; 283(20):2686-2692.

11. O'Connor RE, Domeier RM. An evaluation of the pneumatic anti-shock garment (PASG) in various clinical settings [see comments]. *Prehosp Emerg Care* 1997; 1(1):36-44.

12. Gausche M, Lewis RJ, Stratton SJ, Haynes BE, Gunter CS, Goodrich SM et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial [see comments] [published erratum appears in JAMA 2000 Jun 28;283(24):3204]. *JAMA* 2000; 283(6):783-790.

13. Olsen JC, Johnson BC, Brown AM, Levinson SR. Patient perceptions of the specialty of emergency medicine. *Am J Emerg Med* 2000; 18(3):278-281.

14. Diem SJ, Lantos JD, Tulsky JA. Cardiopulmonary resuscitation on television. Miracles and misinformation [see comments]. *N Engl J Med* 1996; 334(24):1578-1582.

15. Ho J, Casey B. Time saved with use of emergency warning lights and sirens during response to requests for emergency medical aid in an urban environment. *Ann Emerg Med* 1998; 32(5):585-588.

16. Brown LH, Whitney CL, Hunt RC, Addario M, Hogue T. Do warning lights and sirens reduce ambulance response times? *Prehosp Emerg Care* 2000; 4(1):70-74.

17. Health Care Financing Administration. Negotiated Rulemaking Committee on Medicare Ambulance Fee Schedule. http://www hcfa gov/medicare/comstate.htm 2000.

18. Bergner L, Eisenberg M, Hallstrom A. Evaluating emergency medical services: Quasi-experimental outcome studies. *Eval Health Prof* 1979; 2(1):3-19.

19. Stiell IG, Wells GA, Spaite DW, Lyver MB, Munkley DP, Field BJ et al. The Ontario Prehospital Advanced Life Support (OPALS) Study: rationale and methodology for cardiac arrest patients [see comments]. *Ann Emerg Med* 1998; 32(2):180-190.

20. Stiell IG, Wells GA, Field BJ, Spaite DW, De Maio VJ, Ward R et al. Improved out-of-hospital cardiac arrest survival through the inexpensive optimization of an existing defibrillation program: OPALS study phase II. Ontario Prehospital Advanced Life Support [see comments]. *JAMA* 1999; 281(13):1175-1181.

21. Callaham M. Quantifying the scanty science of prehospital emergency care [comment] [see comments]. *Ann Emerg Med* 1997; 30(6):785-790.

22. Cornwell EE, III, Belzberg H, Hennigan K, Maxson C, Montoya G, Rosenbluth A et al. Emergency medical services (EMS) vs non-EMS transport of critically injured patients: a prospective evaluation. *Arch Surg* 2000; 135(3):315-319.

23. Delbridge TR, Bailey B, Chew JL, Jr., Conn AK, Krakeel JJ, Manz D et al. EMS agenda for the future: where we are ... where we want to be. EMS Agenda for the Future Steering Committee. *Ann Emerg Med* 1998; 31(2):251-263.

24. Accidental Death and Disability: The Neglected Disease of Modern Society. *National Academy of Sciences, National Research Council* 1966.

25. Pantridge JF, Geddes JS. A mobile intensive-care unit in the management of myocardial infarction. *Lancet* 1967; 2(7510):271-273.

26. Nagel EL, Hirschman JC, Mayer PW, Dennis F. Telemetry of physiologic data: an aid to fire-rescue personnel in a metropolitan area. *South Med J* 1968; 61(6):598-601.

27. Baum RS, Alvarez H, III, Cobb LA. Survival after resuscitation from out-of-hospital ventricular fibrillation. *Circulation* 1974; 50(6):1231-1235.

28. Jane S. Durch and Kathleen N. Lohr, editors: *Emergency Medical Services for Children: Summary.* National Academy Press 1993. www.ems-c.org.

29. Seidel JS, Henderson D, Tittle S, Jaffe DM, Spaite D, Dean JM et al. Priorities for research in emergency medical services for children: results of a consensus conference [see comments]. *Ann Emerg Med* 1999; 33(2):206-210.

30. Ambulances and the injured. *Br Med J* 1966; 5489:691-692.

31. Hazards of ambulance journeys. *Br Med J* 1967; 4(516):373-374.

32. Ambulance service in New York City. Report by the Committee on Public Health; the New York Academy of Medicine. *Bull N Y Acad Med* 1967; 43(4):336-345.

33. Community-wide emergency medical services. Recommendations by the Committee on Acute Medicine of the American Society of Anesthesiologists. *JAMA* 1968; 204(7):595-602.

34. Resuscitation and survival in motor vehicle accidents. *J Trauma* 1969; 9(4):356.

35. Gibler WB, Kereiakes DJ, Dean EN, Martin L, Anderson L, Abbottsmith CW et al. Prehospital diagnosis and treatment of acute myocardial infarction: a north-south perspective. The Cincinnati Heart Project and the Nashville Prehospital TPA Trial. *Am Heart J* 1991; 121(1 Pt 1):1-11.

36. Valentine PA, Frew JL, Mashford ML, Sloman JG. Lidocaine in the prevention of sudden death in the pre-hospital phase of acute infarction. A double-blind study. *N Engl J Med* 1974; 291(25):1327-1331.

37. Hampton JR, Nicholas C. Randomised trial of a mobile coronary care unit for emergency calls. *Br Med J* 1978; 1(6120):1118-1121.

38. Diederich KW, Fassl H, Djonlagic H, Oltmanns D, Floor-Wieringa A. [Lidocaine prophylaxis in the pre-hospital phase of acute myocardial infarction (author's transl)]. *Dtsch Med Wochenschr* 1979; 104(28):1006-1008.

39. Rose LB, Press E. Cardiac defibrillation by ambulance attendants. *JAMA* 1972; 219(1):63-68.

40. Kaplan BC, Civetta JM, Nagel EL, Nussenfeld SR, Hirschman JC. The military anti-shock trouser in civilian pre-hospital emergency care. *J Trauma* 1973; 13(10):843-848.

41. Diamond NJ, Schofferman J, Elliott JW. Factors in successful resuscitation by paramedics. *JACEP* 1977; 6(2):42-46.

42. Stewart RD. Advances in prehospital immediate care. *Resuscitation* 1989; 18 Suppl:S13-S20.

43. Civetta JM, Nussenfeld SR, Rowe TR, Hirschman JC, McCullough KE, Nagel EL et al. Prehospital use of the military anti-shock trouser (MAST). *JACEP* 1976; 5(8):581-587.

44. Hoffman JR. External counterpressure and the MAST suit: current and future roles. *Ann Emerg Med* 1980; 9(8):419-421.

45. Mackersie RC, Christensen JM, Lewis FR. The prehospital use of external counterpressure: does MAST make a difference? *J Trauma* 1984; 24(10):882-888.

46. Mattox KL, Bickell W, Pepe PE, Burch J, Feliciano D. Prospective MAST study in 911 patients. *J Trauma* 1989; 29(8):1104-1111.

47. Kudenchuk PJ. Intravenous antiarrhythmic drug therapy in the resuscitation from refractory ventricular arrhythmias. *Am J Cardiol* 1999; 84(9A):52R-55R.

48. O'Connor RE, Cone DC, De Lorenzo RA, Domeier RM, Moore WE, Taillac PP et al. EMS systems: foundations for the future. *Acad Emerg Med* 1999; 6(1):46-53.

49. Biros MH, Barsan WG, Lewis RJ, Sanders AB. Supporting emergency medicine research: developing the infrastructure. *Acad Emerg Med* 1998; 5(2):177-184.

50. Ling LJ. Proceedings of the Future of Emergency Medicine Research Conference, part I: executive summary. *Acad Emerg Med* 1998; 5(2):147-151.

51. Maio RF, Garrison HG, Spaite DW, Desmond JS, Gregor MA, Cayten CG et al. Emergency medical services outcomes project I (EMSOP I): prioritizing conditions for outcomes research. *Ann Emerg Med* 1999; 33(4):423-432.

52. Jones SE, Brenneis AT. Study design in prehospital trauma advanced life support-basic life support research: a critical review. *Ann Emerg Med* 1991; 20(8):857-860.

53. Spaite DW, Criss EA, Valenzuela TD, Meislin HW. Prehospital advanced life support for major trauma: critical need for clinical trials. *Ann Emerg Med* 1998; 32(4):480-489.

54. Moore L. Measuring quality and effectiveness of prehospital EMS. *Prehosp Emerg Care* 1999; 3(4):325-331.

55. Brice JH, Garrison HG, Evans AT. Study design and outcomes in out-of-hospital emergency medicine research: a ten-year analysis. *Prehosp Emerg Care* 2000; 4(2):144-150.

56. Levine M, Walter S, Lee H, Haines T, Holbrook A, Moyer V. Users' guides to the medical literature. IV. How to use an article about harm. Evidence-Based Medicine Working Group. *JAMA* 1994; 271(20):1615-1619.

57. Jaeschke R, Guyatt G, Sackett DL. Users' guides to the medical literature. III. How to use an article about a diagnostic test. A. Are the results of the study valid? Evidence-Based Medicine Working Group. *JAMA* 1994; 271(5):389-391.

58. Jayawickramarajah PT. How to evaluate educational programmes in the health professions. *Med Teach* 1992; 14(2-3):159-166.

59. Brazier H, Murphy AW, Lynch C, Bury G. Searching for the evidence in pre-hospital care: a review of randomised controlled trials. On behalf of the Ambulance Response Time Sub-Group of the National Ambulance Advisory Committee. *J Accid Emerg Med* 1999; 16(1):18-23.

60. Singer AJ, Homan CS, Stark MJ, Werblud MC, Thode HC, Jr., Hollander JE. Comparison of types of research articles published in emergency medicine and non-emergency medicine journals. *Acad Emerg Med* 1997; 4(12):1153-1158.

61. Singer AJ, Homan CS, Brody M, Thode HC, Jr., Hollander JE. Evolution of abstracts presented at the annual scientific meetings of academic emergency medicine. *Am J Emerg Med* 1999; 17(6):540-543.

62. Stiell IG, Wells GA, Spaite DW, Nichol G, O'Brien B, Munkley DP et al. The Ontario Prehospital Advanced Life Support (OPALS) study Part II: Rationale and methodology for trauma and respiratory distress patients. OPALS Study Group. *Ann Emerg Med* 1999; 34(2):256-262.

63. Brown CG, Martin DR, Pepe PE, Stueven H, Cummins RO, Gonzalez E et al. A comparison of standard-dose and high-dose epinephrine in cardiac arrest outside the hospital. The Multicenter High-Dose Epinephrine Study Group. *N Engl J Med* 1992; 327(15):1051-1055.

64. Spaite DW, Criss EA, Valenzuela TD, Guisto J. Emergency medical service systems research: problems of the past, challenges of the future [see comments]. *Ann Emerg Med* 1995; 26(2):146-152.

65. Kohli R, Tan JK, Piontek FA, Ziege DE, Groot H. Integrating cost information with health management support system: an enhanced methodology to assess health care quality drivers. *Top Health Inf Manage* 1999; 20(1):80-95.

66. Fox J, Thomson R. Decision support and disease management: a logic engineering approach. *IEEE Trans Inf Technol Biomed* 1998; 2(4):217-228.

67. Mosesso VN, Jr., Davis EA, Auble TE, Paris PM, Yealy DM. Use of automated external defibrillators by police officers for treatment of out-of-hospital cardiac arrest. *Ann Emerg Med* 1998; 32(2):200-207.

68. White RD, Hankins DG, Bugliosi TF. Seven years' experience with early defibrillation by police and paramedics in an emergency medical services system. *Resuscitation* 1998; 39(3):145-151.

69. White LJ, Cooper JD, Chambers RM, Gradisek R. Prehospital use of analgesia for suspected extremity fractures. *Prehosp Emerg Care* 2000; 4:205-208.

70. Johnson DR, Macias D, Dunlap A, Hauswald M, Doezema D. A new approach to teaching prehospital trauma care to paramedic students. *Ann Emerg Med* 1999; 33(1):51-55.

71. Brown LH, Fowler NH. An evaluation of EMS educational programs in North Carolina. North Carolina Community College System Emergency Medical Science Curriculum Improvement Project Advisory and Steering Committees. *Prehosp Emerg Care* 1999; 3(2):157-162.

72. Michael J, French A, King JA. National Highway Traffic Safety Administration (NHTSA) notes: EMS education agenda for the future: a vision for the future of EMS education. *Ann Emerg Med* 2000; 35(6):623-625.

73. Herman LL, Willoughby PJ, Koenigsberg MD, Ward S, McDonald CC. A comparison of EMS continuing education for paramedics in the United States. *Prehospital Disaster Med* 1996; 11(4):292-295.

74. Moshinskie JF. Reader attitudes toward journal-based continuing education for EMS personnel. *Prehospital Disaster Med* 1997; 12(4):258-263.

75. Sayre MR, Sakles JC, Mistler AF, Evans JL, Kramer AT, Pancioli AM. Field trial of endotracheal intubation by basic EMTs [see comments]. *Ann Emerg Med* 1998; 31(2):228-233.

76. Bradley JS, Billows GL, Olinger ML, Boha SP, Cordell WH, Nelson DR. Prehospital oral endotracheal intubation by rural basic emergency medical technicians. *Ann Emerg Med* 1998; 32(1):26-32.

77. Plaisance P, Lurie KG, Vicaut E, Adnet F, Petit JL, Epain D et al. A comparison of standard cardiopulmonary resuscitation and active compression-decompression resuscitation for out-of-hospital cardiac arrest. French Active Compression-Decompression Cardiopulmonary Resuscitation Study Group [see comments]. *N Engl J Med* 1999; 341(8):569-575.

78. Green J, Wintfeld N. Report cards on cardiac surgeons. Assessing New York State's approach [see comments]. *N Engl J Med* 1995; 332(18):1229-1232.

79. Mann NC, Mullins RJ. Research recommendations and proposed action items to facilitate trauma system implementation and evaluation. *J Trauma* 1999; 47(3 Suppl):S75-S78.

80. Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett P, Becker L et al. Recommended guidelines for uniform reporting of data from out-of- hospital cardiac arrest: the Utstein Style. Task Force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council [see comments]. *Ann Emerg Med* 1991; 20(8):861-874.

81. Kuisma M, Suominen P, Korpela R. Paediatric out-of-hospital cardiac arrests--epidemiology and outcome. *Resuscitation* 1995; 30(2):141-150.

82. Dick WF, Baskett PJ, Grande C, Delooz H, Kloeck W, Lackner C et al. "Recommendations for uniform reporting of data following major trauma-- the Utstein style" (as of July 17, 1999). An International Trauma Anaesthesia and Critical Care Society (ITACCS). *Acta Anaesthesiol Belg* 2000; 51(1):18-38.

83. Spaite D, Benoit R, Brown D, Cales R, Dawson D, Glass C et al. Uniform prehospital data elements and definitions: a report from the uniform prehospital emergency medical services data conference. *Ann Emerg Med* 1995; 25(4):525-534.

84. Data Elements for Emergency Department Systems; release 1.0. http://www.cdc.gov/ncipc/pub-res/deedspage.htm 1997.

85. Cone DC, Jaslow DS, Brabson TA. Now that we have the Utstein style, are we using it? [see comments]. *Acad Emerg Med* 1999; 6(9):923-928.

86. Higginbotham EL. In and out of hospital DNR. *Tex Nurs* 1997; 71(7):8-9, 11, 15.

87. Cooper A. *About face: the essentials of user interface design*. IDG Books Worldwide. 1995.

88. Dean JM, Vernon DD, Cook L, Nechodom P, Reading J, Suruda A. Probabilistic linkage of computerized ambulance and inpatient hospital discharge records: a potential tool for evaluation of emergency medical services. *Ann Emerg Med* 2001; 37(6):616-626.

89. Victor TW, Mera RM. Record linkage of health care insurance claims. *J Am Med Inform Assoc* 2001; 8(3):281-288.

90. Spaite DW, Conroy C, Tibbitts M, Karriker KJ, Seng M, Battaglia N et al. Use of emergency medical services by children with special health care needs. *Prehosp Emerg Care* 2000; 4(1):19-23.

91. Clark DE, Hahn DR. Hospital trauma registries linked with population-based data. *J Trauma* 1999; 47(3):448-454.

92. Institute of Medicine. Protecting Voluntary Reporting Systems From Legal Discovery.Kohn L, Corrigan J, Donaldson M, editors: To Err Is Human: Building A Safer Health System. 2000.(6):109-127.

93. Rosman DL. The western Australian road injury database (1987-1996): ten years of linked police, hospital and death records of road crashes and injuries. *Accid Anal Prev* 2001; 33(1):81-88.

94. Biros MH, Fish SS, Lewis RJ. Implementing the Food and Drug Administration's final rule for waiver of informed consent in certain emergency research circumstances [see comments]. *Acad Emerg Med* 1999; 6(12):1272-1282.

95. Smithline HA, Mader TJ, Crenshaw BJ. Do patients with acute medical conditions have the capacity to give informed consent for emergency medicine research? [see comments]. *Acad Emerg Med* 1999; 6(8):776-780.

96. Biros MH, Runge JW, Lewis RJ, Doherty C. Emergency medicine and the development of the Food and Drug Administration's final rule on informed consent and waiver of informed consent in emergency research circumstances. *Acad Emerg Med* 1998; 5(4):359-368.

97. Grim PS, Singer PA, Gramelspacher GP, Feldman T, Childers RW, Siegler M. Informed consent in emergency research. Prehospital thrombolytic therapy for acute myocardial infarction [see comments]. *JAMA* 1989; 262(2):252-255.

98. Zehner WJ, Jr., Scott JM, Iannolo PM, Ungaro A, Terndrup TE. Terbutaline vs albuterol for out-of-hospital respiratory distress: randomized, double-blind trial. *Acad Emerg Med* 1995; 2(8):686-691.

99. Brokaw J, Olson L, Fullerton L, Tandberg D, Sklar D. Repeated ambulance use by patients with acute alcohol intoxication, seizure disorder, and respiratory illness. *Am J Emerg Med* 1998; 16(2):141-144.

100. Whitehead J. On being the statistician on a Data and Safety Monitoring Board. *Stat Med* 1999; 18(24):3425-3434.

101. EMS Agenda for the Future Implementation Guide. http://www.nhtsa.dot.gov/people/injury/ems/agenda/index.html 1998.

102. Perry S, Wilkinson SL. The technology assessment and practice guidelines forum. A modified group judgment method. *Int J Technol Assess Health Care* 1992; 8(2):289-300.

103. Mahoney BD, Mirick MJ. Efficacy of pneumatic trousers in refractory prehospital cardiopulmonary arrest. *Ann Emerg Med* 1983; 12(1):8-12.

104. Mateer JR, Stueven HA, Thompson BM, Aprahamian C, Darin JC. Interposed abdominal compression CPR versus standard CPR in prehospital cardiopulmonary arrest: preliminary results. *Ann Emerg Med* 1984; 13(9 Pt 2):764-766.

105. Olson DW, Thompson BM, Darin JC, Milbrath MH. A randomized comparison study of bretylium tosylate and lidocaine in resuscitation of patients from out-of-hospital ventricular fibrillation in a paramedic system. *Ann Emerg Med* 1984; 13(9 Pt 2):807-810.

106. Paris PM, Stewart RD, Deggler F. Prehospital use of dexamethasone in pulseless idioventricular rhythm. *Ann Emerg Med* 1984; 13(11):1008-1010.

107. Stueven HA, Thompson BM, Aprahamian C, Tonsfeldt DJ. Calcium chloride: reassessment of use in asystole. *Ann Emerg Med* 1984; 13(9 Pt 2):820-822.

108. Bickell WH, Pepe PE, Wyatt CH, Dedo WR, Applebaum DJ, Black CT et al. Effect of antishock trousers on the trauma score: a prospective analysis in the urban setting. *Ann Emerg Med* 1985; 14(3):218-222.

109. Mateer JR, Stueven HA, Thompson BM, Aprahamian C, Darin JC. Pre-hospital IAC-CPR versus standard CPR: paramedic resuscitation of cardiac arrests. *Am J Emerg Med* 1985; 3(2):143-146.

110. Silfvast T, Saarnivaara L, Kinnunen A, Erosuo J, Nick L, Pesonen P et al. Comparison of adrenaline and phenylephrine in out-of-hospital cardiopulmonary resuscitation. A double-blind study. *Acta Anaesthesiol Scand* 1985; 29(6):610-613.

111. Stueven HA, Thompson B, Aprahamian C, Tonsfeldt DJ, Kastenson EH. Lack of effectiveness of calcium chloride in refractory asystole. *Ann Emerg Med* 1985; 14(7):630-632.

112. Stueven HA, Thompson B, Aprahamian C, Tonsfeldt DJ, Kastenson EH. The effectiveness of calcium chloride in refractory electromechanical dissociation. *Ann Emerg Med* 1985; 14(7):626-629.

113. Goldenberg IF, Campion BC, Siebold CM, McBride JW, Long LA. Esophageal gastric tube airway vs endotracheal tube in prehospital cardiopulmonary arrest. *Chest* 1986; 90(1):90-96.

114. Hargarten KM, Aprahamian C, Stueven HA, Thompson BM, Mateer JR, Darin J. Prophylactic lidocaine in the prehospital patient with chest pain of suspected cardiac origin. *Ann Emerg Med* 1986; 15(8):881-885.

115. Mattox KL, Bickell WH, Pepe PE, Mangelsdorff AD. Prospective randomized evaluation of antishock MAST in post-traumatic hypotension. *J Trauma* 1986; 26(9):779-786.

116. Baxt WG, Moody P. The differential survival of trauma patients. *J Trauma* 1987; 27(6):602-606.

117. Bickell WH, Pepe PE, Bailey ML, Wyatt CH, Mattox KL. Randomized trial of pneumatic antishock garments in the prehospital management of penetrating abdominal injuries. *Ann Emerg Med* 1987; 16(6):653-658.

118. Castaigne AD, Duval AM, Dubois-Rande JL, Herve C, Jan F, Louvard Y. Prehospital administration of anisoylated plasminogen streptokinase activator complex in acute myocardial infarction. *Drugs* 1987; 33 Suppl 3:231-234.

119. Cummins RO, Eisenberg MS, Litwin PE, Graves JR, Hearne TR, Hallstrom AP. Automatic external defibrillators used by emergency medical technicians. A controlled clinical trial. *JAMA* 1987; 257(12):1605-1610.

120. Hedges JR, Syverud SA, Dalsey WC, Feero S, Easter R, Shultz B. Prehospital trial of emergency transcutaneous cardiac pacing. *Circulation* 1987; 76(6):1337-1343.

121. Hoffman JR, Reynolds S. Comparison of nitroglycerin, morphine and furosemide in treatment of presumed pre-hospital pulmonary edema. *Chest* 1987; 92(4):586-593.

122. Barthell E, Troiano P, Olson D, Stueven HA, Hendley G. Prehospital external cardiac pacing: a prospective, controlled clinical trial [see comments]. *Ann Emerg Med* 1988; 17(11):1221-1226.

123. Dubois-Rande JL, Herve C, Duval-Moulin AM, Gaillard M, Boesch C, Louvard Y et al. [Prehospital thrombolysis. Evaluation of preliminary experiences at Val- de-Marne]. *Arch Mal Coeur Vaiss* 1989; 82(12):1963-1966.

124. Castaigne AD, Herve C, Duval-Moulin AM, Gaillard M, Dubois-Rande JL, Boesch C et al. Prehospital use of APSAC: results of a placebo-controlled study. *Am J Cardiol* 1989; 64(2):30A-33A.

125. Krischer JP, Fine EG, Weisfeldt ML, Guerci AD, Nagel E, Chandra N. Comparison of prehospital conventional and simultaneous compression- ventilation cardiopulmonary resuscitation. *Crit Care Med* 1989; 17(12):1263-1269.

126. Olson DW, Thakur R, Stueven HA, Thompson B, Gruchow H, Hendley GE et al. Randomized study of epinephrine versus methoxamine in prehospital ventricular fibrillation [see comments]. *Ann Emerg Med* 1989; 18(3):250-253.

127. Barbash GI, Roth A, Hod H, Miller HI, Modan M, Rath S et al. Improved survival but not left ventricular function with early and prehospital treatment with tissue plasminogen activator in acute myocardial infarction. *Am J Cardiol* 1990; 66(3):261-266.

128. Hargarten KM, Stueven HA, Waite EM, Olson DW, Mateer JR, Aufderheide TP et al. Prehospital experience with defibrillation of coarse ventricular fibrillation: a ten-year review. *Ann Emerg Med* 1990; 19(2):157-162.

129. Karagounis L, Ipsen SK, Jessop MR, Gilmore KM, Valenti DA, Clawson JJ et al. Impact of field-transmitted electrocardiography on time to in-hospital thrombolytic therapy in acute myocardial infarction. *Am J Cardiol* 1990; 66(10):786-791.

130. Roine RO, Kaste M, Kinnunen A, Nikki P, Sarna S, Kajaste S. Nimodipine after resuscitation from out-of-hospital ventricular fibrillation. A placebo-controlled, double-blind, randomized trial. *JAMA* 1990; 264(24):3171-3177.

131. Schofer J, Buttner J, Geng G, Gutschmidt K, Herden HN, Mathey DG et al. Prehospital thrombolysis in acute myocardial infarction. *Am J Cardiol* 1990; 66(20):1429-1433.

132. Mathey DG, Buttner J, Geng G, Gutschmidt HJ, Herden HN, Moecke H et al. [The thrombolysis treatment of acute myocardial infarct at the site of the emergency. A randomized double-blind study]. *Dtsch Med Wochenschr* 1990; 115(21):803-808.

133. Mattox KL, Maningas PA, Moore EE, Mateer JR, Marx JA, Aprahamian C et al. Prehospital hypertonic saline/dextran infusion for post-traumatic hypotension. The U.S.A. Multicenter Trial. *Ann Surg* 1991; 213(5):482-491.

134. Risenfors M, Gustavsson G, Ekstrom L, Hartford M, Herlitz J, Karlson BW et al. Prehospital thrombolysis in suspected acute myocardial infarction: results from the TEAHAT Study. *J Intern Med Suppl* 1991; 734:3-10.

135. Vassar MJ, Perry CA, Gannaway WL, Holcroft JW. 7.5% sodium chloride/dextran for resuscitation of trauma patients undergoing helicopter transport. *Arch Surg* 1991; 126(9):1065-1072.

136. Berntsen RF, Rasmussen K. Lidocaine to prevent ventricular fibrillation in the prehospital phase of suspected acute myocardial infarction: the North-Norwegian Lidocaine Intervention Trial. *Am Heart J* 1992; 124(6):1478-1483.

137. Brown CG, Martin DR, Pepe PE, Stueven H, Cummins RO, Gonzalez E et al. A comparison of standard-dose and high-dose epinephrine in cardiac arrest outside the

hospital. The Multicenter High-Dose Epinephrine Study Group. *N Engl J Med* 1992; 327(15):1051-1055.

138. Callaham M, Madsen CD, Barton CW, Saunders CE, Pointer J. A randomized clinical trial of high-dose epinephrine and norepinephrine vs standard-dose epinephrine in prehospital cardiac arrest [see comments]. *JAMA* 1992; 268(19):2667-2672.

139. Feasibility, safety, and efficacy of domiciliary thrombolysis by general practitioners: Grampian region early anistreplase trial. GREAT Group [see comments]. *BMJ* 1992; 305(6853):548-553.

140. Kereiakes DJ, Gibler WB, Martin LH, Pieper KS, Anderson LC. Relative importance of emergency medical system transport and the prehospital electrocardiogram on reducing hospital time delay to therapy for acute myocardial infarction: a preliminary report from the Cincinnati Heart Project. *Am Heart J* 1992; 123(4 Pt 1):835-840.

141. Karpov RS, Markov VA, Danilenko AM, Varvarenko VI, Zakharova RM, Dzhavadov KI et al. [Effectiveness of pre-hospital thrombolytic therapy in acute myocardial infarction]. *Kardiologiia* 1992; 32(9-10):23-26.

142. McAleer B, Ruane B, Burke E, Cathcart M, Costello A, Dalton G et al. Prehospital thrombolysis in a rural community. *Cardiovasc Drugs Ther* 1992; 6(4):369-372.

143. Stiell IG, Hebert PC, Weitzman BN, Wells GA, Raman S, Stark RM et al. High-dose epinephrine in adult cardiac arrest [see comments]. *N Engl J Med* 1992; 327(15):1045-1050.

144. Bertini G, Giglioli C, Rostagno C, Conti A, Russo L, Taddei T et al. Early out-of-hospital lidocaine administration decreases the incidence of primary ventricular fibrillation in acute myocardial infarction [see comments]. *J Emerg Med* 1993; 11(6):667-672.

145. Prehospital thrombolytic therapy in patients with suspected acute myocardial infarction. The European Myocardial Infarction Project Group [see comments]. *N Engl J Med* 1993; 329(6):383-389.

146. Boissel JP. The European Myocardial Infarction Project: an assessment of pre- hospital thrombolysis. *Int J Cardiol* 1995; 49 Suppl:S29-S37.

147. Longstreth WT, Jr., Copass MK, Dennis LK, Rauch-Matthews ME, Stark MS, Cobb LA. Intravenous glucose after out-of-hospital cardiopulmonary arrest: a community-based randomized trial. *Neurology* 1993; 43(12):2534-2541.

148. Vassar MJ, Fischer RP, O'Brien PE, Bachulis BL, Chambers JA, Hoyt DB et al. A multicenter trial for resuscitation of injured patients with 7.5% sodium chloride. The effect of added dextran 70. The Multicenter Group for the Study of Hypertonic Saline in Trauma Patients. *Arch Surg* 1993; 128(9):1003-1011.

149. Vassar MJ, Perry CA, Holcroft JW. Prehospital resuscitation of hypotensive trauma patients with 7.5% NaCl versus 7.5% NaCl with added dextran: a controlled trial. *J Trauma* 1993; 34(5):622-632.

150. Weaver WD, Cerqueira M, Hallstrom AP, Litwin PE, Martin JS, Kudenchuk PJ et al. Prehospital-initiated vs hospital-initiated thrombolytic therapy. The Myocardial Infarction Triage and Intervention Trial [see comments]. *JAMA* 1993; 270(10):1211-1216.

151. Bickell WH, Wall MJ, Jr., Pepe PE, Martin RR, Ginger VF, Allen MK et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries [see comments]. *N Engl J Med* 1994; 331(17):1105-1109.

152. Ellinger K, Luiz T, Denz C, van Ackern K. [Randomized use of an active compression-decompression technique within the scope of preclinical resuscitation]. *Anasthesiol Intensivmed Notfallmed Schmerzther* 1994; 29(8):492-500.

153. Pre-hospital treatment of patients with suspected acute myocardial using a beta-blocking agent: a double-blind feasibility study. EMIP-BB Pilot Study Group. *Clin Trials Metaanal* 1994; 29(2-3):125-138.

154. Rhee KJ, O'Malley RJ. Neuromuscular blockade-assisted oral intubation versus nasotracheal intubation in the prehospital care of injured patients. *Ann Emerg Med* 1994; 23(1):37-42.

155. Staudinger T, Brugger S, Roggla M, Rintelen C, Atherton GL, Johnson JC et al. [Comparison of the Combitube with the endotracheal tube in cardiopulmonary resuscitation in the prehospital phase]. *Wien Klin Wochenschr* 1994; 106(13):412-415.

156. Choux C, Gueugniaud PY, Barbieux A, Pham E, Lae C, Dubien PY et al. Standard doses versus repeated high doses of epinephrine in cardiac arrest outside the hospital. *Resuscitation* 1995; 29(1):3-9.

157. Dybvik T, Strand T, Steen PA. Buffer therapy during out-of-hospital cardiopulmonary resuscitation [see comments]. *Resuscitation* 1995; 29(2):89-95.

158. Dybvik T, Strand T, Steen PA. [Out-of-hospital buffer therapy in heart arrest]. *Tidsskr Nor Laegeforen* 1996; 116(27):3212-3214.

159. Quadrel M, Lavery RF, Jaker M, Atkin S, Tortella BJ, Cody RP. Prospective, randomized trial of epinephrine, metaproterenol, and both in the prehospital treatment of asthma in the adult patient. *Ann Emerg Med* 1995; 26(4):469-473.

160. Schwab TM, Callaham ML, Madsen CD, Utecht TA. A randomized clinical trial of active compression-decompression CPR vs standard CPR in out-of-hospital cardiac arrest in two cities [see comments]. *JAMA* 1995; 273(16):1261-1268.

161. Weiss SJ, Hanhart EJ, McBride R, Johnson H, Denninghof K, Johnson WD. Tympanic membrane thermometry in the care of out-of-hospital patients [see comments]. *Ann Emerg Med* 1995; 25(1):41-47.

162. Brouwer MA, Martin JS, Maynard C, Wirkus M, Litwin PE, Verheugt FW et al. Influence of early prehospital thrombolysis on mortality and event-free survival (the Myocardial Infarction Triage and Intervention [MITI] Randomized Trial). MITI Project Investigators. *Am J Cardiol* 1996; 78(5):497-502.

163. Luiz T, Ellinger K, Denz C. Active compression-decompression cardiopulmonary resuscitation does not improve survival in patients with prehospital cardiac arrest in a physician-manned emergency medical system [see comments]. *J Cardiothorac Vasc Anesth* 1996; 10(2):178-186.

164. Mauer D, Schneider T, Dick W, Withelm A, Elich D, Mauer M. Active compression-decompression resuscitation: a prospective, randomized study in a two-tiered EMS system with physicians in the field. *Resuscitation* 1996; 33(2):125-134.

165. Sayre MR, Daily SW, Stern SA, Storer DL, van Loveren HR, Hurst JM. Out-of-hospital administration of mannitol to head-injured patients does not change systolic blood pressure. *Acad Emerg Med* 1996; 3(9):840-848.

166. Stiell IG, Hebert PC, Wells GA, Laupacis A, Vandemheen K, Dreyer JF et al. The Ontario trial of active compression-decompression cardiopulmonary resuscitation for in-hospital and prehospital cardiac arrest [see comments]. *JAMA* 1996; 275(18):1417-1423.

167. Lindner KH, Dirks B, Strohmenger HU, Prengel AW, Lindner IM, Lurie KG. Randomised comparison of epinephrine and vasopressin in patients with out-of-hospital ventricular fibrillation. *Lancet* 1997; 349(9051):535-537.

168. Mader TJ, Gibson P. Adenosine receptor antagonism in refractory asystolic cardiac arrest: results of a human pilot study. *Resuscitation* 1997; 35(1):3-7.

169. Plaisance P, Adnet F, Vicaut E, Hennequin B, Magne P, Prudhomme C et al. Benefit of active compression-decompression cardiopulmonary resuscitation as a prehospital advanced cardiac life support. A randomized multicenter study. *Circulation* 1997; 95(4):955-961.

170. Rosen CL, Ratliff AF, Wolfe RE, Branney SW, Roe EJ, Pons PT. The efficacy of intravenous droperidol in the prehospital setting. *J Emerg Med* 1997; 15(1):13-17.

171. Rumball CJ, MacDonald D. The PTL, Combitube, laryngeal mask, and oral airway: a randomized prehospital comparative study of ventilatory device effectiveness and cost-effectiveness in 470 cases of cardiorespiratory arrest [see comments]. *Prehosp Emerg Care* 1997; 1(1):1-10.

172. Gueugniaud PY, Mols P, Goldstein P, Pham E, Dubien PY, Deweerdt C et al. A comparison of repeated high doses and repeated standard doses of epinephrine for cardiac arrest outside the hospital. European Epinephrine Study Group [see comments]. *N Engl J Med* 1998; 339(22):1595-1601.

173. Gardtman M, Dellborg M, Brunnhage C, Lindkvist J, Waagstein L, Herlitz J. Effect of intravenous metoprolol before hospital admission on chest pain in suspected acute myocardial infarction. *Am Heart J* 1999; 137(5):821-829.

174. Kudenchuk PJ, Cobb LA, Copass MK, Cummins RO, Doherty AM, Fahrenbruch CE et al. Amiodarone for resuscitation after out-of-hospital cardiac arrest due to ventricular fibrillation [see comments]. *N Engl J Med* 1999; 341(12):871-878.

175. Mader TJ, Smithline HA, Gibson P. Aminophylline in undifferentiated out-of-hospital asystolic cardiac arrest. *Resuscitation* 1999; 41(1):39-45.

176. Skogvoll E, Wik L. Active compression-decompression cardiopulmonary resuscitation: a population-based, prospective randomised clinical trial in out-of- hospital cardiac arrest. *Resuscitation* 1999; 42(3):163-172.

177. Plaisance P, Lurie KG, Payen D. Inspiratory impedance during active compression-decompression cardiopulmonary resuscitation: a randomized evaluation in patients in cardiac arrest. *Circulation* 2000; 101(9):989-994.

178. Schneider T, Martens PR, Paschen H, Kuisma M, Wolcke B, Gliner BE et al. Multicenter, randomized, controlled trial of 150-J biphasic shocks compared with 200- to 360-J monophasic shocks in the resuscitation of out-of-hospital cardiac arrest victims. Optimized Response to Cardiac Arrest (ORCA) Investigators. *Circulation* 2000; 102(15):1780-1787.

179. Turner J, Nicholl J, Webber L, Cox H, Dixon S, Yates D. A randomised controlled trial of prehospital intravenous fluid replacement therapy in serious trauma. *Health Technol Assess* 2000; 4(31):1-57.