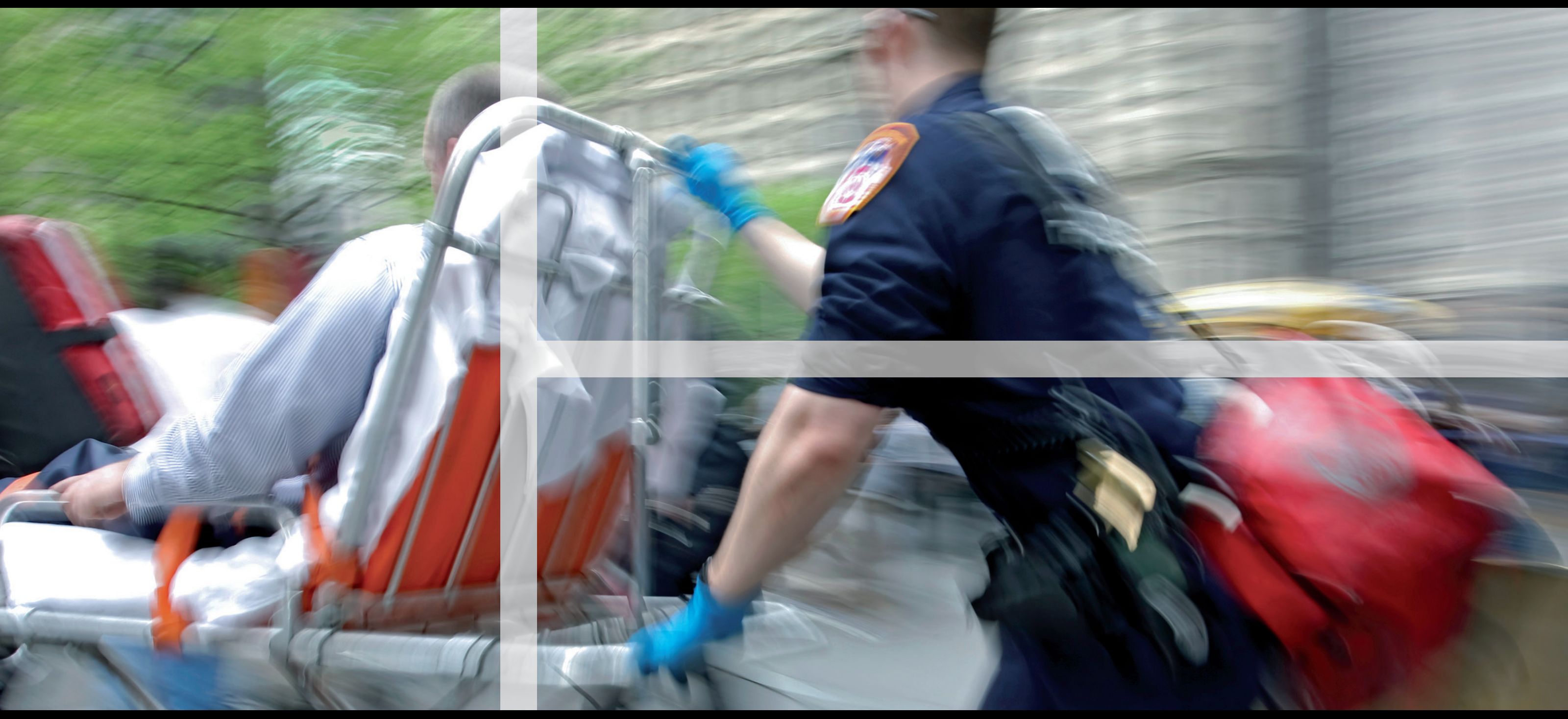
Emergency Medicine International

Prehospital Care

Guest Editors: Stephen H. Thomas, Christopher Colwell, Jean-Claude Deslandes, Sophia Dyer, and Jeffrey M. Goodloe



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Editorial Board

Contents

Prehospital Care, Stephen H. Thomas, Christopher Colwell, Jean-Claude Deslandes, Sophia Dyer, and Jeffrey M. Goodloe
Volume 2012, Article ID 965480, 2 pages

Tulsa Oklahoma Oktoberfest Tent Collapse Report, Kelly E. Deal, Carolyn K. Synovitz, Jeffrey M. Goodloe, Brandi King, and Charles E. Stewart
Volume 2012, Article ID 729795, 9 pages

Subcutaneous Fluid Administration: A Potentially Useful Tool in Prehospital Care, Annette O. Arthur, Jeffrey M. Goodloe, and Stephen H. Thomas
Volume 2012, Article ID 904521, 5 pages

EMS Stretcher Misadventures in a Large, Urban EMS System: A Descriptive Analysis of Contributing Factors and Resultant Injuries, Jeffrey M. Goodloe, Christopher J. Crowder, Annette O. Arthur, and Stephen H. Thomas
Volume 2012, Article ID 745706, 4 pages

Patients Refusing Prehospital Transport Are Increasingly Likely to Be Geriatric, Peyton Holder, Annette O. Arthur, Grady Thiems, Travis Redmon, Matt Thomas, Jeffrey M. Goodloe, T. J. Reginald, and Stephen H. Thomas
Volume 2012, Article ID 905976, 3 pages

Medical Transport of Children with Complex Chronic Conditions, Carlos F. Lerner, Robert B. Kelly, Leslie J. Hamilton, and Thomas S. Klitzner
Volume 2012, Article ID 837020, 6 pages

Helicopter EMS Transport Outcomes Literature: Annotated Review of Articles Published 2007–2011, Brandon S. Brown, Korby A. Pogue, Emily Williams, Jesse Hatfield, Matthew Thomas, Annette Arthur, and Stephen H. Thomas
Volume 2012, Article ID 876703, 21 pages

Helicopter EMS: Research Endpoints and Potential Benefits, Stephen H. Thomas and Annette O. Arthur
Volume 2012, Article ID 698562, 14 pages

Can Peak Expiratory Flow Measurements Differentiate Chronic Obstructive Pulmonary Disease from Congestive Heart Failure?, John E. Gough and Kori L. Brewer
Volume 2012, Article ID 912570, 3 pages

Measuring Quality in Emergency Medical Services: A Review of Clinical Performance Indicators, Mazen J. El Sayed
Volume 2012, Article ID 161630, 7 pages

Hindawi Publishing Corporation
Emergency Medicine International
Volume 2012, Article ID 965480, 2 pages
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Editorial

Prehospital Care

Stephen H. Thomas,[1] Christopher Colwell,[2] Jean-Claude Deslandes,[3] Sophia Dyer,[4] and Jeffrey M. Goodloe[1]

[1] *Department of Emergency Medicine, The University of Oklahoma, Norman, OK 13019-0390, USA*
[2] *Department of Emergency Medicine, Denver Health and University of Colorado, Denver, CO 80217, USA*
[3] *France's Urgence Pratique Formation, Ganges 34190, France*
[4] *Department of Emergency Medicine, Boston University, Boston, MA 02215, USA*

Correspondence should be addressed to Stephen H. Thomas, stephen-thomas@ouhsc.edu

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The emergence of emergency medical services (EMS) as a realm within emergency medicine (EM) has recently been completed, with EMS gaining status as a boarded subspecialty. While there are excellent journals and a rich literature addressing EMS and out-of-hospital care, we embraced, with enthusiasm, the invitation of the editors to coordinate an EMS-related special issue on prehospital Care. The open access and online nature of the offers a unique chance for widespread attention to EMS, at a time when that attention is particular *a propos* given the new focus associated with subspecialty status.

As guest editors, we bring to the issue's review process over a century of experience in ground EMS, air transport, and disaster operations. Our backgrounds include experience with urban and rural ground and air EMS systems all over the U.S. and abroad. Our responsibilities include involvement with ground and/or air EMS care in the USA east coast (S. Dyer, of Boston University), the USA west (C. Colwell, Denver Health and University of Colorado), and the U.S. southwest (J. Goodloe and Stephen Thomas of the University of Oklahoma). International experience comes from J. Deslandes (France's Urgence Pratique Formation).

The breadth of interests from our collective background has translated into a similarly broad range of topics covered in this special issue on prehospital care. The solicitation of manuscripts allowed for virtually any topic within prehospital and out-of-hospital care, and the manuscripts received were a testament to the excellence of work around the world, in our chosen fields. We believe that the papers that were ultimately approved for publication in this special issue represent important contributions to the state of the evidence in EMS as follows.

A paper focuses on an EMS angle of a subject that has become one of the most important rooms in the house of medicine: quality. In his review of clinical performance indicators, M. J. El Sayed outlines EMS's place in the dialogue about quality measurement. His overview provides background discussion, education, and practical direction for EMS services.

Another article takes on a clinical conundrum facing acute care providers every day: what's causing this patient's dyspnea? J. E. Gough and K. L. Brewer address the differentiation of various causes of dyspnea-differentiation that can be tricky even in the hospital setting. The divergence of therapeutic approaches to varying dyspnea etiologies means that the earlier the true causes can be identified, the more rapidly patients can receive appropriately tailored therapy. In their pilot study, J. E. Gough and K. L. Brewer suggest that peak expiratory flow rate may provide useful clues to allow earlier differentiation of two major causes of dyspnea.

Air medical transport is one of the more controversial aspects of EMS. Unfortunately, both sides of the HEMS debate frequently mischaracterize the existing evidence, with the statement "there is very little data addressing HEMS outcomes." In an attempt to provide an overview of the existing evidence, so that those with HEMS outcomes interest can get the original research and judge quality and impact for themselves, J. Hatfield et al. provide an annotated bibliography of HEMS outcomes research since 2007.

Another paper addresses patient safety. C. T. Crowder et al. provide a look into a matter which has managed to elude attention despite the recent increased emphasis on patient safety. Rather than examine issues related to medical care, the study assesses the safety of patient transport. Specifically, F. J. Crowder et al. focus on stretcher-related problems and patient (and EMS crew member) safety issues related to stretcher misadventures.

A different paper is a review of a potentially interesting possibility for improving drug and fluid delivery in the prehospital and disaster settings. Hyaluronidase, used a half-century ago for "hypodermoclysis," fell out of favor decades ago due to immune reactions to the animal-based enzyme. With the relatively new availability of human recombinant hyaluronidase, the early literature suggests there might be a potential role for subcutaneous fluid administration in some prehospital settings. A. O. Arthur et al. outline the current state of the evidence and provide some directions for potential future research.

In the paper of B. King et al., they continue the focus on disaster and mass casualty situations. In their report on a wind-caused collapse of a large tent at a city festival, the authors outline the benefits of planning and provide some important lessons learned for future planning.

The review by L. J. Hamilton et al. changes focus to another area of importance in EMS: pediatric care. While most of the literature addressing pediatric prehospital care has understandably focused on general pediatrics and trauma situations, Hamilton et al. narrow the discussion to children with complex chronic conditions. While there are (thankfully) relatively few of these patient numbers, transports of children with chronic complex medical conditions can occupy a disproportionately large percentage of an EMS service runs. The experience and insights of L. J. Hamilton et al. should assist those EMS services and providers who care for this special patient population.

A study by A. O. Arthur et al. changes focus to the other end of the age spectrum. With the aging of the population (especially in the US), any suggestive trend of a problem regarding older adults can be a harbinger of a major upcoming issue. Arthur et al. identify such a potential trend, potentially related to economic concerns, of a rise in the proportion of "transport refusal" patients who are geriatric. It is of course unknown whether economic or other identifiable factors are responsible for this finding, but the authors' preliminary findings should prompt further analysis of the issue.

The special issue wraps up with an overview of HEMS research endpoints and potential benefits. The summary is intended not so much to make the case for (or against) HEMS as having outcomes benefits, as it is intended to highlight specific areas of investigation and focus for future efforts to define HEMS role in prehospital care.

It has been our pleasure to bring this special issue to the readership of this journal. We hope that the literature in the edition helps to move the EMS world forward or at least inform debates and discussions regarding how to provide the best possible care in the out-of-hospital setting. Of course, we would be delighted to hear from you, the readers, as to comments or questions about any of the articles.

Stephen H. Thomas
Christopher Colwell
Jean-Claude Deslandes
Sophia Dyer
Jeffrey M. Goodloe

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Research Article

Tulsa Oklahoma Oktoberfest Tent Collapse Report

Kelly E. Deal,[1] Carolyn K. Synovitz,[2,3] Jeffrey M. Goodloe,[2] Brandi King,[1] and Charles E. Stewart[2,3]

[1] *OTEMS (Oologah-Talala EMS), 18955 S 4150 Road, Claremore, OK 74017-3609, USA*
[2] *Department of Emergency Medicine, University of Oklahoma School of Medicine, Tulsa, OK 74135, USA*
[3] *Oklahoma Disaster Institute, Tulsa, OK 74135, USA*

Correspondence should be addressed to Charles E. Stewart, charles-e-stewart@ouhsc.edu

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Background. On October 17, 2007, a severe weather event collapsed two large tents and several smaller tents causing 23 injuries requiring evacuation to emergency departments in Tulsa, OK. *Methods*. This paper is a retrospective analysis of the regional health system's response to this event. Data from the Tulsa Fire Department, The Emergency Medical Services Authority (EMSA), receiving hospitals and coordinating services were reviewed and analyzed. EMS patient care reports were reviewed and analyzed using triage designators assigned in the field, injury severity scores, and critical mortality. *Results*. EMT's and paramedics from Tulsa Fire Department and EMSA provided care at the scene under unified incident command. Of the 23 patients transported by EMS, four were hospitalized, one with critical spinal injury and one with critical head injury. One patient is still in ongoing rehabilitation. *Discussion*. Analysis of the 2007 Tulsa Oktoberfest mass casualty incident revealed rapid police/fire/EMS response despite challenges of operations at dark under severe weather conditions and the need to treat a significant number of injured victims. There were no fatalities. Of the patients transported by EMS, a minority sustained critical injuries, with most sustaining injuries amenable to discharge after emergency department care.

1. Introduction

On October 17, 2007 a severe weather alert was issued for Tulsa, Oklahoma, and the surrounding area by the Tulsa office of the National Weather Service of the National Oceanic and Atmospheric Administration (NOAA). This weather alert forecast two separate fronts moving through the area separated by about 2 hours. Each of these fronts was forecast to produce thunderstorms and high winds (Appendix D).

At the time, Tulsa was hosting an annual outdoor Oktoberfest celebration, considered to be the third largest in the world. Although the venue had not yet opened to the general public, corporate sponsors, event organizers, and volunteers were in attendance for "corporate night." More than 7,000 people were present at the festival when the second storm front arrived, spawning tornadoes and winds up to 80 miles per hour. These winds collapsed two large tents and several smaller ones at approximately 1930 hours. Twenty-three people were transported by EMS to area hospital emergency departments, with six listed in serious condition and two listed as critical. The others were reported in fair condition. In addition to these patients transported by EMS, others injured at the event were either evaluated and released on scene or sought medical care after self-extrication and leaving via personal transportation.

1.1. Location: Tulsa. Situated on the Arkansas River at the foothills of the Ozark Mountains in northeast Oklahoma, a region of the state known as "Green Country," Tulsa is the second-largest city in the state of Oklahoma and 45th-largest in the United States. With an estimated population of 382,872 and approximately 950,000 in the statistical metropolitan area according to the 2006 census, Tulsa serves as the governmental seat of Tulsa County, the most densely populated county in Oklahoma. Located near "Tornado Alley", the city frequently experiences severe weather.

1.2. Event: Oktoberfest. The Tulsa Oktoberfest is operated by Oktoberfest, Inc. (a nonprofit organization). The profits from the Oktoberfest are used in Tulsa's River Parks to create new playgrounds for the city's children and to make other improvements to the parks. The event site is located on the west bank of the Arkansas River, across the river from all major hospitals in Tulsa. Although the festival is located across the river from the major hospitals, there are no access problems to these hospitals by established routes.

2. Methods

Retrospective data analysis and interviews of investigator-selected responders at the scene were approved by the University of Oklahoma Health Science Center Institutional Review Board (IRB). Interviews were conducted using a script approved by the IRB (Attachment 1).

EMS patient assessment and care data were obtained from computerized EMS transportation records. Protected data was carefully redacted per NSA Report number I333-015R-2005 guidelines.

Injury severity scores were calculated by the senior author (C. E. Stewart) and reviewed by two other authors (J. M. Goodloe and C. K. Sinuitz). One author was the EMSA MMRS Director who responded to the incident (K. E. Deal), and one author was on duty at the hospital that received the bulk of both walk-in and transported patients (J. M. Goodloe).

3. Results

The following is a brief description of the events that occurred at the Oktoberfest site as reported by the various agencies, hospitals, and individuals that were involved.

3.1. Emergency Medical System Response. The Medical Emergency Response Center (MERC) was notified by NWS-Tulsa in a conference call of the impending weather at about 1400 hours. This briefing included the chance of high winds and severe thunderstorms. NWS forecasters felt that if a warming trend occurred, these storms could spawn tornadoes. NWS also mobilized the local SkyWarn amateur radio network of storm spotters. (Appendix A is the 1111 AM updated weather forecast.)

Following these specific and accurate warnings given by NWS, the Metropolitan Medical Response Service (MMRS) Director at MERC initiated a severe weather protocol that mobilized all EMS supervisors and administrators, readied all available ambulances for deployment (including those with drivable conditions that were in maintenance garages), and prestocked resupply vehicles with additional equipment, cervical collars, and trauma supplies. The MMRS Director cancelled an impending personal leave and staffed his response vehicle with an EMT who was also an amateur radio operator. These two personnel monitored the SkyWarn amateur radio frequency for severe weather and tornado warnings.

The first weather front passed at approximately 1600 hours with only minor damages including a motor vehicle accident on US Route 169. Following the passage of the storm front, clear skies prevailed. The local warming trend that NWS had predicted would worsen the oncoming second front that began to occur.

NWS issued a high wind/severe storm warning at 1858 hours for Tulsa County. A tornado watch was already in effect for Tulsa County at that time. The second storm front passed through the southern Tulsa area at approximately 1920 hours, just as darkness fell. This storm was accompanied by winds in excess of 70 mph (on-site estimates ranged as high as 80 mph). SkyWarn volunteers noted cyclonic rotation of the storm, though no tornadoes were noted in the Tulsa area.

Public warnings were limited to radio, television, and NOAA broadcast storm warnings. Severe storm warning sirens were not activated based on the city of Tulsa policy limiting wind-based use of weather sirens to winds of 80 miles per hour or greater. As the storm front hit, Oktoberfest staff felt that the safest area was under the tents due to rain and approximately 1/2 inch sized hail accompanying the storm.

It is unknown whether the Oktoberfest staff had knowledge of the second NWS severe storm warning prior to the arrival of the storm front. Many of the sponsors were local television stations and their weather offices did call their staff on site with the threat. One television station did advise their staff to try and shut down the event due to the predicted severity of the storm's second front.

The second storm front picked up the leading (southwestern) edge of Der Bier Garten tent (labeled number 6 in the Oktoberfest event map) with about 2500 people under the canvas. Wind pressure raised the tent lifting the canvas like a parachute. The corner posts held firm, so the interior 400 pound tent poles were lifted off of the ground. This tent pole destabilization occurred three times, with injuries occurring each time. During the third wind gust, one tent pole was entrapped by falling tent fabric and vertical motion was converted to a horizontal scything motion. The sweeping tent pole struck multiple victims and indiscriminately flung equipment and tables about. Collapse of the Der Bier Garten tent occurred 24 minutes after the gust front arrived. Simultaneously, a smaller tent, number 3 on the diagram, Die Bierstube, also collapsed. Heavy rain accompanied the high winds and the sun had set, so the area was in darkness.

At approximately 19 : 27 on October 17, 2007, the 911 dispatcher received approximately 30 phone calls within a 10-minute period. The first EMS vehicle on scene was dispatched for a single patient, and the reporting caller gave no mention of multiple patients. Although multiple calls arrived in rapid succession, it was not until the fourth or fifth phone call that the tent collapse was reported. Subsequent calls detailed a collapse of tents at the Oktoberfest and noted that multiple injuries had occurred. The dispatcher immediately vectored multiple ambulances to the area and notified fire and police to respond. The first responding EMS unit arrived within 2 minutes of the first call.

The first responding ambulance was met by several hundred people who directed the ambulance in conflicting directions. The ambulance proceeded into the crowd and was unable to provide effective care or transportation due to the crowd. Multiple responders described dozens of individuals with bleeding head and extremity wounds, walking to cars or aiding other victims.

The first responding supervisor (and EMS unit) was the EMSA MMRS Director, who responded to the series of 911 calls. He established an incident command site, directed incoming ambulances to a staging area, and established liaison between police and EMS. The responding supervisor intercepted subsequent units and issued ingress instructions. When the fire department arrived, a unified incident command was established.

As noted earlier, the first arriving unit was unable to egress the area due to the crowd. Accordingly, the first incident command direction was for the police to establish open egress and ingress to the area. This was done within 5 minutes.

Tulsa Fire Department responded with five units including Rescue 4, Ladder 4, Engine 26, Ladder 26, and District Chief car 641. This response included 15 personnel. The responding District Chief assumed command of the fire department personnel at the scene.

The MERC Coordinator started hospital notification of the disaster and updated the hospitals at via EMResource (a proprietary real-time MCI event notification and hospital capability status website). There were six subsequent MCI event status updates sent via EMResource to Tulsa area hospitals during the progression of the mass casualty event.

Initial victim identification and triage proved challenging aside from the environmental milieu. EMTs and paramedics from the Tulsa Fire Department were directed to multiple clusters of reported victims, often by confusing and contradictory bystander directions. There were at least 3 areas where bystanders were simultaneously trying to rally EMS presence.

The MMRS Director was in constant contact with the Tulsa Area Emergency Management Agency (TAEMA) to assure continued weather monitoring during the incident response. A weather satellite review revealed no further incoming hazardous weather. Relatively early into the event, he was advised by TAEMA that there was no additional weather threat expected.

A central triage verification and treatment area was established in an unaffected tent which was carefully evaluated for structural integrity, arriving EMSA paramedics gathered in this central area to receive subsequent assignments.

A map of the Oktoberfest event obtained by an onsite internet query proved to be inaccurate, reflecting last year's Oktoberfest tent configuration (Figure 1). After noting that the event maps were not accurate, incident command established "left," "right," and "central" casualty areas in relation to the treatment and transport sites. These tactical designators proved helpful in resolving confusing terminology for the victim locations. EMSA EMTs remained in the ambulances to ensure timely mobilization of these vehicles for patient transport and ongoing ingress/egress clearance. Subsequent arriving field supervisory EMSA paramedics sequentially staffed these positioned ambulances.

All EMS-transported patients were triaged and tagged accordingly. These triaged patients were moved to the central treatment area by Tulsa Fire personnel. For unexplained reasons, triage tags were removed from three patients at the juncture of extrication and treatment. Re-identification of these patients rapidly occurred without significant clinical impact upon patient outcome. A total of 23 patients were ultimately transported by 9 EMSA ambulances. Several ambulances were able to make multiple transports due to the proximity of area hospitals to the MCI event site.

3.2. Casualty Transport Destination Distribution. Review of casualty transport destinations reveals that EMS-transported patients were equitably transferred and distributed throughout the Tulsa acute care hospitals (Figure 2). Distribution of the patients by MERC in coordination with incident command and transport/triage at the scene was in a "far first" pattern based on the Israeli model with transportation of the first patients to the furthest hospitals equipped to receive casualties [1]. Patients were sent into hospitals in a "trauma rotation," to ensure reasonably equitable distribution of transported casualties.

One of the authors (J. M. Goodloe) was the attending emergency physician at Saint Francis Hospital during this MCI. Personal observation of this emergency physician indicated minimal impact on typical emergency department operations at this hospital. Ancillary and nursing staff attended to the received casualties without duress.

Four "walking wounded" patients were transported by a "lift" bus with three paramedics in attendance to the furthest hospital from the scene (St. Francis South). (These transports and their calculated injury severity scores are described in Table 1.)

One critical patient was transported with spinal injuries and subsequent paraplegia. One seriously ill patient was transported with concussion, loss of consciousness, and head injury.

A total of 35 walking wounded casualties presented to local hospitals later that evening. The bulk of these presented to the largest hospital in Tulsa (Saint Francis Hospital) and to SouthCrest Hospital which was further away from the Oktoberfest event than Saint Francis Hospital. (The available information about these patients is detailed in Table 2).

It was assumed that the walking wounded casualties would present to the closest hospital (Oklahoma State University Medical Center). This assumption was found to be in error with this population. The reasons for this distribution cannot be conclusively determined but are felt to be demographically related to the site of the personal residences of the participants. (On this evening only the vendors and sponsors were celebrating and the majority of these would live in the southern part of the city due to socioeconomic characteristics.)

4. Discussion

Since the events of September 11, 2001, and the more

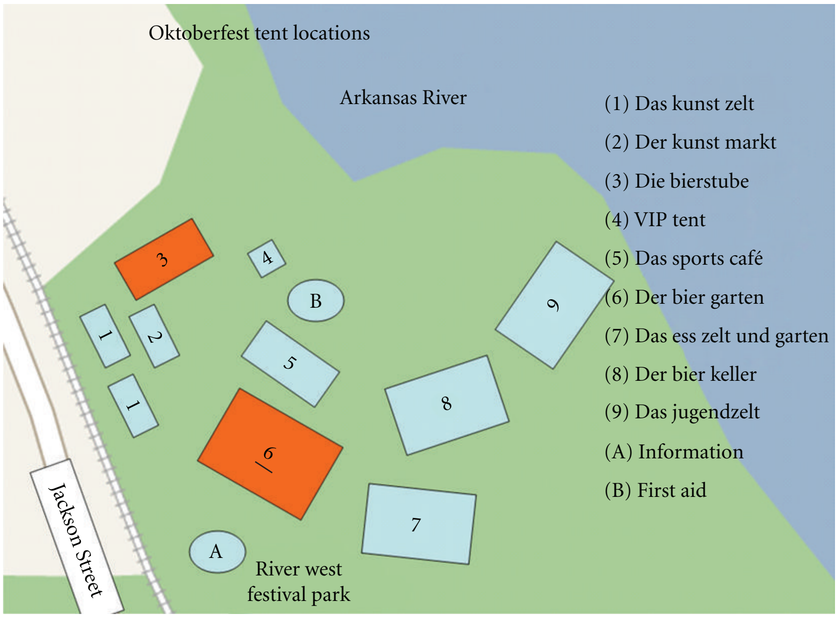

Figure 1

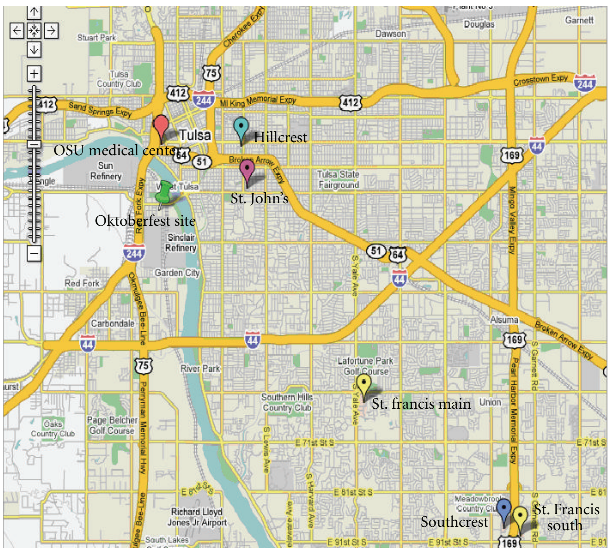

Figure 2: Legend: red = OSU Medical Center, light blue = Hillcrest Medical Center, maroon = St. John's Medical Center, yellow = St. Francis Hospital (Main) on Yale Avenue, yellow = St. Francis Hospital (South) at bottom of map, dark blue = Southcrest Hospital, Green "tack" = site of Oktoberfest celebration.

recent Hurricane Katrina in 2005, significant attention has been focused on mass casualty preparedness and response. In Oklahoma, severe weather is common with tornadoes and severe thunderstorms occurring frequently during about one-fourth of the year.

Convectively generated windstorms occur over broad temporal and spatial scales as was seen in this event. The longer-lived, larger-scale, and most intense of these windstorms are given the name "derecho." Individual derechos have been responsible for up to 8 fatalities, 204 injuries, and forest blowdowns affecting over 3,000 km^2 of timber [3]. These losses totaled \$500 million. When casualty statistics and damage estimates from hurricanes and tornadoes are contrasted with those from derechos, it is obvious that derechos can be as hazardous as tornadoes and hurricanes [3]. This windstorm was part of a derecho that affected the plains states and extended into the Ozarks.

A derecho is associated with a fast-moving band of severe thunderstorms. Derechos are usually not associated with a cold front, but a stationary front within a highly buoyant, warm air mass. A warm weather phenomenon, derechos occur mostly in summer, especially July (in the northern hemisphere), but can occur at any time of the year and occur as frequently at night as in the daylight hours. They occur commonly only in North America.

Derecho comes from a Spanish word for "straight". The word was first applied to the storm front in the American Meteorological Journal in 1888 by Gustavus Hinrichs [4]. He intended to contrast this with tornado, which comes from the Spanish word "tornar" meaning "to turn". Derechos come from a band of thunderstorms that are bow- or spearhead-shaped and hence are also called a bow echo or spearhead radar echo.

Multiple instances of tent collapse with fatalities and severe injuries have been reported in the media as a result of windstorm, but similar instances have been reported only twice in the medical literature available for online searching [5–15]. Tent collapse due to high wind is well known to the owners of marquee tents. EMS and fire have little documentation of this as a hazard of severe weather; thus, public safety preparedness efforts do not commonly include this hazard.

Table 1: Transported Patient Summary. Injury severity code = sum of squares of the AIS grade in each of the three most severely injured areas as described by Baker et al. [2]. Injury severity score for these transported patients was assigned from description in the transport records, vital signs, and was verified by three of the authors.

Facility	Age	Sex	Reported Injury	Transport Mode	ISS
OSU Medical Center	36	M	Head and jaw trauma (Immobilized)	Ambulance	9
	50	M	Laceration to finger	Ambulance	4
	48	M	Head trauma—no spinal immobilization	Ambulance	4
Hillcrest Medical Center	23	F	Back pain (immobilized)	Ambulance	9
	25	M	Head trauma (immobilized)	Ambulance	9
	55	M	Leg pain	Ambulance	4
	24	F	Closed head injury	Ambulance	9
St. Francis Hospital	40	M	Head and neck pain—LOC	Ambulance	16 + 4 = 20
	39	M	Head injury (immobilized)	Ambulance	9
	33	F	Shoulder trauma. Head injury—immobilized	Ambulance	4 + 4
	32	F	Hit on head by tent pole (immobilized)	Ambulance	9
Southcrest Hospital	29	M	Head laceration	Ambulance	9
	42	F	Hip pain, right ankle pain, left elbow pain	Ambulance	4 + 4+ 1
	26	F	Back pain	Ambulance	9
Saint Francis South Hospital	32	M	Facial and eye injuries	Transit bus with paramedic	4
	57	M	Leg injury (abrasion)	Transit bus with paramedic	1
	1	F	Scalp injury	Transit bus with paramedic	4
	44	M	Leg injury	Transit bus with paramedic	1
St. John Medical Center	54	F	Back pain	"Walking wounded" Ambulance EVAC	4
	48	F	Back pain (immobilized)	Ambulance	9
	34	M	Head laceration (immobilized)	Ambulance	9
	54	M	Head trauma (immobilized)	Ambulance	9
	46	F	Spinal Trauma (immobilized—paralyzed)	Ambulance	25
Totals	A total of 23 patients were identified as transported to a Tulsa emergency department from the Oktoberfest tent collapse.				

The details presented and described Previously comprise the City of Tulsa's emergency services response to the uncommon consequence of a common natural hazard in Oklahoma. EMSA had nine ambulances staffed by 21 paramedics and EMTs and seven supervisors who coordinated triage, transport, and logistics with the Tulsa Fire Department and Tulsa Police Department.

Although this was a structural collapse, the response scene at the time of emergency services personnel arrival was structurally safe. All power lines were rendered safe by the Oktoberfest management within moments of the incident, so Tulsa Fire Department actions were allocated completely to patient care without the competing needs of fire suppression, structural stabilization, or hazard mitigation.

4.1. Role of the Media. The media plays a vital role during disasters as the chief source of public information [16]. Mass communication is also critical to public safety to ensure that appropriate information is passed to the public and panic is prevented. The media has to be monitored and handled with care, so information is delivered as precisely as possible during a disaster. This event was no exception.

During the Oktoberfest tent collapse, the police department staged the media across the street from the tent collapse and the triage areas. This location gave them event coverage, preserved patient confidentiality, and ensured that media did not negatively impact clinical operations during the event. The police department managed the media until the Public Information Officer (PIO) for EMSA arrived, approximately 50 minutes after the initial 911 calls. There was some difficulty with her gaining access to the scene that further delayed EMSA management of the media response.

Local television, radio, and newspaper agencies were present on site. Information was given by telephone to some state and national media outlets, though most used local affiliate reports. Briefings occurred and individual interviews were granted on site through 2200 hours; telephone and e-mail updates were provided through the overnight hours and

Table 2

Facility	Age	Gender	Reported Injury	Outcome
OSU Medical Center	48	M	Back and head injury	Treated/Released
	37	M	Back and neck pain	Treated/Released
	57	M	Finger injury	Treated/Released
Hillcrest Medical Center	??	??	Head laceration	Treated/Released
St. Francis Hospital	23	M	??—Oktoberfest mentioned in patient history	Treated/Released
	33	F	??—Oktoberfest mentioned in patient history	Treated/Released
	41	M	??—Oktoberfest mentioned in patient history	Treated/Released
	25	F	Hit on head by tent pole	Treated/Released
	38	M	Hit on head by tent pole	Treated/Released
	29	M	Hit on head by tent pole	Treated/Released
	53	F	??—Oktoberfest mentioned in patient history	Treated/Released
Southcrest Hospital	Southcrest Hospital stated that they had 9 presenting patients but would not provide any further information.			
Saint Francis South Hospital	45	M	Leg injury	Treated/Released
St. John Medical Center	St. John Medical Center stated that they had 4 presenting patients but would not provide any further information.			
Totals	A total of 25 patients were identified as self-presenting to a Tulsa emergency department and related to the Oktoberfest tent collapse.			

the following day. Local reports conveyed key messages (such as, "Citizens should not report to the site") and positively portrayed rescue efforts for the two-hour event. The six local hospitals experienced no problems with the media at their facilities. A press briefing was given the day following the tent collapse, and all hospitals, EMSA, Tulsa Fire Department, and other responders were represented in this briefing.

4.2. After-Action Report. Several important points were made during after-action discussion. Multiple agency-specific debriefings occurred. A multiagency debriefing was co-coordinated by the Tulsa Area Emergency Management Agency and was well attended by all participants. There was widespread acknowledgement that tent collapse should be a factored hazard of severe weather. Specific to this event, the following items were identified for further hazard planning education and operations.

(1) In this crowded nighttime venue, it was difficult for EMS and fire providers to locate the command post and patient collection area.

(2) NWS weather warnings should have been distributed to the event planners.

  (a) With the abundant warning of the oncoming storm, evacuation of the event would have been relatively easily accomplished in a timely fashion.

  (b) This would have prevented all injuries to the crowd.

(3) A map of the event area and location of tents should have been provided to EMS, fire, and police providers so that orientation of incoming units could be planned and coordinated.

  (a) Although the map in Figure 2 was available online, there were no copies distributed to police, fire, or EMS. Indeed, responding supervisors found a different placement of tents than was depicted on the map which ultimately proved representative of the 2006 Oktoberfest.

  (b) Emergency access and egress lanes should be planned/provided for fire, police, and EMS vehicles.

(4) Further training about triage and triage tag use for multiple casualty responses was requested.

(5) EMS/fire supervisors should be integrated in weather warnings and have access to weather channels.

(6) The city of Tulsa is considering "special event" planning for large attendance community events. Specific requirements would include hazard(s) identification and emergency service command post, patient treatment and transport sectors, and staging point location determinations as well as ingress and egress routes.

Appendices

A. Interview Script

Tulsa MMRS Oktoberfest Injury Analysis Interview Script

All interviewees must be informed before interview.

(1) All answers are voluntary. You may decline to participate. There is no requirement to complete the questions once started. If you wish that the information given not included in the final paper, you may request that at any time before the research is published.

(2) Please make responses general to protect the anonymity of responders and civilians.

(3) This is a confidential interview.

(4) No personal information will be recorded.

These questions concern the October 17, 2007, Medical Response at the Oktoberfest in Tulsa, Oklahoma.

(1) What was your general role during the response?

(2) How were you notified of the incident?

(3) What do you think were the biggest strengths of the response?

(4) What are you most impressed by in this response?

(5) What is your opinion of the coordination of agencies during the response?

   (a) How could this be improved?

(6) What was the most hazardous problem you encountered in providing patient care?

   (a) How did you deal with it?

(7) How do you think this incident could have been mitigated (lessened) or prevented?

(8) What were the biggest problems that you encountered during the incident?

(9) Do you have any ideas that might improve a medical response to such an incident in the future?

(10) How did your previous training or experience prepare you for this incident?

(11) What actions would you change that happened during this incident?

(12) What actions really worked during this incident?

(13) How can we improve next time this happens?

(14) Do you have a story that helps illustrate this event?

B. The Weather Report

NATIONAL WEATHER SERVICE TULSA OK
1111 AM CDT WED OCT 17 2007
.UPDATE.....

SIGNIFICANT SEVERE WEATHER EVENT EXPECTED LATE THIS AFTERNOON AND
EVENING WITH THE POTENTIAL FOR STRONG/LONG LIVED TORNADOES...
LINE OF THUNDERSTORMS DEVELOPED IN RESPONSE TO A STRONG LOW LEVEL
JET OVER THE CENTRAL PART OF OKLAHOMA...AND WAS MOVING TO THE
NORTH NORTHEAST THIS MORNING...WITH STRONG TO SEVERE THUNDERSTORMS
OCCURRING WITHIN THIS LINE. THE MAJORITY OF THIS ACTIVITY WILL
AFFECT NORTHEAST OKLAHOMA INTO THE EARLY AFTERNOON...WITH STRONG
WIND AND MARGINALLY SEVERE HAIL POSSIBLE. THIS LINE WILL LEAVE A
TEMP/DEWPOINT GRADIENT ACROSS NORTHEAST OKLAHOMA...WHICH MAY
PROVIDE A FOCUS FOR THE LOCATION/MOVEMENT OF STORMS THAT DEVELOP
ALONG THE DRY LINE THIS AFTERNOON. THE TEMP GRADIENT MAY BE
FURTHER ENHANCED NOW THAT THE CLOUDS ARE BEGINNING TO THIN ACROSS
EASTERN OKLAHOMA AND NORTHWEST ARKANSAS.

C. Typical Severe Weather Clause in Tent Rental Agreement

Weather

Client understands that tents are temporary structures designed to provide limited protection from weather conditions, primarily sun and rain; however there may be situations, particularly those involving strong winds and lightning, in which the tents will not provide protection and may even be damaged or blown over. Evacuation of tents to avoid possible injury is recommended when severe weather threatens the area where the tents are erected. People must leave the tents and not seek shelter in tents during such conditions. It is best to evacuate when in doubt. Marquee Tent offers an on-sight technician during the event for an additional charge to assist with weather assessment and equipment maintenance. If client declines those services, client understands that it is client's responsibility to be aware of changing weather conditions and to exercise its best judgment with regard to the evacuation of tents. client agrees that in the event of a predicted or actual storm or excessive winds, Marquee Tents may dismantle any equipment that has been previously installed to ensure safety of all involved.

D. Critical Information Dissemination—Oktoberfest Event, October 17, 2007, National Weather Service, Tulsa

The wind damage that occurred across Tulsa County, including Oktoberfest, on the evening of October 17, 2007, was the result of a thunderstorm downburst. The downburst produced wind gusts of up to around 85 mph across Tulsa County, which resulted in fairly widespread straight-line wind damage. The peak measured wind gust during the event was observed at the Tulsa International Airport at around 727 pm, when an instrument measured an 85 mph gust. Wind gusts that were experienced at Oktoberfest were likely no more than 85 mph.

As noted in the product issuance timeline hereinafter, the National Weather Service issued a Tornado Watch that included Tulsa County at 226 pm, a Severe Thunderstorm Warning for Tulsa County at 702 pm, and a follow-up Severe Weather Statement to update the warning for Tulsa County at 714 pm. Estimated time of the Oktoberfest damage was at 723 pm.

The following information was disseminated from the NWS Office in Tulsa on October 17, 2007 preceding the damage in Tulsa County, which included the Oktoberfest Event. NWS Tulsa actually began highlighting the possibility of a significant severe weather event in its products as early as Friday, October 12. The following items *summarize* what was issued from this office in the preceding 18 hours.

151 am: Area Forecast Discussion highlighting "significant severe weather event late this afternoon and evening".

335 am: Zone Forecast Product "occasional showers and thunderstorms today—some thunderstorms may be severe this afternoon. Rain chance 90 percent. Showers and thunderstorms likely in the evening—some thunderstorms may be severe. Rain chance 60 percent."

345 am: Public Information Statement "review of severe weather safety rules" prior to "an outbreak of severe thunderstorms across eastern Oklahoma and northwest Arkansas", including tornado, lightning, hail, and damaging straight-line wind.

500 am: Hazardous Weather Outlook "severe weather outbreak expected by late afternoon and evening with the possibility of strong tornadoes…large hail and damaging straight-line winds".

743 am: Tornado Watch 708 until 4 pin including Tulsa County and surrounding counties.

924 am: Area Weather Summary "severe weather anticipated".

1028 am: Zone Forecast Product updated to increase evening rain chance to 70 percent.

1111 am: Area Forecast Discussion "significant severe weather event expected late this afternoon and evening".

1153 am: Hazardous Weather Outlook "significant risk of tornadoes, hail to baseball size and wind gusts to 75 mph".

1200 pm: GoToWebinar briefing for Emergency Managers and state officials; TAEMA attended the briefing.

1245 pm: telephone briefing for TAEMA, which included timing of severe weather into Tulsa County that evening, possibility of tornadoes, hail to tennis ball size, and wind gusts in excess of 80 mph with severe storms.

1248 pm: Area Forecast Discussion "a second round of strong to severe thunderstorms could move into the forecast area by 1930z".

144 pm: Significant Weather Alert through 230 including Tulsa for small hail and 50 mph wind gusts.

221 pm: Area Forecast Discussion (mesoscale) increasing severe weather threat this afternoon; increasing tornado potential this evening.

222 pm: Significant Weather Alert through 3 pm including western Tulsa County for small hail and 50 mph wind gusts.

226 pm: Tornado Watch 711 through 10 pm including western Tulsa County and surrounding counties.

230 pm: Zone Forecast Product updated to include new tornado watch and to increase rain chance tonight to 80 percent.

241 pm: Area Forecast Discussion (mesoscale) severe potential increasing with ongoing storms in eastern Oklahoma and round 3 developing on dry line to the west.

245 pm: Significant Weather Alert through 330 pm including Tulsa County for small hail and 50 mph wind gusts.

257 pm: Area Forecast Discussion "parameters continue to align for a significant severe weather outbreak this evening".

331 pm: Significant Weather Alert through 415 pm including Tulsa County for small hail and wind gusts to 50 mph.

346 pm: Severe Thunderstorm Warning through 445 pm for Tulsa County (penny hail and wind gusts to 60 mph).

354 pm: Severe Weather Statement updating warning (penny hail and wind gusts to 60 mph).

401 pm: Area Forecast Discussion (mesoscale) numerous reports of downed trees in Tulsa and wind gust of 62 mph in west Tulsa; thunderstorms in central OK will move into the area this evening and significant wind damage…very large hail…and tornadoes are likely.

413 pm: Severe Weather Statement cancelling SVR for Tulsa County.

415 pm: Local Storm Report noting several high wind and hail reports for Tulsa County.

633 pm: Severe Thunderstorm Warning though 745 pm for Creek County (penny size hail and 60 mph wind gusts).

634 pm: Short Term Forecast through 745 pm "strong to severe thunderstorms will be affecting portions of" Osage… Pawnee.. Washington… Creek… Okfuskee…Tulsa…and Nowata Counties.

639 pm: Area Forecast Discussion (mesoscale) increasing severe weather threat with storms moving northeast from Lincoln County.

702 pm: Severe Thunderstorm Warning through 815 for Tulsa County (penny size hail and 60 mph wind gusts).

708 pm: Hazardous Weather Outlook addressing tornado potential, golf ball size hail and wind gusts to 80 mph (potential).

713 pm: Severe Weather Statement updating Creek County warning (penny size hail and wind gusts to 70 mph).

714 pm: Severe Weather Statement updating Tulsa County warning (wind gusts to 70 mph).

727 pm: Local Storm Report mentioning thunderstorm wind damage at Oktoberfest at 723 pm with injuries; penny hail report 3 miles east of Sapulpa at 719 pm.

731 pm: Severe Weather Statement canceling Creek County warning.

728 pm: Local Storm Report mentioning thunderstom1 wind gust of 63 mph at Tulsa International Airport.

737 pm: Severe Weather Statement updating Tulsa County warning (wind gusts to 70 mph).

8 11 pm: Severe Weather Statement expiring Tulsa County warning.

Conflict of Interest

No author has an ethical or financial conflict of interest.

Acknowledgments

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Review Article

Subcutaneous Fluid Administration: A Potentially Useful Tool in Prehospital Care

Annette O. Arthur, Jeffrey M. Goodloe, and Stephen H. Thomas

Department of Emergency Medicine, School of Community Medicine, The university of Oklahoma-Tulsa, Tulsa, OK 74135, USA

Correspondence should be addressed to Annette O. Arthur, annette-arthur@ouhsc.edu

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Mass casualty incidents (MCIs) and disaster medical situations are ideal settings in which there is need for a novel approach to infusing fluids and medications into a patient's intravascular space. An attractive new approach would avoid the potentially time-consuming needlestick and venous cannulation requiring a trained practitioner. In multiple-patient situations, trained practitioners are not always available in sufficient numbers to enable timely placement of intravenous catheters. The novel approach for intravascular space infusion, described in this paper involves the preadministration of the enzyme, human recombinant hyaluronidase (HRH), into the subcutaneous (SC) space, via an indwelling catheter. The enzyme "loosens" the SC space effectively enhancing the absorption of fluids and medication.

1. Introduction

Hyaluronidase-facilitated subcutaneous infusion (HRH-SCI), also denoted by "enzymatically assisted subcutaneous infusion" (EASI), appears based upon available evidence to be an easy, safe, and effective means of infusing fluids and some medications into the intravascular space. The relevance of EASI to the prehospital setting appears to be highest in the disaster/MCI arena, where there may be limited numbers of practitioners treating numerous persons. In short, EASI may be a partial solution to the problem of mismatch between numbers of patients requiring intravascular access and capabilities of available providers to provide that access.

Building on reports of EASI use in other settings, namely, in hospice care and in pediatric patients, prehospital investigators have assessed EASI as placed by first EMT-paramedics (EMT-Ps) [1] and then in a follow-up study with EASI placed by EMT-basic (EMT-B) level providers [2]. In its first two studies in simulated prehospital situations, EASI access was placed with 100% effectiveness and no significant complications.

This paper is not intended to be a comprehensive treatment of the complex subject of prehospital vascular access and fluids/medication administration. Rather, the intent is to briefly outline the possible role for a novel approach to the long-standing challenge of access. The paper will open by making a case for the need to investigate new avenues for intravascular access. Next, we will outline the existing work with EASI access and infusion as performed by prehospital personnel. The paper concludes with consideration of potential future directions for EASI research and application.

2. The Rationale for Considering a Novel Route of Access to the Intravascular Space

2.1. Importance of Intravascular Access. The most vital component of the case for importance of access to the intravascular space is the consistent message in the literature, that out-of-hospital hydration is often critical. Experts aver that administration of fluids in the out-of-hospital setting remains an important intervention in disaster and MCI circumstances [3–5]. Clinical practice as well as standard emergency medicine and trauma resuscitation teaching emphasizes the importance of early fluid resuscitation for a variety of injuries and illnesses [5]. The literature addressing MCI situations (e.g., crush injuries) makes a strong case for the importance of fluid replacement [3]. Therefore, for fluid resuscitation alone, there is a strong case to be made that access to the intravascular compartment is an important priority for prehospital providers (particularly in disaster/MCI situations). Fluid administration as considered herein includes glucose-containing fluids such as D_5NS (normal saline with dextrose 5%).

2.2. Challenges in Obtaining Vascular Access in the Out-of-Hospital Setting. Despite the widespread acknowledgment of the importance of prehospital intravascular access, obtaining that access through the traditional intravenous (IV) line is not always simple. As is the case with many other procedures, that which is usually straightforward in the hospital and emergency department (ED) setting can be difficult in the field.

The out-of-hospital setting can pose special challenges to the provider attempting to gain access to the intravascular compartment. These challenges can be categorized as being related to establishing an individual patient's IV, or those being related to establishing access in a large number of patients.

In an individual patient encounter, placement of an IV catheter may be hampered by a number of situations. The anatomy may be difficult, as is the case with venous collapse in hypotension. Positioning issues (e.g., entrapment) may render it difficult to reach the vein. IV access placement problems may be compounded by environmental conditions ranging from inadequate lighting to jarring vehicular motion.

In daily practice in the single-patient setting, experienced field practitioners usually rely on training and experience as they overcome IV access difficulties and achieve access. Nonetheless, there are certainly cases in which the problems are not surmounted and prehospital IV access either fails or requires multiple attempts. In these situations, there may be room in the prehospital armamentarium, for a new approach to the intravascular compartment.

The situation with respect to multiple-patient encounters (such as MCI situations) may be characterized by just the same problems as those described for individual attainment of prehospital IV access, but on a larger scale. A few-minute delay in attaining IV access in an individual patient is not often life threatening. That same delay can cause major morbidity in a situation in which a small group of providers is faced with starting dozens of IVs in a difficult situation. In a disaster or MCI situation, there may actually be insufficient healthcare provider resources to place IV access in a timely fashion, even if the IV placement goes smoothly in each individual patient. A lesser concern, but one warranting mention, is the fact that repeated venipuncture attempts may cause pain that is rated as "significant" by patients and parents [6–11].

The "bottom line" of the challenges that can face prehospital providers attempting to establish IV access in the field is that in some cases there is room for a new approach. Whether the problem is repeated IV "sticks" in a given patient, or the need to establish dozens of intravascular access lines in a short time period, there is potential utility in a rapid, easily taught, and simple system for establishing reliable access to the intravascular compartment.

2.3. Limitations in Alternatives to IV Access. The need for assessing alternative mechanisms for intravascular compartment access has already been recognized. Noting the significance of the problems that can occasionally be encountered in the field execution of IV access, trauma researchers have investigated alternative methods of hydration, such as proctoclysis, infusion of fluids into the rectum [12]. If the need for alternative methods of fluid administration is sufficient to prompt serious consideration of proctoclysis—the drawbacks of which are not limited to impracticality, the search for alternative routes to the intravascular compartment should include SC infusion (which is much easier to place and better tolerated).

The main alternative at this time, to IV access, is the intraosseous (IO) line. Just as IV cannulation is the usual answer to the question of how to obtain intravascular access, IO access has historically been the (only) alternative approach. To be clear, there is a definite role for IO lines in out-of-hospital care. However, the myriad situations that may be encountered in the field, combined with the disadvantages of IO lines, make a case for assessing viability of a non-IO approach. IO lines have an acknowledged role in prehospital medicine, but their risks include pain, extravasation, infection, and fracture. IO placement is not necessarily quick, and the capability to perform the procedure requires initial and ongoing skills maintenance [13, 14]. One study found that while 18 of 19 IO lines appeared to be correctly placed on initial attempt, there were 5 cases with serious complications (e.g., dislodgment, extravasation, failure of infusate to flow), leading to an overall IO success rate of 68% [14]. In about a third of the cases, IO placement required over a minute to establish [14].

The just-cited literature does not mean that there is not a role for IO lines in out-of-hospital care. IO is occasionally useful (and even life saving). However, the limitations of IO and other currently used alternatives to IV access do leave room for assessment of a possible role for a new mechanism to get to the intravascular space.

3. Existing Evidence and Method for Use of Subcutaneous Infusion

3.1. Physiology of HRH-Assisted SC Infusion. A now-outdated term for SC fluid infusion, "hypodermoclysis," was in use for decades [15]. For all practical purposes, the practice ceased in the USA with the arrival of modern IV catheter equipment, but SC infusion is still in use in some settings [15, 16]. In addition to the fact that "new" (nonmetal) IV catheters were simple to use and quite safe, hypodermoclysis abandonment was due in part to the physiology of the SC interstitial matrix which serves as the main barrier to diffusion of SC-administered fluid.

The extraadipocyte portion of the SC compartment is a gel-like matrix of collagenous fibrils and glycosaminoglycans. Subcutaneously administered drugs and infusates must traverse this interstitial matrix to enter the vascular or lymphatic system. The interstitium resistance to drug permeation can be envisioned as functioning like a three-dimensional filter through which drugs/infusates must pass. There are large molecules such as elastin and collagen inhabiting a matrix of hydrated gel-like glycosaminoglycans and proteoglycans. Among the most important glycosaminoglycans (for purposes of this review) is hyaluronan, which contributes to the resistance of fluid flow through the interstitium. Though hyaluronan is found in lower concentration than collagen in the skin, it plays a disproportionately large role in resisting fluid movement [17].

Hyaluronidase modifies connective tissue permeability via hydrolyzing hyaluronic acid, effecting a cleavage of the glucosaminidic bond between *N*-acetylglucosamine and glucuronic acid moieties. The cleavage results in a decrease in viscosity of the cellular cement and promotes diffusion of injected fluids, facilitating their absorption. The decrease in viscosity is reversed within 24 hours, due to the rapid inactivation of the hyaluronidase enzyme and also due to the rapid turnover rate of skin hyaluronan [18–20].

Hyaluronidase-spreading agents, historically derived from animal extracts, have been used clinically to facilitate dispersion and absorption of other drugs for over 50 years [18]. This long history of successful use contributed to a relatively rapid FDA approval for HRH (in 2005), which states the drug is "indicated as an adjuvant to increase the absorption and dispersion of other injected drugs, for hypodermoclysis, and as an adjunct in subcutaneous urography for improving resorption of radiopaque agents" [21].

3.2. EASI Access to the Intravascular Compartment. The HRH used in the most recent literature on SC infusion has as its main advantage over previous hyaluronidase products the absence of immunogenicity. As a human recombinant agent, HRH poses far less allergy/anaphylaxis risk (essentially, none) as compared to animal-derived hyaluronidase. The HRH otherwise works as described above, in facilitating "spread" of fluids and medications administered into the SC space.

The concept of using HRH in actual patients has been demonstrated feasible and effective. The initial clinical experience concentrated on the hospital and hospice settings [18, 22]. Hospice patients needed indwelling catheters for delivery of fluids and analgesia, and pediatric patients in the hospital benefited from rapidly placed lines that served as a mechanism for hydration [23]. These studies revealed that the HRH-facilitated hydration was very easily placed, lasted for many hours (or days) without complication, and alleviated the need for IVs.

The studies with the most likely relevance to the prehospital and MCI situation are probably the EASI Access I and EASI Access II trials (conducted in part by some of this review's authors) [1, 2]. These studies are important, because of two major "new" angles: (1) institution of HRH-facilitated infusion lines by prehospital providers and (2) use of stable-isotope labeling techniques to definitively demonstrate rapid and significant uptake into the intravascular compartment of SC-infused (glucose-containing) fluid.

In EASI Access I, 4 EMT-Ps instituted EASI access in 20 healthy volunteers. The EASI access lines were successfully placed in under 15 seconds, in all study subjects. Normal saline with 5% dextrose (some of which was ^{13}C-labeled) was infused at rates that were held at no more than 150 mL/hour. Gas chromatography/mass spectrophotometry (GC/MS) was used to demonstrate uptake of the isotopic glucose in the infusate, as early as 15 minutes into the infusion (this was the first time of analysis). Since the EASI access lines were placed more quickly than IV lines, and since the infusates were administered with zero significant adverse effects, the study concluded that EMT-P administration of fluids and glucose via EASI was likely a viable option for some prehospital circumstances.

EASI Access II followed up the result of EASI Access I, by assessing the placement of HRH-facilitated SC infusion lines by EMT-Bs. This was undertaken after the EASI Access I investigators observed that the placement of the EASI access lines appeared to require very little medical expertise and minimal training. EASI Access II main findings were (1) confirmation of rapid and consistent uptake of SC-infused labeled glucose (as detected with GC/MS at the first assessment time, 5 minutes into infusion) and (2) demonstration of 100% success rates in rapid and effective establishment of EASI access in 18 subjects by 18 EMT-B practitioners (the same 18 individuals served as both study subjects and the EASI line placement operators). In EASI Access II, the infusate of 5% dextrose in water (D_5W) was administered at a median rate of 400 mL/hour.

3.3. Mechanism for Use of EASI Access. One reason that EASI access appears to be attractive for use in the prehospital setting is that the technique requires minimal training and little in the way of additional supplies. The EASI Access I and II studies each entailed no more than 5–10-minute training (time varied depending on time required by each subject to reach comfort level). Furthermore, the HRH used comes in unit-dose vials that are easily reconstituted before being administered through an initially placed SC line in a dose of 150 units (1 mL).

First comes placement of the SC line. A fold of skin—preferably on the upper back as this area is accessible and allows for painless fluid administration—is pinched (Figure 1). Into the fold is placed a standard IV catheter; 22- or 24-gauge catheter works well but sizes can be varied (Figure 2). After the catheter is taped into place, HRH is administered into the catheter in a painless step that begins by thinning of the SC tissues. Finally, standard IV tubing is to be connected and secured. A photo of an EASI line in place is depicted in Figure 3.

It is noteworthy that the upper back location is not required. Any location that is accessible in a given situation may serve as the access point for an EASI line. Locations in

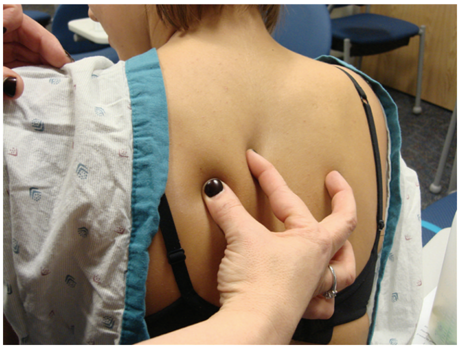

Figure 1

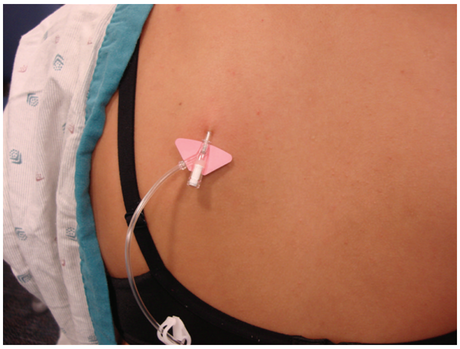

Figure 2

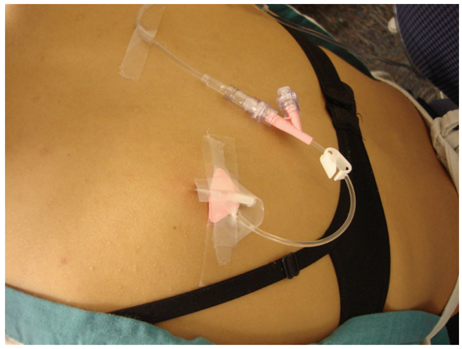

Figure 3

which the subcutaneous space may be "tight" (e.g., dorsum of the hand) may theoretically be associated with infusion discomfort that is not seen with locations in the upper arm or the back.

Regardless of where EASI is placed, it is sensible to begin with a low infusion rate, increasing the fluid infusion pace only after confirmation of painless infusion at lower rates. The authors have found that infusion rates in the 400 mL/hr range are easily attainable (and painless) [1, 2]. Other investigators have used small-gauge catheters (24 g) and infused isotonic solution (lactated Ringer's) with no discomfort, at maximal gravity-assisted rates exceeding 500 mL/hr [24].

The best fluid to be chosen is probably the one that contains glucose. Glucose is an important component of fluids in prehospital (especially MCI) situations, and EASI Access I and II clearly demonstrated rapid and significant uptake of EASI-infused glucose into the intravascular space [1, 2]. Palliative care and hospice data include reports of painless administration of a breadth of fluids including normal saline (NS) and variants with and without dextrose (e.g., D_5NS, D_5 0.5 NS); 5% dextrose in water (D_5W) has also been infused without problems [25].

4. Future Research and Practice Directions

The preceding information paints a tantalizing, if incomplete, picture of a novel method of fluid administration. Since IV access is markedly more of a problem in the prehospital setting than in the hospital, and since the difficulties are magnified in MCI situations, the relevance of EASI access to out-of-hospital care may prove to be high.

One question that arises is whether prehospital providers can adjudicate which cases may be appropriate for SC infusion. Just as prehospital providers currently exercise (protocol-guided) judgment as to who requires IV (or IO) access, those providers can appropriately triage patients to SC infusion. It appears possible that, in some cases where IV access fails, SC may be a more viable option for rapid fluid and medication administration than IO (e.g., when patient requirements are for minimal fluids and rapid analgesia). The guidance for prehospital personnel and respondents to disasters or MCIs will need to include consideration of both individual patients and aggregate situations.

The existing literature demonstrates administration of a variety of fluids, as well as glucose and opioid analgesia (in the palliative care setting) [15, 24, 25]. Future focus should include assessment of which agents may be administered via EASI, with safety and efficacy. Fluids and analgesia are a reasonable starting point (especially since the latter may be given both SC and IV already), but there remain possibilities for other agents' administration (e.g., midazolam) after appropriate research.

In our area, meteorological disasters (especially tornadoes) occur with unfortunate frequency. Situations in which dozens (or scores) of patients with mild-moderate injury, who need fluid resuscitation, are easily imagined. Our next EASI Access III study is planned to include administration of EASI access in actual prehospital patients for whom IV access fails and in whom prehospital providers do not judge IO placement as appropriate. This study will be a good assessment of the use of EASI access in routine prehospital fluid administration. HRH is also being planned for utilization with our local disaster response teams, in anticipation of caring for large numbers of patients or individual disaster patients with need (e.g., entrapment and no IV access). Another use of EASI access worthy of investigation is its effect on subsequent IV access attempts in patients who need improved intravascular volume or with increased interstitial edema.

It appears that the existing evidence, while not establishing a concrete role for EASI access in the prehospital setting, does support the continued investigation of this

FDA-approved approach for fluid resuscitation in the field. Time will tell whether SC infusion proves a useful part of the prehospital and disaster armamentarium.

Disclosure

The investigators have had unrestricted grant support from the manufacturer of the FDA-approved human recombinant hyaluronidase (HRH), to study the administration of HRH by prehospital providers. The manufacturer had no control over either study design or reporting for the funded studies, and the manufacturer did not provide support for this review.

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Research Article

EMS Stretcher "Misadventures" in a Large, Urban EMS System: A Descriptive Analysis of Contributing Factors and Resultant Injuries

Jeffrey M. Goodloe,[1] Christopher J. Crowder,[2] Annette O. Arthur,[1] and Stephen H. Thomas[1]

[1] *Department of Emergency Medicine, University of Oklahoma School of Community Medicine, Tulsa, OK, USA*
[2] *College of Medicine, The University of Oklahoma Health Sciences Center, Oklahoma City, OK, USA*

Correspondence should be addressed to Jeffrey M. Goodloe, jeffrey-goodloe@ouhsc.edu

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Purpose. There is a paucity of data regarding EMS stretcher-operation-related injuries. This study describes and analyzes characteristics associated with undesirable stretcher operations, with or without resultant injury in a large, urban EMS agency. *Methods*. In the study agency, all stretcher-related "misadventures" are required to be documented, regardless of whether injury results. All stretcher-related reports between July 1, 2009 and June 30, 2010 were queried in retrospective analysis, avoiding Hawthorne effect in stretcher operations. *Results*. During the year studied, 129,110 patients were transported. 23 stretcher incidents were reported (0.16 per 1,000 transports). No patient injury occurred. Four EMS providers sustained minor injuries. Among contributing aspects, the most common involved operations surrounding the stretcher-ambulance safety latch, 14/23 (60.9%). From a personnel injury prevention perspective, there exists a significant relationship between combative patients and crew injury related to stretcher operation, Fisher's exact test 0.048. *Conclusions*. In this large, urban EMS system, the incidence of injury related to stretcher operations in the one-year study period is markedly low, with few personnel injuries and no patient injuries incurred. Safety for EMS personnel and patients could be advanced by educational initiatives that highlight specific events and conditions contributing to stretcher-related adverse events.

1. Introduction

The majority of patient transportation in the prehospital emergency medical care environment involves the use of mobile stretchers. Stretcher utilization occurs in three distinct phases: (1) unloading from the ambulance; (2) loading into the ambulance; (3) transporting over surface structures. Several commercially manufactured devices have been designed to best accomplish these activities. Constraints on the stretcher system are myriad, including weight and size of the patient, ease of use, and durability. With these limitations in mind, finding the balance of performance and safety is an important mission.

Thus, ambulance stretcher operations constitute a necessary, yet risky, part of the provision of prehospital emergency medical services. Despite generally widespread acknowledgement of risk to patient and EMS professional alike, there remains a paucity of data addressing ambulance stretcher associated injury analysis. A review of the past decade's literature in the PubMed database (http://www.ncbi.nlm.nih.gov/pubmed) searching with the unrestricted term of "ambulance stretcher" yields few relevant investigations [1–5]. With the noted exception of Wang et al., these studies are largely simple ergonomic evaluations in nature. Wang et al. used the United States Food and Drug Administration's Manufacturer and User Facility Device Experience database to describe adverse events related to the ambulance stretcher. Their dataset captures significant events over a large time period. However, due to lack of a "denominator" (i.e., total number of transports over which stretcher mishaps were analyzed), they are unable to define an event rate. It is also likely that many stretcher events—perhaps some significant—went unreported to the USFDA database.

While helpful in reminding EMS professionals that physical stressors are attendant to stretcher operations, the lessons of nearly all extant literature can best be summed as being primarily risk assumptive, without analysis of actual injuries sustained. Wang et al. provides the lone peer-reviewed study (to our knowledge) of any data measuring the injuries related to stretcher "adverse events."

As many in EMS will know, there is widespread recognition of the potential for EMS professionals to sustain back injury in the performance of basic patient transportation. Many entrepreneurial ventures utilize this concern of back injury risk in marketing new stretcher designs and stretcher lifting and loading capabilities. Certainly, no national organization tracks all relevant incidents of ambulance stretcher-related injuries. In the present era, despite the presence of many groups advocating for increased safety in prehospital emergency medical care, it appears unlikely there will be significant movement towards comprehensive reporting that could facilitate widespread evidence-based progress in limiting stretcher-related injuries.

Against this important background, we sought to critically analyze the types and frequencies of injuries sustained by patients and EMS professionals directly related to stretcher operations occurring in a large, urban EMS system in the southwestern United States. This investigation was additionally conceived to design educational initiatives for purposes of injury prevention as well as to add knowledge in this important, yet underreported, arena.

2. Methods

2.1. Study Design. This was a retrospective, observational study of all patient transports conducted in a single large, urban EMS system. The event of interest was an injury sustained by a patient and/or EMS professional directly related to use and operation of the stretcher.

2.2. Study Setting and Population. The study EMS agency, Emergency Medical Services Authority (EMSA), is a public utility model agency serving central and metropolitan Oklahoma City and Tulsa, OK. The two geographical service areas combined comprise approximately 1100 square miles and are populated by 1,201,232 residents. [6]. In this study year, EMSA's ambulance fleet was comprised of 93 Type I modular units on the Ford F450 chassis. Ambulance design met federal emergency vehicle specifications [7]. The nonpowered, manual-lift stretchers were uniform, manufactured by Stryker Corporation, Portage, MI. There were no changes in stretcher design or operation during the study year. All EMS personnel operating the stretcher had received formal one-hour stretcher operation instruction, designed to thoroughly orient each personnel to the loading, movement, and unloading mechanisms of the stretcher. One stretcher type and model is exclusively utilized throughout the study EMS agency. Immediately after-instruction, all personnel exhibited desirable stretcher operation ability during 20–30 minutes of practical assessments involving loading, movement, and unloading exercises supervised by training officers. Personnel must complete the didactic and practical components described prior to unsupervised duty. An annual continuing education forum regarding patient safety is conducted, including brief discussion of patient movement responsibilities, though no formal ongoing education is scheduled to replicate the initial stretcher-related education. All field personnel at EMSA are certified at a minimum at the EMT level. Ambulance tours are 12 hours in duration. Ambulances are located throughout the service area, utilizing system status management designated posts.

2.3. Study Protocol. EMSA mandates that all adverse events related to stretcher transport of a patient, however minor in force or resultant injury, are reported by the involved EMS personnel utilizing incident reporting; these reports, with details entered as free text, are logged and maintained in a computerized database (Ninth Brain Suite, NinthBrain, Grand Rapids, MI). The study period was chosen by convenience and by inclusion of all weather seasons to be from July 1, 2009 to June 30, 2010.

All stretcher-related incident reports related to patient movements during this study year were queried. These incident reports were compiled by the Safety and Risk Manager for EMSA and reviewed in detail by two of the researchers (CJC, JMG) for appropriate inclusion in the study as well as for agreement upon descriptive characteristics of contributing factors and sustained injuries.

Data recorded included the nature of the adverse event as well as any documented contributing factors, patient body habitus if notably obese, patient behavior if notably combative or otherwise physically disruptive, timing of incident (e.g., loading), and presence of suspected injury to the patient and/or EMS personnel. All events were categorized into three time periods: unloading, loading, and surface movement. Subtype characterizations included equipment failure, safety latch malfunction, poor surface conditions, obese patient, and uncooperative patient. The data were abstracted into a spreadsheet using Microsoft Excel (Microsoft Corporation, Redmond, WA).

2.4. Outcome Measures. The primary outcome measure was the rates of stretcher operation associated injury to patients and to EMS professionals. These rates were assessed using the analytical methods described below. The secondary outcome measure was assessment of the particular contributing factors and timeframes of stretcher operation associated with stretcher-related incident reports filed by EMS personnel. *A priori* analytical emphasis was placed upon unloading or loading patients. These timeframes are generally accepted as events of requiring higher energy to safely move patients, and thus, events that seemed particularly likely to contribute to injury.

2.5. Analytical Methods. The primary analytic approach followed the general lines of the reporting in the previous study by Wang et al. Because of our having the total number of "exposures" (transports), we were also able to execute event rate calculations.

The number of stretcher events was determined, and an event rate per 1,000 transports was calculated; 95% Poisson

Table 1: Timing of stretcher-related adverse events ($n = 23$).

Timing of event	Number of events	Percent of total events	95% CI
Unloading	15	65.2	42.7–83.6
Loading	5	21.7	7.5–43.7
Surface Movement	3	13.0	2.8–33.6

confidence intervals (CIs) were then calculated around the overall estimate for event rates. For construction of CIs in which the point estimate was zero (e.g., patient injuries), a one-sided 97.5% CI was calculated. For proportional data (e.g., percentages of stretcher events with crew injury), binomial exact 95% CIs were calculated.

For comparative analyses, lack of overlap between CIs was taken as indicative of statistical significance. For tabular data, results were analyzed using Fisher's exact text. For analyses, significance was defined at the $P < 0.05$ (95% CI) level. STATA 11 MP (StataCorp, College Station, TX) was used for all testing.

2.6. Institutional Review Board Review. This study protocol was reviewed and approved by The University of Oklahoma Health Science Center Institutional Review Board.

2.7. Study Association and Funding. The entire costs of this study were borne by EMSA and the OU Department of Emergency Medicine. Stryker Corporation (the manufacturer of the stretchers utilized throughout the study period) had no association with (or knowledge of) this study. Stryker Corporation did not fund the study and did not provide study-associated product pricing to EMSA.

3. Results

During the study year period, the EMS agency transported 129,110 patients. There were 23 adverse stretcher events reported, yielding an event rate of 0.018 per 1,000 transports. Stretcher events were relatively evenly divided (44% and 56%) between the service's two geographic locations (Oklahoma City and Tulsa). There were no patient injuries (1-side 97.5% CI 0 to 0.28 per 1,000 transports). There were 4 EMS provider injuries, event rate 0.031 per 1,000 transports (95% CI 0.01 to 0.08 per 1,000 transports). All EMS injuries were minor and no time off was requested or required due to these injuries. These included 2 knee injuries and 2 back injuries.

The timing of reported adverse stretcher events was analyzed (Table 1). The majority occurred during unloading 15/23 (65.2%; 95% CI 42.7–83.6%). 5 of 23 (21.7%; 95% CI 7.5–43.7%) events occurred during loading and 3 of 23 (13.0%; 95% CI 2.8%–33.6%) events occurred during surface movement.

In addition to the timing of the event, we also investigated contributing factors (Table 2). In some cases there were multiple factors. The most common cause of an adverse event was a stretcher-ambulance safety latch malfunction 14/23 cases (60.9%; 95% CI 38.5%–80.3%). Poor surface conditions contributed to 4/23 cases (17.4%; 95% CI 5.0%–38.8%). In the four surface conditions reviewed each contributing to a stretcher/patient drop, two events were caused by wheels of the stretcher becoming caught in an uneven surface, specifically a crack in a paved road and on a gravel parking lot. The remaining two poor surface conditions were described as ice-covered sloping driveways contributing to both slippery movement and patient imbalance on the stretcher mattress. Equipment failure occurred in 3/23 cases (13.0%; 95% CI 2.8%–33.6%). In these three equipment failures reviewed, each contributing to a stretcher/patient drop, two events were caused by stretcher undercarriage failure. In one case, the undercarriage failed to lower by manual lever engagement during unloading. In the other undercarriage failure, the stretcher legs became stuck during a loading attempt. The remaining instance of equipment failure was described as the ambulance floor-mounted safety latch breaking while the stretcher was being unloaded. In 2/23 cases (8.7%; 95% CI 1.1%–28.0%), the patient being transported was over 450 lbs. In addition, in 2/23 cases (8.7%; 95% CI 1.1%–28.0%), the patient was uncooperative during the transport.

There was also no association ($P = 0.63$) between location, Oklahoma City or Tulsa metropolitan service area, and cause of incident (i.e., cot failure, crew error, patient factors, surface factors). There was also no association between location and whether stretcher events occurred during patient movement ($P = 0.11$). For other analysis, events from each of the two EMSA metropolitan service areas were combined.

Since there were no patient injuries, no analysis could be performed for factors associated with patient injury. Univariate analysis of the endpoint "crew injury" revealed an association between that endpoint and the type of stretcher problem: patient factors (weight) were positively correlated with increased risk of crew injury ($P = 0.048$). Overall numbers of outcomes were too low to allow for multivariate exploration of this endpoint. No other factor was found to have a significant associated with provider injury, although low event numbers precluded a robust statistical analysis.

4. Discussion

In this study, the incidence of adverse events related to stretcher operations is markedly, if not surprisingly, low. There were few personnel injuries and no patient injuries during the study period. Hawthorne effect was possible, but not likely due to retrospective study nature and study time comprising one year.

Anecdotally, the study service has rarely experienced adverse stretcher operations leading to lost work productivity and at least minor patient injury. For these reasons and in additional prevention efforts, this study was conceived to establish baseline stretcher-related adverse event and sustained injury rates to benchmark educational and operational initiative impacts. The study year was chosen at random and specifically was not chosen with any predetermination of results.

Table 2: Contributing factors to stretcher-related adverse events ($n = 23$).

Contributing factor	Number of events	Percent of total events	95% CI
Latch malfunction	14	60.9	38.5–80.3
Surface condition	4	17.4	5.0–38.8
Equipment failure	3	13.0	2.8–33.6
Pt weight >450 lbs	2	8.7	1.1–28.0
Pt uncooperative	2	8.7	1.1–28.0

While adverse events and resultant injury can occur during any phase of stretcher operations and due to multiple contributing factors, this study does help to delineate higher likelihood times and factors. The stretcher safety latch, mounted on the ambulance floorboard, proved prominent in this analysis of related factors. Adverse incidents more frequently occurred if the stretcher did not "catch" on this latch when being retracted from the ambulance, thereby preventing a more controlled unloading of the patient without unexpected carriage collapse, itself either partial or complete. The proper safety latch-stretcher interface, should be stressed to EMS personnel in both initial and continuing training regarding safe stretcher operations. It is important for EMS personnel to be aware of these composite results in order to further protect themselves and maintain patient safety.

Additional investigation into this topic is greatly needed to attain firmer established insights into necessary injury-avoidance training in ambulance stretcher operations. It is discouraging to find such paucity of available peer-reviewed data addressing results of specific interventions designed to improve related safety. Perhaps a prevailing belief that little can be done outside of generic safe movement and lifting instructions persists to an extent that few academic studies of EMS stretcher operations are endeavored. Clearly, new patient transport and lifting devices designed for EMS use encourage such inquiry; our hope is this study will serve as an impetus for further evaluation of such technology.

5. Limitations and Future Research

An obvious limitation of the study is dependence upon EMS personnel to self-report adverse events related to stretcher operations. Within the study agency, a culture of safety is fostered, promoting self-reporting of these incidents to assist in injury prevention, limiting concern of EMS personnel regarding untoward employment repercussion for such reporting. In reality, the repercussion of "not reporting" a later discovered event is substantially more stringent. Serious patient injury in this realm would most likely be additionally discovered through patient or legal surrogate complaint, including litigation initiation. Particularly minor injuries could have been missed by EMS providers, especially if not verbalized by affected patients.

Low absolute numbers of ambulance stretcher-related patient and EMS professional injuries occurring during the study period are markedly advantageous in injury prevention and operational efficiency paradigms. From an academic inquiry view, these low numbers are not given to form statistically robust conclusions. Thus, our results should be considered preliminary. Further similar data collection in this and other large volume EMS systems will aid in determining if a larger dataset will result in narrower confidence intervals with resultant higher statistical significance. Multivariate analysis of these suggested larger data sets will aid in determining if specific interventions are warranted against discrete types of situations more prone to ambulance stretcher-related injuries.

Additionally, EMS systems utilizing different stretchers may not find direct applicability of these findings.

6. Conclusions

In this large, urban EMS system, the incidence of injury related to stretcher operations in the one-year study period is markedly low, with few personnel injuries and no patient injuries incurred. EMS personnel should be aware of the risk of injury to themselves that can occur during stretcher operations when moving morbidly obese and/or combative patients. Safety for EMS personnel and patients could be advanced by educational initiatives that highlight specific events and conditions contributing to stretcher-related adverse events.

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Research Article

Patients Refusing Prehospital Transport Are Increasingly Likely to Be Geriatric

Peyton Holder, Annette O. Arthur, Grady Thiems, Travis Redmon, Matt Thomas, Jeffrey M. Goodloe, T. J. Reginald, and Stephen H. Thomas

Department of Emergency Medicine, OU Schusterman Center, University of Oklahoma School of Community Medicine, 4502 East 41st Street Suite 2E14, Tulsa, OK 74135, USA

Correspondence should be addressed to Stephen H. Thomas, stephen-thomas@ouhsc.edu

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Objective. Elderly patients are becoming an increasingly larger proportion of our population, and there is a paucity of data regarding the epidemiology of geriatric patients refusing transport. Treatment refusal rates range from 5% to 15% in many studies. This study sought to test the hypothesis that geriatric patients constituted an increasing proportion of those persons refusing prehospital transport. *Methods*. This study was a retrospective analysis of data from a query of a large urban EMS service. *Results*. There were a total of 22,347 adult transport refusals recorded during the 16-month study period. Multivariate logistic regression incorporating covariates for sex, race, season, chief complaint, metropolitan region, and whether any treatment occurred prior to transport refusal confirmed the increasing likelihood of Period 2 patients being geriatric, as compared with Period 1 (OR 1.24, 95% CI 1.14–1.35, Wald $P < .001$). *Conclusion*. This data shows that despite controlling for these covariates, patients refusing transport in the second period of this study were nearly 25% more likely to be geriatric as compared to those in the initial 8 months of the study.

1. Introduction

Emergency medical services (EMSs) are the system that is responsible for the prehospital treatment and transportation. When EMS is activated, they appropriately respond by arriving to give on the scene care. Of course, patients then have the right to receiving treatment and transportation or refuse one or both, against the advice of the treating paramedic (AMA). Treatment refusal rates range from 5% and 15%, in many studies [1–3]. Refusal of care or transport may happen for many reasons such as the patient not feeling they need further care and financial restraints. There may be negative outcomes associated with refusing treatment/transport, such as a subsequent Emergency Department (ED) visit, hospital admission, or even death.

Despite an increased emphasis on geriatric care, the health status of this age range is still meager. Elderly patients are becoming an increasingly larger proportion of our population, and there is a paucity of data regarding the epidemiology of geriatric patients refusing transport. This would be an alarming trend if found and would then require further study to look at the etiology of the refusal. This study sought to test the hypothesis that geriatric patients constituted an increasing proportion of those persons refusing prehospital transport.

2. Methods

This study was a retrospective analysis of data from a query of a large urban EMS service associated with the Oklahoma City, OK, and Tulsa, OK, metropolitan areas. The study includes all EMS interactions from January 1, 2010, to May 31, 2011, with patients who were at least 18 years old. There were no exclusions for gender, race, or diagnoses. The data includes EMS vehicle region (Eastern or Western), month and year of EMS interaction, response outcome (treated at the scene, patient refused care, care transferred), chief complaint, gender, age in years, and race. No patient identifiers such as encounter number, medical record number, or name were included.

All adult transport refusals over 16 months were included, with the study timeline of 16 months divided into the first

Table 1: Characteristics of patients refusing transport.

	Period 1	Period 2	Total
Number of refusals	10622	11725	22347
Male	4832	5227	10059
Female	5555	6293	11848
Race			
Asian/PI	105	115	220
Black	2106	2249	4355
Native Amer	201	232	433
Other	143	108	251
White	6909	7971	14880
Age ≥65 yo	2,104	2619	4723
Treatment prior to transport refusal	1404	1391	2795

8 months (Period 1) and the second 8 months (Period 2). Periods 1 and 2 patients were assessed with univariate categorical analysis for proportions with chi-square testing. Next, multivariate logistic regression was used to determine association between the study period and geriatric status (age 65 or older), after adjustment for covariates such as sex, chief complaint, metropolitan region (of the two areas served by the study EMS service), race, season, and whether any treatment occurred prior to transport refusal. Analyses were conducted with STATA 11 MP (StataCorp, College Station, TX); P was set at 0.05 for all analyses and 95% confidence intervals (CIs) were calculated for odds ratios (ORs).

3. Results

There were a total of 22,347 adult transport refusals recorded during the 16-month study period. Total refusals of 10,622 (48.0%) versus 11,725 (52.0%) occurred during Period 1 and Period 2, respectively. Of the total transport refusals 4,723 (21.1%) were ≥65 years old (2,104 versus 2,619 during Period 1 and Period 2, resp.). Patient characteristics of transport refusals are presented in Table 1. Univariate categorical analysis revealed that Periods 1 and 2 differed ($P < .001$) with respect to proportions of geriatric patients (19.8% versus 22.3% in Period 1 and Period 2, resp.). Multivariate logistic regression incorporating covariates for sex, race, season, chief complaint, metropolitan region, and whether any treatment occurred prior to transport refusal confirmed the increasing likelihood of Period 2 patients being geriatric, as compared with Period 1 (OR 1.24, 95% CI 1.14–1.35, Wald $P < .001$). Table 2 provides a breakdown of all EMS responses by chief complaint, with trauma being the most common. The number and percentage of patients refusing transport within each individual age group is found in Table 3. The finding of increased likelihood of geriatric status in those patients refusing transport was also present when the 16-month dataset was analyzed for overall trend during the 16 individual months of the study (OR 1.02, 95% CI 1.01–1.03, $P < .001$).

Table 2: Breakdown of EMS responses by chief complaint.

CC	Freq.	Percent	Cum.
Abdominal Pain (Medical)	284	1.95	1.95
Allergic Reaction	105	0.72	2.67
Altered Mental Status	329	2.26	4.93
Animal Bites/Stings	138	0.95	5.88
Assault	779	5.35	11.23
Back-Pain (Medical)	68	0.47	11.70
Bleeding (Medical)	128	0.88	12.58
Burn	83	0.57	13.15
Cardiac	156	1.07	14.22
Cardiac Arrest	4	0.03	14.25
Catheter Complications	5	0.03	14.28
Chest Pain (ACS)	272	1.87	16.15
Chest Pain (Non-Cardiac)	306	2.10	18.25
Choking	296	2.03	20.28
Diabetic Emergency	1,108	7.61	27.90
Dizziness	249	1.71	29.61
Electrocution/Lightning	19	0.13	29.74
Environmental Cold/Heat	140	0.96	30.70
Eye Problems	51	0.35	31.05
Hazardous Material Exposure	57	0.39	31.44
Headache	174	1.20	32.63
Mental health/Psychiatric Illness	669	4.60	37.23
Near Drowning	3	0.02	37.25
OB-GYN Problems	37	0.25	37.51
Other...	952	6.54	44.04
Pain	739	5.08	49.12
Poisoning/Overdose/Ingestion	416	2.86	51.98
Pregnancy/Childbirth	22	0.15	52.13
Respiratory Arrest	2	0.01	52.14
Respiratory Distress	883	6.07	58.21
Seizures/Convulsions	737	5.06	63.27
Sick Person	1,114	7.65	70.92
Stroke/CVA/TIA	54	0.37	71.29
Syncope/Near Syncope	960	6.59	77.89
Trauma-Abdominal	33	0.23	78.12
Trauma-Altered Mental Status	24	0.16	78.28
Trauma-Breathing Problems	5	0.03	78.31
Trauma-Chest	75	0.52	78.83
Trauma-Multisystem	29	0.20	79.03
Trauma-Penetrating	83	0.57	79.60
Trauma-Other	2,494	17.13	96.73
Unconscious	12	0.08	96.81
Unresponsive	21	0.14	96.96
Weakness	443	3.04	100.00
Total	14,558	100.00	

Of the 22,347 transport refusals, no treatment was given before transport refusal in 19,552 instances (9,218 versus

Table 3: Refusal rate among individual age groups.

Age Range	Freq.	Percent	Cum.
0–11 Mos	2	0.01	0.01
1–4 yrs	613	4.32	4.33
5–10 yrs	493	3.47	7.80
11–16 yrs	693	4.88	12.68
17–21 yrs	1,340	9.44	22.12
22–30 yrs	1,908	13.44	35.56
31–40 yrs	1,867	13.15	48.71
41–50 yrs	1,951	13.74	62.45
51–60 yrs	1,784	12.57	75.03
61–70 yrs	1,287	9.07	84.10
71–80 yrs	1,054	7.43	91.53
81–90 yrs	902	6.35	97.88
91+ yrs	301	2.12	100.00
Total	14,195	100.00	

10,334 in Period 1 and Period 2, resp.). Treatment was given before refusal in the remaining 2,795 instances. There was no significance found for the presence of treatment on transport refusal rates (OR 1.02, 95% CI 92–1.13).

4. Discussion

Prior anecdotal evidence suggests an increasing prevalence of geriatric patients refusing EMS transport [1–3]. The data from this study strengthens the validity of this claim. However, the etiology and impact of this trend remains unclear. Patient sex, race, seasonal variations, and chief complaint all offer a plausible potential impact on transport refusal rates. Yet, this data shows that despite controlling for these covariates, patients refusing transport in the second period of this study were nearly 25% more likely to be geriatric as compared to those in the initial 8 months of the study. Although comparing subsequent individual months has obvious limitations, this trend remained true when dividing and analyzing the total 16-month study period into 16 individual time periods (2% increase in geriatric likelihood over each month during the study period). This rate of increase is rather alarming and warrants further investigation. One possible explanation for this observed increase could be financial constraints. The continued rise in cost of ambulance transport and hospital care combined with fixed income levels of many geriatric patients may be serving as a barrier to patient willingness to be transported. This study did not account for the financial means of those individuals who refused transport. A follow-up study seeking to elicit the cause of this increased refusal rate among the geriatric population would be both interesting and potentially impactful on the development of new strategies to improve appropriate EMS utilization by the elderly. In conclusion, the data from this study demonstrated a nearly 25% increased likelihood of geriatric patients to refuse EMS transport from the first 8-month period to the second 8-month period when controlling for covariates. Further investigation into the characterization and impact of this trend is warranted.

Appendix

See Tables 1, 2, and 3.

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Review Article

Medical Transport of Children with Complex Chronic Conditions

Carlos F. Lerner, Robert B. Kelly, Leslie J. Hamilton, and Thomas S. Klitzner

Department of Pediatrics, Mattel Children's Hospital UCLA, David Geffen School of Medicine at UCLA, Los Angeles, CA 90095, USA

Correspondence should be addressed to Carlos F. Lerner, clerner@mednet.ucla.edu

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One of the most notable trends in child health has been the increase in the number of children with special health care needs, including those with complex chronic conditions. Care of these children accounts for a growing fraction of health care resources. We examine recent developments in health care, especially with regard to medical transport and prehospital care, that have emerged to adapt to this remarkable demographic trend. One such development is the focus on care coordination, including the dissemination of the patient-centered medical home concept. In the prehospital setting, the need for greater coordination has catalyzed the development of the emergency information form. Training programs for prehospital providers now incorporate specific modules for children with complex conditions. Another notable trend is the shift to a family-centered model of care. We explore efforts toward regionalization of care, including the development of specialized pediatric transport teams, and conclude with recommendations for a research agenda.

1. Introduction

Since the National Academy of Sciences issued its seminal white paper in 1966, "Accidental Death and Disability" [1], which provided the impetus for the development of the modern emergency medical services in the United States, there have been profound changes in the health care needs of the American population. In child health, while injuries remain a significant contributor to pediatric morbidity and mortality, one of the most notable trends has been an increase in the number of children with chronic conditions [2–5]. In this review, we examine recent developments in health care, with a particular focus on medical transport and prehospital care, that have emerged in recent decades to adapt to this remarkable increase in children with complex medical conditions.

2. Methodology

We summarize trends in the care of children with complex chronic conditions in the United States, and we review the published literature on the transport and prehospital care of these children. In areas where there is little published evidence, we describe the relevant experience of our institution. Finally, we identify gaps in the published literature to generate a suggested research agenda.

3. Results and Discussion

3.1. Growing Impact of Children with Complex Chronic Conditions. Advances in neonatology, critical care, emergency medicine, and many other areas of pediatric medicine have resulted in increased survival of children with complex chronic conditions. Extremely premature infants, children with complex congenital heart disease, and children with rare genetic or metabolic conditions are surviving in greater numbers and living longer, frequently into adulthood [6–11]. These children typically have multisystem diseases, complex medication regimens, and sometimes utilize an array of medical technologies such as home ventilators or gastrostomy tubes [7, 9]. Care for this population of children accounts for a significant and growing fraction of health care resources, and places increased demands at every level of the health care system. In 2006, children with complex chronic conditions accounted for 26.1% of pediatric hospital days and 43.2% of charges in the United States [12]. In an analysis from a single health plan, children with chronic conditions, representing 10% of the population, accounted for nearly 50% of total medical charges; those with catastrophic or multiple significant chronic medical conditions (excluding cancer) represented 0.5% of the total population and over 15% of total medical charges [13]. A study of unscheduled admissions to a regional pediatric intensive care unit noted that technology-assisted children comprised <0.5% of the population and 14% of admissions [14].

In the prehospital context, advances in technology and changing cultural norms have allowed more children with complex or technology-dependent chronic disease to live at home or in community settings, further increasing their demand for prehospital services. Published data describing these trends, however, remain quite limited and outdated. Suruda et al. review emergency medical service (EMS) run records between 1991 and 1992 in Utah [15]. Using various definitions of children with special health care needs (CSHCNs), these authors noted that between 23% and 78% of EMS runs for CSHCN were for interfacility transports. They also noted that these children were more likely to receive advanced life support and prehospital procedures. Spaite et al. analyze EMS responses for CSHCN in Tucson, Arizona in 1997-98 [16]. They found that children accounted for 18% of all EMS responses, but only 2% of responses were for CSHCN. These studies are limited by their small size, by methodological challenges of defining CSHCN, and by their focus on single geographic regions. Nevertheless, well-documented population-level trends [6–11], and data from other parts of the health care system [12–14], justify a continued focus on expanding capacity to provide quality prehospital care to children with complex conditions.

3.2. Increased Focus on Care Coordination and Integration. Typically, children with complex chronic conditions receive services from multiple physicians and other health care providers, including advanced practice nurses, physical therapists, occupational therapists, physiatrists, and pharmacists as well as various community and school-based agencies. They depend on complex medication regimens, care plans, and various medical technologies. Enhancing care coordination has become a central focus of efforts to improve the care of these children. The Medical Home, a model of primary care delivery first introduced within pediatrics, has recently been endorsed by the major American primary care organizations as a model for quality primary care [17]. Robust care coordination is one of the pillars of the Medical Home [17, 18].

In the prehospital setting, the perceived need for improved care coordination has catalyzed the development of the emergency information form (EIF). A readily available, concise, accurate, and updated summary of the child's medical record can facilitate the provision of quality care by prehospital providers. In 1999, a joint policy statement by the American Academy of Pediatrics and the American College of Emergency Physicians introduced the emergency information form (EIF), a single-sheet medical summary of essential medical information for the initial treatment of CSHCN [19]. In 2010, these organizations updated their EIF recommendations, noting that the EIF has been underused due to lack of awareness among health care providers and families, and the perception among many providers that completing such a document is time consuming and of limited usefulness [20]. The updated statement affirms that the completion of the EIF "should be the responsibility of the medical home primary care physician and specialty care providers for every child with special health care needs." Additionally, the statement calls for the establishment of a central standardized electronic repository of EIFs. At present, however, we are unaware of any published data regarding adherence to these recommendations, aside from single-program descriptions, such as the Minnesota Emergency Medical Services for Children Information System, which provides a web-based repository of EIFs for infants and children with heart disease [21].

3.3. Enhanced Training for Prehospital Care and Transport of Children with Special Health Care Needs. Recognizing the increasing numbers of children with complex chronic conditions, and the increasing complexity of their care, training programs pertinent to prehospital care providers have incorporated instruction on the care of these children. Three well-established programs include specific modules for this population: the Pediatric Advanced Life Support (PALS) course (developed by the American Heart Association) [22], the Pediatric Education for Prehospital Professionals (PEPP) course (from the Academy of Pediatrics) [23], and the Advanced Pediatric Life Support (APLS) course (jointly presented by the American Academy of Pediatrics and the American College of Emergency Physicians) [24].

Additionally, specific training programs have been developed for this population. The Center for Prehospital Pediatrics at Children's National Medical Center developed a continuing medical education curriculum, special children's outreach and prehospital education (SCOPE), which provides basic information on chronic medical conditions and an overview of commonly used medical technologies [25]. The investigators also published a resource template for the development of local emergency medical service protocols implementing the SCOPE program [26]. Similarly, two reports in the medical literature address the emergency medical management of technology-assisted children [27, 28]. Technologies reviewed in these reports include tracheostomies, apnea monitors, home ventilators, central venous catheters, enteral feeding tubes, colostomies/ileostomies, artificial pacemakers, and cerebrospinal fluid shunts.

Another component of prehospital care of medically complex children involves the readiness of pediatric offices to manage medical emergencies and stabilize patients pending transport to higher level of care. The American Academy of Pediatrics has recently outlined recommendations for pediatric office emergencies [29]. Of utmost importance is the identification of a medical team leader. Ideally, this physician should have knowledge of basic pediatric critical care stabilization, particularly of airway and cardiac support. Pediatric Advanced Life Support certification is recommended. Recommended office equipment at a minimum includes an oxygen source, a nonrebreather mask, a bag-valve-mask resuscitator, suction, nebulizer, oropharyngeal airways, pulse oximeter, drug dose reference, rigid board, sphygmomanometer, splints, sterile dressings, epinephrine, and albuterol for inhalation [29]. For practices caring for children with complex conditions, we additionally suggest intravenous catheters, intraosseous needles, a cardiac monitor, an automated external defibrillator, atropine, adenosine, and amiodarone.

Although evidence now strongly supports the use of simulation training in pediatric residency education [30], prehospital resuscitation training need not involve expensive computerized pediatric simulators. Simply organizing an office emergency plan, stocking essential airway equipment, purchasing basic cardiac medications, and regularly running mock scenarios can prepare office staff for decompensating medically complex patients. Data reported by Toback et al. demonstrate the increased confidence gained by ambulatory clinic personnel after a mock code initiative [31]. Mock scenarios should ideally establish roles for each member of the staff, including ancillary office personnel. Common roles during an emergency should include an individual who calls local emergency medical personnel, one who leads the resuscitation, one who assumes care of the airway, one who establishes vascular access, one who records medical interventions, and one who provides family support. Current evidence supports the inclusion of caregivers during inpatient cardiopulmonary resuscitation [32], and, by extension, we recommend this practice in the prehospital care setting.

3.4. Focus on Family-Centered Care. The shift to a family-centered model of care, in which families and medical providers comprise equal partners in the medical care of the child, has transformed the care of children with special health care needs [33]. Strong partnerships with families constitute another pillar of the medical home [17, 18]. Family-centered care for CSHCN has been associated with improvements in efficient use of services, health status, satisfaction, and access to care [34].

In the prehospital setting, participation of the family (and, if available, the home health nurse) in the evaluation and management of the medically complex child has been recommended as the key to quality care [25, 27, 28]. In our experience at the Pediatric Medical Home Program at UCLA [35], the principal caregiver for the child is typically best suited to describe the child's baseline vital signs, to evaluate mental status and abilities, to assess the changes from baseline and the severity of the child's condition, to assist with manipulating and troubleshooting medical technology devices, and to suggest a course of treatment. We strongly endorse this family-centered approach based on clinical experience and extrapolation from findings in other areas of health care [34].

3.5. Regionalization of Care. Care for this highly complex population can require specialized skills and knowledge as well as intensive care coordination. The Patient-Centered Medical Home concept emphasizes enhancing the infrastructure of community pediatric practices to be able to better care for such children [17, 18]. An alternative approach to deliver such care has been the development of regional programs, frequently associated with academic medical centers, which centralize the primary care of highly medically complex children [35–37]. Such programs have been associated with decreased Emergency Department visits [35] and decreased inpatient lengths of stay [36].

A parallel effort in the medical transport setting has been the development of specialized pediatric transport teams, particularly for the interfacility transport of children to higher levels of care. Specialized pediatric transport teams were found in one report to have fewer deaths and fewer unplanned events, including airway-related events, cardiopulmonary arrest, sustained hypotension, and loss of intravenous access [38]. When multiple options for the transport of pediatric patients are available, we recommend creating and disseminating an algorithm for the pediatric transport of medically complex patients. In our health system, for example, transport services can be provided by local emergency medical services, hospital-based emergency medical technicians (EMTs), or a specialized hospital-based pediatric transport team consisting of EMTs, a nurse, a respiratory therapist, and, if required, a pediatric physician. For immediate, life-threatening emergencies at one of our medical offices, local emergency medical services are called. For nonemergent responses, hospital-based EMTs independently transport any pediatric patient unless the patient meets certain exclusion criteria (Figure 1). In those situations, including patients with particularly complex care, our specialized pediatric transport team is dispatched. The sending physician serves as the medical control officer for the entire transport and must approve the appropriate level of care. All transport requests completed by our health system transport personnel are requested electronically, providing a timeline for legal and quality review, as needed.

Open and direct communication between sending and receiving medical teams ensures a smooth transfer of care. Centralized communication centers should be utilized to facilitate conference calls between all parties involved in the care of these complex patients. We recommend consulting the Guidelines for Air and Ground Transport of Neonatal and Pediatric Patients published by the American Academy of Pediatrics for further guidance on establishing such a transport system [39].

4. Conclusions: Setting a Research Agenda

A growing body of medical literature describes the increase in the number of children with complex chronic diseases, the impact of this increase on the health care system, and novel approaches to care for these children. As described in this review, however, minimal work in this area has been published that is specifically relevant to prehospital medicine

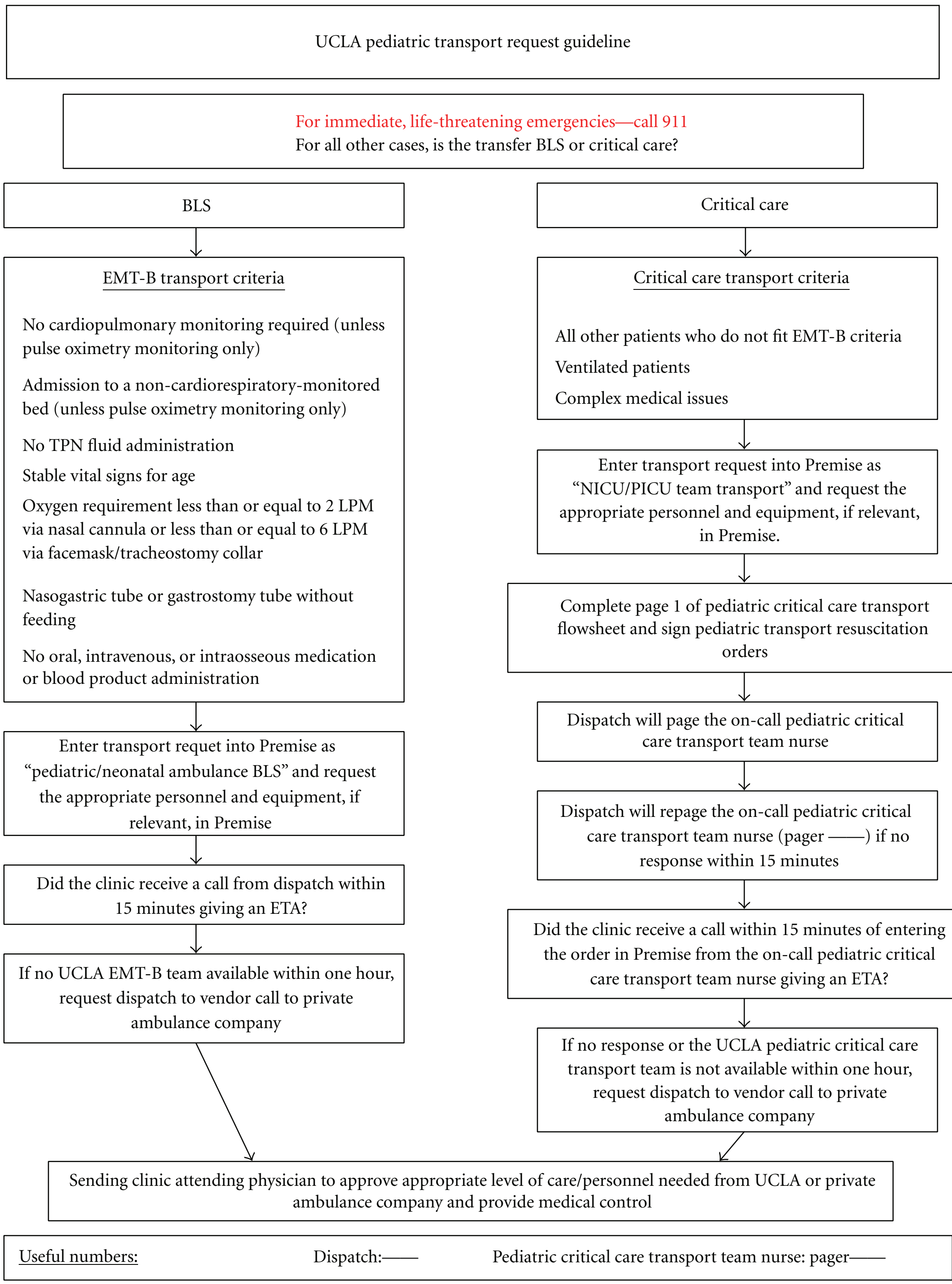

Figure 1: UCLA algorithm for transport of pediatric patients from medical offices to a higher level of care.

and medical transport for this population. Research in a range of areas is urgently needed for prehospital medicine to adapt to this major demographic transformation. We highlight several suggested areas for further research.

(1) Description of the Epidemiology of Prehospital Care for Children with Complex Chronic Conditions. What is the resource utilization for prehospital and EMS services for children with complex chronic conditions, at the local,

regional, and national level? How has this pattern changed over time? What are the characteristics of these children? What are the characteristics of prehospital responses for these patients?

(2) Emergency Information Forms. What are the optimal components of such forms? How widely are such forms being used? What are the barriers to their implementation? Can quality improvement efforts succeed in increasing their use? How can primary care medical homes support the delivery of quality prehospital care through the use of such forms or other mechanisms?

(3) Training Programs for Prehospital Care and Transport of Children with Special Health Care Needs. How widely accessible and utilized are such programs? What training program components lead to measurable improvement in the delivery of prehospital care to these children? What is the most effective way to manage specific technologies in the prehospital setting?

(4) Specialized Pediatric Transport. What is the optimal role of specialized pediatric transport teams? What is the cost and efficacy of such teams?

Medical care provided in the prehospital setting is a key component in the continuum of care for all patients, but particularly for children with chronic complex medical conditions. Understanding the answers to these questions is becoming increasingly important as the number of these children grows, and as their options continue to expand for living in their homes and communities.

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Review Article

Helicopter EMS Transport Outcomes Literature: Annotated Review of Articles Published 2007–2011

Brandon S. Brown, Korby A. Pogue, Emily Williams, Jesse Hatfield, Matthew Thomas, Annette Arthur, and Stephen H. Thomas

Department of Emergency Medicine, OU Schusterman Center, University of Oklahoma School of Community Medicine, 4502 East 41st Street, Suite 2E14, Tulsa, OK 74135-2553, USA

Correspondence should be addressed to Stephen H. Thomas, stephen-thomas@ouhsc.edu

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Helicopter EMS (HEMS) and its possible association with outcomes improvement continues to be a subject of discussion. As is the case with other scientific discourse, debate over HEMS usefulness should be framed around an evidence-based assessment of the relevant literature. In an effort to facilitate the academic pursuit of assessment of HEMS utility, in late 2000 the National Association of EMS Physicians' (NAEMSP) Air Medical Task Force prepared annotated bibliographies of the HEMS-related outcomes literature. As a result of that work, two review articles, one covering HEMS use in nontrauma and the other in trauma, published in 2002 in *Prehospital Emergency Care* surveyed HEMS outcomes-related literature published between 1980 and mid-2000. The project was extended with two subsequent reviews covering the literature through 2006. This review continues the series, outlining outcomes-associated HEMS literature for the three-year period 2007 through the first half of 2011.

1. Introduction

Despite the frequency of HEMS transport, there remains controversy surrounding its use and benefits. In 2002, two annotated bibliographies prepared by the National Association of EMS Physicians' (NAEMSP) Air Medical Task Force addressed the HEMS outcomes-related literature for trauma and nontrauma diagnoses [1, 2]. Although commentary was provided for each article, the bibliographies and their summaries of over 50 studies were intended to serve primarily as a central reference listing to aid parties interested in HEMS research. The bibliography has been updated twice, to cover studies published through 2006 [3, 4]. The current paper aims to extend the previous reviews, assessing outcomes studies published 2007 through the time of this review's preparation, in mid-2011. As with earlier reviews in the series, the article summaries include commentary intended to place the research into perspective. The primary goal of this article, like the prior reviews, is to present the most important HEMS outcomes literature published in the 2007–2011 time frame as an aid to those who wish to explore the evidence basis for HEMS use.

2. Methods

A computerized literature search was performed. The search database was the National Library of Medicine's MEDLINE (online Index Medicus), extending from 2007 through 2011. The search methods and terminology used for this review were the same as those employed, and reported, in the previous reviews [1–4]. For the current review, there were over 1500 studies assessed for possible inclusion (by review of title, abstract, or full-length paper).

As noted for the previous reviews, eligibility for article inclusion was usually easy to determine, but there was inevitably some degree of subjectivity. The authors acknowledge that the process of article selection may have excluded some worthy research and emphasize that the attempt to capture all relevant papers probably missed some studies.

The papers that are included in this review are categorized into diagnostic areas. The first category is *Airway*, followed by *Cardiac* and *Costs and Benefits*. The next two categories are *Drowning* and *Pediatrics*. The injury categories follow: *Drowning, Trauma-Scene* (studies limited to scene, or primary, HEMS transport), *Trauma-Scene and Interfacility* (casemix consisting of both primary and secondary missions), and *Trauma-Interfacility* (secondary missions only). For interpretation of the trauma studies, some knowledge of TRISS methodology (survival probability based upon trauma and injury severity scores as well as age and injury mechanism) is helpful. TRISS is outlined in detailed elsewhere [5]. The next category, *Trauma-Scene and Interfacility*, addresses the use of HEMS for a patient population comprising both primary (i.e., scene) and secondary (i.e., interfacility) HEMS missions. The review concludes with *Drowning* and *Cardiac* sections. Within categories, articles are listed chronologically with earlier papers first.

3. Airway

3.1. Nakstad AR, Heimdal HJ, Strand T, Sandberg M. "Incidence of desaturation during prehospital rapid sequence intubation in a physician-based helicopter emergency service", *Am J Emerg Med*, 2010 April 30 (epub ahead of print).

Objective. This study attempts to establish the incidence of hypoxemia in patients intubated by a physician in a helicopter emergency service.

Methods

Study Design. This was a prospective, observational study of all RSIs performed by helicopter emergency service physicians during a 12-month period. Hypoxemia was defined as a decrease in S_p0_2 to below 90% or a decrease of more than 10% if the initial S_p0_2 was less than 90%.

Setting. This Norwegian (Oslo) HEMS operates two helicopters 24/7/365 and serves a population of about 2.1 million covering an area of approximately 200 km. Each crew has a pilot, paramedic, and an attending anesthesiologist on board.

Time Frame. Data were collected for transports April 1, 2008 to March 31, 2009, including all cases in which drug-assisted Rapid Sequence Intubation (RSI) was provided.

Patients. 2621 patients were transported; of those, 122 meet criteria for prehospital RSI attempt.

Results. Trauma patients comprised the majority of the study cases requiring RSI (79 of 122 patients). There were complete S_p0_2 data for 101 (82.8%) of the 122 intubations. On average, RSI took 40.8 seconds with very little difference in times between trauma and medical patients. Neither Cormack-Lehane laryngoscopic view nor operator-defined intubation difficulty was associated with medical versus trauma patient group, and there were also no factors associated with desaturation (which occurred in 11 of 101 patients with complete records).

Authors' Conclusions. This study reports a hypoxemia rate of 11.1% in trauma patients and 10.5% in medical patients; these rates are better than many prehospital intubation studies. However, there were 21 cases with incomplete S_p0_2 recordings and occult desaturation cannot be ruled out in these cases. The study's relatively low desaturation rates may be explained by training: the study program's HEMS physicians are anesthesiologists with extensive prehospital experience. In this study, inadequate preoxygenation (as defined by preprocedure low saturation) was the only factor associated with desaturation events. Anatomical and technical difficulties increased the time required for intubation but were not associated with increased risk of hypoxemia.

Commentary. This study provides compelling evidence that prehospital RSI by a physician-staffed HEMS team yields excellent results which compare favorably to most from the existing (ground EMS) literature.

3.2. Le Cong M. "Flying doctor emergency airway registry: a 3-year, prospective, observational study of endotracheal intubation by the Queensland Section of the Royal Flying Doctor Service of Australia", *Emerg Med J.*, 2010 Sep 15 (epub ahead of print).

Objective. This study attempts to describe the profile and success rates of emergency endotracheal intubation conducted by the Queensland Royal Flying Doctor Service (RFDS) aeromedical retrieval team comprising a doctor and a flight nurse.

Methods

Study Design. Each intubator completed a study questionnaire at the time of each intubation for indications, complications, overall success, drugs utilized, and deployment of rescue airway devices.

Setting. The Queensland section of the Australian RFDS has seven aeromedical operations bases and covers about 780,000 sq miles.

Time Frame. The questionnaire was distributed from January 1, 2007 to January 1, 2010.

Results. 76 patients had intubation attempts. 72 were successful attempts. Three failed attempts were managed using Larygneal Mask Airways (LMAs). The 4th failed intubation was managed successfully by simple airway positioning for support. Complications included two cardiac arrests during intubation. Both were resuscitated within 1 minute of arrest.

Authors' Conclusions. A 95% intubation success rate is comparable to other studies of Australian aeromedical support. The two cardiac arrests account for nearly the same rate of cardiac arrest as documented in a recent study on ICU cardiac arrest frequency. This study also demonstrates the utility of the LMA device in the retrieval and transport setting, in particular for managing a failed intubation. These findings add to the growing body of prehospital literature on the intubating LMA as a rescue airway device in the field.

Commentary. This short report produced an intubation rate and complication rates that appear comparable to much of the HEMS literature, although the binomial exact confidence interval for ETI success rate is wide (87–99%). Furthermore, the nearly 3% rate of peri-ETI cardiac arrest (95% CI, 0.3–9.2%) is higher than expected from reviewing other HEMS data. Interpretation of these results would be aided by inclusion of more patient and provider characteristics.

3.3. Sollid SJM, Lossius HM, Soreide E. "Prehospital intubation by anaesthesiologists in patients with severe trauma: an audit of a Norwegian helicopter emergency medical service", *Scandinavian J Trauma Resuscitation and Emer Med,* 2010; 18 : 30.

Objective. This study aims to evaluate the trauma airway management quality and patient safety associated with prehospital endotracheal intubation (ETI) by anesthesiologists.

Methods

Study Design. This study was a retrospective medical records review.

Setting. The setting for this study was Rogaland County, Norway. The county has a population of over 400,000 and is serviced by the Stavanger HEMS. The HEMS operates day and night and the crew is a pilot, medical crewmember, and physician. The physician must have at least 2 years of anesthesiology training. Both helicopter and ground rapid response vehicle (RRV) are available, with RRV being deployed only as a back-up to helicopter services. Patients were transported to Stavanger University Hospital.

Time Frame. The study included all patients with severe trauma that were transported by Stavanger HEMS between 1994 and 2005.

Patients. Study patients consisted of 1255 trauma cases defined as severe by a score of 4 or higher on the National Committee on Aeronautics severity of injury or illness index (NACA).

Analysis. This analysis used independent sample t-tests to compare means, the Mann-Whitney U-test to compare nonparametric mean values, and 2×2 tables with the chi-squared test for proportions.

Results. No significant difference was found with respect to patient age, sex, NACA score, RTS, or GCS when comparing helicopter to RRV transport. While the mean time to the scene and scene time were significantly shorter with RRV, there was no significant difference in transport time between helicopter and RRV. There was also no significant difference in resident or specialist treating physician between helicopter and RRV transport. Of the 1255 study cases, 240 (19%) intubation attempts were made prior to hospital arrival and 47 (16% of total intubations) intubations were conducted upon ED arrival. Of the prehospital intubations, a 99.2% success rate was found; 40 of these patients died before hospital arrival. Of the ED intubations, a 100% success rate was found. The median GCS and RTS were both significantly lower for patients who received prehospital intubation (GCS 3, RTS 3.8) compared to those who received ED intubation (GCS 6, RTS 5.0). Of the prehospital intubations, 71 were conducted without any pharmacologic facilitation and 3 procedural complications were reported. By 2005, capnography use had also increased in these patients to 79% (in successful intubations). Prehospital intubations were found to be made more commonly during helicopter missions versus RRV missions. A significantly greater number of patients (78 versus 55%) who received ED intubation were found to be alive at the time of discharge, compared to those who received prehospital intubation. However, no significant differences were found in days in the hospital, in ICU, or on the ventilator.

Authors' Conclusions. This study found that anesthesiologist-managed HEMS ETI had a high success rate with few complications. These findings help to confirm the patient safety in prehospital ETI of this setting. However, 43 patients with GCS ranging from 3 to 8 were not intubated in the prehospital setting, instead receiving ED ETI, with no clear explanation for lack of pre-ED ETI. The authors believe that future prospective studies with data collected in a uniform manner could help to provide better evidence for the quality of prehospital airway management.

Commentary. This retrospective study showed that there appears to be no patient safety "cost" (and potentially even some benefit) associated with anesthesiologist-managed airways in the prehospital setting. However, there was a significant shortcoming in terms of available information describing the lack of ETI in patients who seemingly should have been intubated in the field but who were not. As the author states, previous studies have shown failure to adhere to prehospital guidelines and this gap in care is an area that warrants further study in the future.

3.4. Sollid SJM, Lossius HM, Nakstad AR, Aven T, Soreide E. "Risk assessment of prehospital trauma airway management by anaesthesiologists using the predictive Bayesian approach", *Scandanavian J Trauma Resuscitation and Emer Med,* 2010; 18 : 22.

Objective. This study's objective was to evaluate quality of care in anesthesiologist-headed prehospital airway management and to identify areas in which improvement may be possible.

Methods

Study Design. This study used information obtained from a retrospective medical records review, along with author expertise and literature review, to conduct a risk assessment along the principle of the Bayesian approach.

Setting. The records reviewed for this study were obtained from the Stavanger HEMS of Rogaland County, Norway. This is considered by the authors to be a typical Norwegian HEMS.

Time Frame. Risk assessment was conducted with consideration of the above-mentioned patients with severe trauma that were transported by Stavanger HEMS between 1994 and 2005.

Patients. Risk assessment was conducted with consideration of the above-mentioned 1255 trauma cases defined as severe by a score of 4 or higher on the National Committee on Aeronautics severity of injury or illness index (NACA).

Analysis. This risk assessment was conducted using the Bayesian approach. This study focused on patients who arrived to the ED without intubation despite prehospital indications (referred to as the "top event"). Probability of this event was predicted. Assessment was also used to evaluate the factors leading to the event and consequences following the event. A fault tree was constructed to identify potential causation of this event. Major categories found in the fault tree included indication for airway management not recognized and airway intentionally not secured (both leading to airway management not being attempted) and tracheal tube in esophagus and attempt aborted (both leading to attempted airway management being unsuccessful). Further, risk influencing factors (RIFs) were applied to each of these basic events in the fault tree. These RIFs included culture and attitudes, provider experience and knowledge, and system/protocol compliance. Each of these was given a score of good, average, or poor related to the quality of functioning within the system. An event tree was also constructed to evaluate potential outcomes following the failure to intubate. These potential outcomes were illustrated based on the authors' knowledge of the system and applied to the risk matrix resulting in placement into five categories of probability. Uncertainty factors that could potentially affect risk factors were also identified and categorized into minor, moderate, or major.

Results. In this study, four basic events were discussed as contributing to the non-intubation of the patient. As previously mentioned, these are indication for airway management not recognized, airway intentionally not secured, tracheal intubation in the esophagus, or attempt aborted because patient could not be intubated. Additional risk influencing factors including culture and attitudes, system, provider experience and knowledge, and protocol compliance were identified. Based on study information and knowledge of the system, the authors placed a score on each of the RIFs as follows: culture and attitudes: average; system: poor; provider experience and knowledge: average; and protocol compliance: poor. The scored RIFs were then applied to each of the four basic events with each RIF being given an appropriate adjusted weight (scored as a fraction of 1.0) according to how likely the RIF was to influence the basic event. This information was used by authors to calculate a probability of the top event equaling 29% (meaning 29 of 100 cases). Using the event tree to evaluate potential patient outcomes, authors found that the probability of no harm and of possible sequelae with prolonged hospital stay were approximately equal. As applied to the risk matrix, the patient outcome of no harm was found to have a frequency prediction of 1–10 incidences per year. The patient outcome of possible sequelae with prolonged hospital stay was found to have at least 10–50% probability during one year, but likely to have less than 1–10 incidences per year. Patient death was found to have a probability of less than 1% during one year. The uncertainty factors identified included amount of training to maintain airway skills, need for special training in prehospital airway management, impact of patient's condition on consequences, reliability of data recorded in patient charts, and criteria used to decide whether or not patient should be intubated. All of these factors were decided to have at least moderate effect on risk for the top event. However, none of the factors were deemed to have significant sensitivity in predicting the top event.

Authors' Conclusion. The authors' risk assessment resulted in a potentially high probability, as high as 29%, of lack of prehospital ETI in patients with indications for prehospital ETI. Evaluation of patient outcomes also revealed high probability for possible sequelae. It was also found that of potential RIFs, changes in system and in culture and attitudes show the greatest potential for improving patient outcomes.

Commentary. The risk assessment conducted in this study is certainly not the "usual" HEMS outcomes analysis. The authors have identified an interesting perspective on HEMS and prehospital patient care, in applying rigorous Bayesian analysis to the endpoint that "should've been intubated but was not." The results themselves are interesting, but the idea of using these methods to assess HEMS care may be the most important message of this paper.

4. Cardiac

4.1. Blankenship JC, Haldis TA, Wood GC, et al. "Rapid triage and transport of patients with ST-elevation myocardial infarction for percutaneous coronary intervention (PCI) in a rural health system", *Am J Cardiol,* 2007; 100 : 944–948.

Objective. This study examined the endpoints of time savings and health outcomes, to assess the effects of a new triage and HEMS transfer system designed to expedite community hospital evaluation and referral of STEMI patients to a PCI center.

Methods

Study Design. This study was "ambispective" in that some of the data were assessed retrospectively, and other patients' data were assessed prospectively. In mid-July 2004, retrospective chart review was performed to assess study variables back to January 2004. From mid-2004 through the end of the study period (December 2005), data were entered prospectively. The overall study design was a "before-and-after" approach, in which endpoints of interest were compared prior to, and after, January 2005 institution of new protocols for community hospital STEMI care and expedited HEMS dispatch. In brief, the protocol changes which were effective mid-way through the study included (1) community hospital STEMI care changes emphasizing time savings (e.g., elimination of heparin and nitroglycerin infusions), (2) simultaneous PCI lab and HEMS activation from a single call to the receiving center, and (3) bypass of the receiving center's ED after HEMS transport.

Setting. This study took place in central Pennsylvania, with the receiving center (Geisinger Medical Center) serving 37 counties with a population of 2.4 million. Geisinger is a 437-bed rural PCI center and operates 4 helicopters based at 4 sites in central Pennsylvania. HEMS staffing is primarily by a nurse and flight paramedic, with occasional physician crewmembers. The study HEMS service had a high completion rate (97%) for the cardiac patients transported during the study period.

Time Frame. This study took place from January 1, 2004 to December 31, 2005.

Patients. Patients eligible for inclusion were drawn from STEMI transports to the study center over the study period. Exclusion criteria included transport >12 hours after symptom onset, failure of thrombolytic therapy, or PCI contraindications. Most of the 226 patients comprising the study sample were male (80%), and the mean age was 58.

Analysis. The main time endpoint was the proportion of patients with a time interval from initial community hospital presentation to wire-crossing (in the PCI lab) of under 90 minutes. The time periods were reported as medians, and intervals for the two study periods were compared using nonparametric Kruskal-Wallis testing. Other continuous variables were assessed using Students t-test. Categorical data were compared using chi-square or Fisher's exact test as appropriate.

Results. For the main endpoint (community hospital presentation to wire-crossing time), the "after" period was associated with significantly shorter times (105 versus 205 minutes, $P = 0.0001$). Part of the time savings were achieved by faster HEMS dispatch (from 35 to 16 minutes, $P = 0.0004$), and further time savings were accrued by streamlining time intervals between HEMS dispatch and PCI center arrival (from 56 to 45 minutes, $P = 0.002$). Additional time savings occurred after arrival to the PCI center; receiving center arrival to wire-crossing times decreased from 91 to 29 minutes ($P = 0.0001$). Of the decrease in total time, 37% (36 minutes) was due to some combination of improved efficiency in STEMI diagnosis, HEMS dispatch, and pre-transport stabilization. The remaining 63% of time savings were accrued by a combination of bypassing the receiving center ED, simultaneous cath lab activation (at time of HEMS dispatch), and optimization of PCI lab procedures. The proportion of patients with door to wire-crossing times under 90 minutes increased from 0% to 24% ($P = 0.0001$), and the percentage with door to wire-crossing times under 120 minutes also increased (from 2% to 67%, $P = 0.0001$). There were no significant differences between the before and after periods, with regard to the following patient outcomes: death ($P = 0.28$), urgent revascularization ($P = 0.62$), or hospital length of stay ($P = 0.46$).

Authors' Conclusions. The authors concluded that in the rural setting the goal of treating STEMI patients within 90 minutes can be achieved for some transfer patients given a rapid diagnosis, triage, and transfer system.

Commentary. This study has particular strengths in its clear demonstration of time savings at a number of steps in the diagnosis/transfer process, with potential for clinical significance. While the lack of identification of any health outcomes benefits is appropriately highlighted in the authors' discussion, it is hard to dispute the criticality of the STEMI care surrogate endpoints relating to time. Considering the lack of downside to the types of protocol changes that were adopted by the authors (and which have been previously described by other HEMS services) [6] there seems sufficient evidence to support broader application of these streamlining principles. In addition to the lack of mortality benefit, there were other limitations to the study. Perhaps most importantly, although 14 community hospitals received training in STEMI stabilization and transport streamlining, the final data analysis excluded 6 hospitals since they cumulatively accounted for only 22 transports. Thus, the "real-world" generalizability of the study results may be lessened, since it is not uncommon for a significant proportion of any HEMS service's transports to come from relatively infrequent users.

4.2. Pitta SR, Myers LA, Bjerke CM, White RD, Ting HH. "Using prehospital electrocardiograms to improve door-to-balloon time for transferred patients with ST-elevation myocardial infarction", *Circ Cardiovasc Qual Outcomes,* 2010; 3 : 93–97.

Objective. The purpose of this study was to demonstrate that in patients transferred from a rural ST-elevation myocardial infarction (STEMI) referral hospital located 50 miles away from a receiving STEMI center, it is possible to achieve the guideline-recommended goal of first medical contact-to-balloon time of less than 90 minutes.

Methods

Study Design. This study was a case report of an instance of "positive result" during a 7-month period of prehospital ECG and early cardiac catheterization lab activation. A 12-lead prehospital (PH) ECG program was implemented at a rural hospital that had been achieving door 1-to-first PCI device time of 116 minutes. Implementation of a one-day training program allowed for training EMS personnel to acquire and interpret PH ECG for STEMI. A process was developed for EMS personnel to activate a STEMI protocol that included autolaunching HEMS to intercept the patient and transport to an awaiting cardiac catheterization team. The process would only allow the paramedics to activate the STEMI protocol during a definite STEMI, defined as both EMS paramedics and computer interpretation identifying the presence of acute ST elevation.

Setting. This took place at a 77-bed rural community hospital in Minnesota, located 50 miles away from the STEMI receiving center.

Time Frame. This case occurred during protocol implementation as monitored between February and August 2009.

Results. 60 PH ECGs were acquired, resulting in one patient identified with a definite STEMI. The remaining 59 cases were categorized as not STEMI. For the patient identified with a definite STEMI, the first medical contact-to-balloon time was 82 minutes. Symptom onset to balloon time was 117 minutes. These times are within the guideline-recommended performance measures for a patient with STEMI transferred for primary PCI. The door 1 in-to-door 1 out time at the STEMI referral hospital was 11 minutes. The on-scene-to PH ECG acquired time was 15 minutes. At 30-day follow-up, the patient did not have any adverse outcomes. His ventricular ejection fraction improved from 39% following PCI to 52% at 30-day follow-up.

Author's Conclusions. The clinical case demonstrates the successful use of PH ECG in order to improve door-to-balloon times for transferred patients with STEMI.

Commentary. This case report makes the point that, when incorporated into a system of prehospital and cardiology care, HEMS can be a critical contributor to improved outcome. While the single case report is noteworthy, the article is also potentially important in terms of the 59 cases where HEMS was *not* activated (presumably appropriately). With the growing acceptance of surrogate endpoints such as time savings, HEMS investigators and assessors have more tools to evaluate potential contributions of air medical transport.

5. Costs and Benefits

5.1. Taylor CB, Stevenson M, Stephen J, et al. "A systematic review of the costs and benefits of helicopter emergency medical services", *Injury Int J Care Injured,* 2010; 41 : 10–20.

Objective. This study's objective was to conduct a systematic review of available literature that included economic evaluations of HEMS.

Methods

Study Design. This was a retrospective literature review.

Setting. The reviewed studies were conducted across several countries including the United States, Canada, Norway, Germany, Finland, and the UK.

Time Frame. The reviewed studies were conducted between 1988 and 2007.

Patients. The reviewed studies included a wide variety of patients including trauma, cardiac, stroke, and obstetric patients. Reviewed studies included primary transport patients and patients being transferred between facilities.

Analysis. The chosen articles were placed into categories based upon primary patient diagnosis (trauma, nontrauma, and nonspecific) and then further divided based on the type of financial analysis provided within the study (cost-analysis, cost-minimization, cost-effectiveness, and cost-benefit). All financial information obtained from the articles was converted to US dollars and adjusted for inflation between the time of the study and January 2008.

Results. Fifteen articles were chosen for this literature review. Seven of these studies focused on the transport of trauma patients. These were subdivided into those focused on primary patient transport, interfacility secondary transport, and studies that included both types of patients. One study that focused on primary patient transport showed a 21-fold variation in the annual cost of HEMS between three services (ranging from $115,777 to $2,436,178). Another one estimated annual HEMS operation at $210,221. None of these studies were able to correlate the increased cost of HEMS to increased patient benefits. Of studies that focused on secondary patient transport, one reported the HEMS per mile cost to be $40 while the fixed wing transport cost was $10 (this study also found no increased patient benefit associated with HEMS transport). Of the studies that focused on both primary and secondary transport, one concluded that annual HEMS cost was $3,023,568 and that was broken down to a cost per patient transport of $15,849. This study also reported the cost per patient of ground transport to be 7 times less than HEMS (at $2,145) without clear benefit to patients. However, two studies of this category found HEMS provided patient benefit of prevention of expected deaths following trauma. These studies found cost-effectiveness ratios of $3,292 and $2,227 per year of life saved. Four studies focused on transport of nontrauma patients. One study in stroke patients found a ratio of $40,954 per each additional good outcome (of minimal to no disability). STEMI patients were found to gain 0.7 life years and decrease lifetime care costs by $7,854 when transported to percutaneous coronary intervention by helicopter. One study showed HEMS transport cost of $3,258 per neonate saved when transporting obstetric patients. Finally, four studies focused on the transport of patients categorized as "nonspecific." Two of these studies found HEMS transport to be less expensive annually than ground transport for a given geographical area. Two other studies found HEMS to increase patient benefits above "usual care" and to have increased societal benefits.

Authors' Conclusions. This review demonstrates that while HEMS can be expensive, air medical transport may in fact be found to be cheaper than ground transport—and may improve patient outcome. While the use of HEMS has been long-reported in the setting of trauma, this review demonstrates that a growing base of evidence may also justify its use in nontrauma patients. Differences in the delivery of HEMS and the systems in which it is delivered render direct comparison of ground and HEMS difficult; further studies of cost-effectiveness will be useful.

Commentary. This study shows the breadth of approaches to, and results from, financial assessment of HEMS and patient outcomes. With the *caveat* that the results are only as good as the estimates and assumptions (with respect to both costs and benefits), the overview is a useful step toward rigorous definition of HEMS' place in prehospital care.

5.2. Rylski B, Berchtold-Herz M, Olschewski M, Zeh W, Schlensak C, Siepe M, Beyersdorf F. "Reducing the ischemic time of donor hearts will decrease morbidity and costs of cardiac transplantations", *Interactive Cardiovascular and Thoracic Surgery,* 2010; 10; 945–947.

Objective. The study's objective was to evaluate the effect of total ischemic time (TIT) during cardiac transplantation on length of stay in the intensive care unit (LOS in ICU) and its economic consequences.

Methods

Study Design. This was a retrospective single center study.

Setting. The study took place at the University Medical Center in Freiburg, Germany.

Time Frame. All eligible patients were included between 1998 and 2009.

Patients. There were 72 recipients included from a group of 195 cardiac transplant patients. Recipients with prior mechanical support and heart-lung transplantation were not included in this study. In order to make the results representative for the common transplant patient, patients were excluded with TIT less than 100 min and longer than 250 min. Patients who died within 30 days were not included because the cause of death during this period is usually due to acute rejection or surgical complications, which are not associated with TIT.

Analysis. Graft TIT was defined as the time interval between aortic cross-clamp application in the donor and aortic cross-clamp removal in the recipient. LOS in ICU with respect to TIT and other clinical parameters was investigated with univariate and multivariate linear regression.

Results. The mean age of the 72 recipients (56 men, 16 women) was 50.6 ± 13.2 years (range 15–68 years), and the mean age of the donors was 41.5 ± 12.9 (range 11–51 years). The median TIT was 181.2 (range 107–243) min and mean LOS in ICU was 19.8 ± 19 days. Analysis of the correlation coefficient indicates a statistically significant linear relationship between TIT and LOS in ICU ($r\ (72) = 0.327$, $P = 0.005$). The linearity implies that each 5 min and 38 s of TIT equates to one more day in the ICU. Univariate analysis of factors associated with LOS in ICU showed that among pre- and intraoperative parameters, only ischemic time significantly impacted LOS. Postoperative parameters revealed that renal failure, defined as a compromise in kidney function requiring hemofiltration, was significantly associated with increasing LOS in ICU. In patients with TIT greater than 180 min, the median LOS in ICU increased 1.7-fold ($P < 0.01$), use of hemofiltration due to renal failure increased 3.2-fold ($P < 0.05$), and nitric oxide (NO) use increased 5.2-fold ($P < 0.05$). Intra-aortic balloon pump (IABP) was required by 3 patients with TIT greater than 180 min. Kaplan-Meier survival analysis revealed that the only significant predictor of survival was postoperative renal failure requiring hemofiltration (hazard ratio 9.1, 95% hazard ratio confidence limits 1.6–51.3, $P = 0.01$).

Authors' Conclusions. In this study, increased TIT resulted in greater resource utilization due to postoperative complications. The increased use of hemofiltration, IABP, and NO resulted in longer LOS in ICU and escalated financial expense. The use of the fastest possible transport (Learjet, helicopter) would have economic advantages by decreasing TIT. Also, methods such as beating-heart transport using the organ care system should be considered to reduce morbidity and possibly costs by reducing the actual TIT. This study confirms the findings of other studies suggesting that prolonged TIT during heart transplantation does not significantly influence survival.

Commentary. This study is admittedly only tangentially related to HEMS. However, as more pressure is appropriately brought to bear on HEMS to demonstrate cost-effectiveness, there is corresponding impetus to broaden the scope of relevant literature. For those HEMS programs participating in these types of transports, it is quite fair to take this study as a starting point, for generating estimates of benefits associated with HEMS and reduction of total ischemia time.

6. Drowning

6.1. Barbieri S, Feltracco P, Delantone M, et al. "Helicopter rescue and prehospital care for drowning children: two summer season case studies", *Minerva Anestesiol,* 2008; 74 : 703–707.

Objective. This study examined the neurological outcomes of nonfatal pediatric immersion injuries, in patients with on-scene apnea, who were treated and transported by HEMS.

Methods

Study Design. This was a retrospective observational report based upon medical records review.

Setting. This study took place in the Veneto Region on the coast of Italy. The area has a coastline of 150 km and a summer population of about 2.5 million. The HEMS unit is staffed by an anesthesiologist and a nurse with prehospital training. Patients were transported to a regional hospital with pediatric intensive care expertise.

Time Frame. Data were collected during the May-October time periods for two years (2006 and 2007).

Patients. Of the 14 pediatric submersion victims, 9 (64%) were rescued from public pools and 5 (36%) were rescued from lakes or rivers. The victims were up to 16 years old with most of the victims being 4 years old or younger (71%). Ten (71%) were male. While most of the incidents were not witnessed, available data identified submersion times ranging from 5 to 15 minutes. All victims were first rescued by bystanders or a BLS paramedic service, and all were in respiratory arrest at the time of initial rescue.

Analysis. Analysis was descriptive. Survival rates and neurological outcomes were assessed at time of discharge and at a 3-month follow-up.

Results. At the time of HEMS assessment, 8 of 14 (57%) had deep cyanosis and 10 of 14 (71%) remained in cardiocirculatory arrest despite receiving basic life support efforts by bystanders and BLS-level ground ambulance crews. HEMS crews intubated all patients upon air medical team arrival. HEMS also performed ACLS maneuvers on all patients for a period of pretransport time ranging from 10 to 50 minutes; only 2 failed to respond with a perfusing rhythm within 30 minutes. All patients had a perfusing rhythm by the time of loading onto the helicopter. During flight, 5 patients had persistent hypotension requiring fluids and inotropic support. All victims were mildly hypothermic (mean rectal temperature <35°C; range 32–36°C). IV access was attained on all patients. The on-scene GCS was <8 in all cases. During the transport (average flight time, 14 minutes with a range of 8–20 minutes), the children were warmed with protective blankets. On arrival to the hospital, 10 children had a GCS between 10 and 13, and 2 remained <8. While all patients spent 3–6 days in the intensive care unit, survival with complete/normal neurological recovery occurred in every case. Lack of neurological sequelae was confirmed at three-month follow-up in all cases.

Authors' Conclusions. The advanced interventions provided by HEMS crews (e.g., airway and hemodynamic support) were responsible for improved outcome. Promptly dispatching a helicopter with a specialized medical crew is worth the expense as it provides an increased chanced of survival.

Commentary. In one sense, the series is certainly impressive. The results are attention-getting: 100% neurologically intact survival in a group of 14 patients with cardiorespiratory arrest from near-drowning. On the other hand, the observational nature of the study combines with the lack of a ground EMS control group to attenuate the strength of conclusions about HEMS' impact. It seems likely that, in an area where the choice is either BLS-level ground response or extended practice-scope HEMS response, pediatric immersion injury patients' best chance at optimal outcome may include air medical care.

7. Neurosurgery

7.1. Walcott BP, Coumans JV, Mian MK, Nahed BV, Kahle KT. "Interfacility helicopter ambulance transport of neurosurgical patients: Observations, utilization, and outcomes from a quaternary care hospital", *PloS One,* October, 2011; 6 : e26216.

Objective. This study examined a series of neurosurgical interfacility transports, to determine whether clinically significant time savings occurred due to use of helicopter transport.

Methods

Study Design. This was a retrospective observational report based upon medical records review.

Setting. The study took place at the Massachusetts General Hospital, a Harvard-affiliated adult and pediatric level I trauma center in Boston that serves as a regional referral center for a wide variety of neurosurgical patients. The specific transporting HEMS units were not identified in the study, but based upon geographical transport patterns, the vast majority of such cases would have been transported by Boston MedFlight, an RN/EMTP-staffed service.

Time Frame. Data were collected for patients transported during the year 2008.

Patients. Interfacility-transported patients were eligible if they were transferred from an ED, and who were admitted to (or consulted by) neurosurgery with a primary neurosurgical diagnosis. Excluded patients included those who died during transport, or those who were transported to any area of the hospital other than the ED.

Analysis. Analysis was descriptive. Endpoints included patient outcomes, neurosurgical interventions and timing of those interventions, and time savings accrued by air transport (as calculated from air transport times compared to GoogleMaps-calculated driving times).

Results. Of 167 patients studied, a breadth of neurosurgical disease and injury was seen (ranging from brain tumor to cerebrovascular disease to trauma and other diagnoses). 4 (2%) died, 4 were discharged from the ED, and the remainder were admitted. 34% of the patients had estimated ground transport times under 45 minutes; only 16% of patients had estimated ground transport times exceeding 80 minutes. Median time to non-neurosurgical interventions (cricothyrotomy, thoracotomy, or laparotomy) on 14 patients (8%) was 29 minutes. Fiberoptic bolts for traumatic brain injury were placed in 8 patients, a median 1.0 hours after ED arrival. Including those bolt placements, the overall median time-to-neurosurgery was 3.2 hours; times varied widely depending on the procedure (e.g., for the 2 spine fusion cases, a median 118 hours after ED arrival). Discharge dispositions were home (34%), inpatient rehab (38%), and death/hospice (28%); 6 patients (4%) were discharged home within 24 hours of admission. Overall, 56 patients (34%) in the HEMS transport cohort neither died nor required any invasive procedure at the receiving institution.

Authors' Conclusions. Many patients undergoing interfacility HEMS transport are inappropriately triaged to helicopter transport, as evidenced by actual times to intervention at the accepting institution and estimated ground transportation times from the referring institution.

Commentary. This is a fascinating study by a group of neurosurgeons from a world-class institution (disclosure: one of this review's authors, ST, has worked closely in the clinical setting, with at least one of the study's authors). The clinical depth these authors bring to the HEMS discussion is noted and appreciated. The results—which to these reviewers clearly demonstrate overall appropriateness and utility of HEMS—are obviously subject to interpretation. The authors' preexisting notions are delineated in their Introduction statement that "We hypothesize that many of these patients are inappropriately triaged to helicopter transport." Questionable study presumptions include the positions that (1) HEMS benefit is predicated solely on time savings (the authors' own discussion outlines the importance of physiologic critical care management), (2) a posteriori-estimated ground transport times in a metropolitan area are reliable, and (3) HEMS use should be deemed "inappropriate" for any patients who did not undergo emergency neurosurgical intervention (this ignores the well-accepted principle that avoidance of undertriage results in some level of overtriage). The authors do note some of these limitations, as well as pointing out the major problems associated with lack of ground or HEMS record review (the authors never followed up a late-2010 email exchange with Boston MedFlight, to call and discuss the study and to arrange forwarding of records). The authors also correctly identify the most important issue with the paper: absence of a ground-transported comparison cohort. With the understanding that there is always room for ongoing education and improvement (e.g., through telemedicine, as suggested by the authors), this study's results strongly support the appropriateness of HEMS triage and utilization for this population.

8. Pediatrics

8.1. Gerritse BM, Schalkwijk A, Pelzer BJ, Scheffer GJ, Draaisma JM. "Advanced medical life support procedures in vitally compromised children by a helicopter emergency medical service", *BMC Emerg Med*, 2010 Mar 8; 10 : 6.

Objective. This study's goals were to evaluate the advanced medical interventions performed by EMS and physician-staffed HEMS in vitally compromised children and to examine how often HEMS provided additional medical care which was not or could not be provided by the ground EMS.

Methods

Study Design. This study employed a prospective cohort analysis for HEMS calls in a region of eastern Netherlands and enrolled all patients aged 16 or younger. The data points recorded for each patient included age, sex, type of incident, physiological parameters, GCS, prehospital treatment given, diagnosis in the emergency department, and survival until 24 hours after hospital admission. Additionally, all patients transported by HEMS received a NACA (National Advisory Committee for Aeronautics) score.

Setting. The HEMS Trauma Region Netherlands–East covers one of the 4 HEMS regions in The Netherlands and covers an area of about 10,000 square kilometers in which 4.5 million people reside.

Time Frame. Study patients were those transported from 2001 to 2009.

Patients. The study included 803 HEMS calls. 245 of these were cancelled before HEMS could arrive. HEMS attended to 558 children, all of whom are included in this study.

Results. The 558 patients received 1649 advanced medical procedures and 818 of those procedures required a HEMS physician. 65% of HEMS-transported patients received advanced medical procedures they could not have gotten if transported by ground EMS. Furthermore, HEMS often added value even when performing procedures within the practice scope of ground EMS. For example, intubation by ground EMS paramedics (arriving at the scene before HEMS) was characterized by a 77% success rate in 86 children. In 20 of these patients (23%) emergency correction of the endotracheal tube or ventilator settings was performed by HEMS upon arrival. HEMS intubated 214 children with 100% success rate, and the difference in success rates between EMS and HEMS intubations was statistically significant. Pain management data showed that 77% of patients in need of pain management (as defined by pain medication administration by HEMS) failed to receive analgesia from ground EMS. The youngest patient receiving with pain management by ground EMS was 4 years old; HEMS providers administered analgesia to patients as young as 2 months of age. No detrimental effects of pain management were recorded in this study. Also, the majority of all patients transported by HEMS had a NACA score IV–VII (indicating relatively high acuity).

Authors' Conclusions. The HEMS group studied provides essential medical expertise not provided by ground EMS. The authors call for a lower threshold for HEMS activation in any serious incident involving children, preferably based on the type of primary emergency call. Special attention should be paid to the training involved with treating pediatric patients with high NACA scores. Also, the high rate of failed intubations by EMS and the inappropriately infrequent use of analgesia and intraosseous access devices need improvement.

Commentary. This study addresses the issue of physician-manned HEMS versus (nonphysician) ground EMS and finds many clear advantages to HEMS. Intubation success rates (100% as compared with 77%) are probably the most critical, but the importance of prehospital pain management as an independent endpoint should not be disregarded. The data are make a convincing case that, in the region studied, physician-staffed HEMS brings substantial benefits to pediatric patients. While no cost-benefit results were reported, it should be remembered that life-saving interventions (e.g., intubation) are financially attractive in children who will lead long healthy lives as a result of HEMS transport.

9. Trauma-Scene Transports

9.1. McCowan CL, Swanson ER, Thomas F, Handrahan DL. "Outcomes of blunt trauma victims transported by HEMS from rural and urban scenes", *Prehosp Emerg Care,* 2007; 11 : 383–388.

Objective. The study's goal was to determine whether HEMS-transported rural scene trauma patients have the same mortality as HEMS-transported urban scene trauma patients.

Methods

Study Design. This was a retrospective consecutive-case review of records from two HEMS services and three receiving Level I trauma centers. The authors' endpoint analysis incorporated multivariate logistic regression controlling for age, gender, and ISS.

Setting. The trauma centers in the study are located in Salt Lake City, Utah; the regional population is 1.4 million. The area's two HEMS services are staffed by paramedic/nurse and nurse/nurse teams (variable depending on patient age).

Time Frame. Study patients were those transported during 2001.

Patients. The study included 271 urban and 141 rural blunt trauma scene transports. Study patients were aged at least 15 years, and all blunt trauma scene transports were included except for those related to winter resort activities. The authors defined "rural" counties *a priori*, as those with fewer than 99 residents per square mile.

Results. There were no significant differences between rural and urban patients' age, gender, or receiving hospital, but the urban group had significantly more autopedestrian/bike victims and the rural group had more "other motorized" vehicle crash victims (e.g., ATV, snowmobile). Urban transports were characterized by shorter scene times (16 versus 21 minutes), shorter flight times (30 versus 79 minutes), and greater likelihood of pre-HEMS IV access and ETI. Urban and rural patients had similar vital signs upon HEMS arrival, but the former group had lower GCS and TS. The main endpoint analyses found that rural and urban patients outcomes were similar with respect to hospital and ICU length of stay, ED death, or inpatient mortality; there were also no differences in discharge status dispositions.

Authors' Conclusions. After controlling for age, gender, and ISS, there were no significant mortality differences between rural and urban scene trauma patients undergoing HEMS transport. The lack of mortality difference was also present when analysis was limited to motor vehicle and motorcycle crashes.

Commentary. As the stack of TRISS-based studies demonstrating HEMS' trauma outcomes improvement grows, there is shrinking incremental benefit of adding another such study onto the pile. Thus, novel approaches to assessing for HEMS benefit are particularly valuable. These authors took a unique and clever approach to the outcomes assessment problem, taking as their foundation the well-known fact that trauma in the rural setting is associated with worse outcome. There is always potential for residual confounding (e.g., by acuity), but the Utah group went to great lengths to minimize study flaws. The authors' discussion incorporates many points of interest and relevance, but the bottom line is that HEMS use appears to be an "equalizer" for rural trauma patients—air transport eliminated the rural/urban trauma outcomes differences for both mortality and nonmortality endpoints.

9.2. Davis DP, Peay J, Good B, et al. "Air medical response to traumatic brain injury: A computer learning algorithm analysis", *J Trauma,* 2008; 64 : 889–897.

Objective. The study's goal was to determine whether air medical transport of head-injured patients from trauma scenes was associated with mortality benefit.

Methods

Study Design. This retrospective study generated predictive models using artificial neural network (ANN), support vector machine (SVM), and decision tree methods. ANN was used to calculate differential survival (actual versus predicted) for each patient, and SVM used chi-squared testing to compare (between air- and ground-transported patients) the ratios of unexpected survivors to unexpected deaths. Decision tree analysis was used to explore the indications for air transport.

Setting. This was a registry-based analysis from the San Diego County Trauma Registry.

Time Frame. Study patients were those transported during 1990–2003.

Patients. The study included 11,961 patients with head AIS at least 3; 3,023 were transported by air and the others by ground ambulance (usually with paramedic-level care).

Results. All three algorithms generated by the study's methodology predicted a survival benefit associated with air transport across all patients. The benefit was most pronounced in cases with higher acuity as denoted by GCS, ISS, head AIS, or hypotension.

Authors' Conclusions. Air medical response confers a survival advantage in traumatic brain injury (TBI).

Commentary. This was not a "TRISS" study, but some parts of the methodology are reminiscent of that approach. Specifically, the ability of the study to identify unexpected survivors (and unexpected deaths) is an important function. The authors' study, while necessarily complex, appears to represent an unbiased, reproducible, valid (as tested statistically) mechanism for identifying the differential effect of transport mode on survival outcome. Based upon means of the three best ANN models, the differential survival attributable to HEMS as compared to ground transport was calculated to be 3.6 per 100 (95% CI 3.4 to 3.9) for all patients studied. When the study group was AIS at least 4, the survival benefit rose to 5.7/100; in patients with GCS between 3 and 8 the benefit was 7.1/100 patients. Since these same authors have also demonstrated that HEMS improves nonmortality outcome (i.e., functional survival), the results of the current study's methods are a useful complement to the existing body of evidence that strongly suggests HEMS impacts TBI outcome.

9.3. Ringburg AN, Spanjersberg WR, Frankema SPG, et al. "Helicopter Emergency Medical Services (HEMS): Impact on on-scene times", *J Trauma,* 2007; 63 : 258–262.

Objective. The study's objective was to compare prehospital on-scene times (OSTs) for patients treated by nurse-staffed ground emergency medical services (EMS) with OSTs for patients treated by a combination of ground EMS and physician-staffed helicopter emergency medical services (HEMSs). Due to relatively short ground transport times from scenes, the responding HEMS unit rarely performs actual patient transports; HEMS crews perform patient stabilization and attend the patients while *en route* to hospital. A second aim was to investigate the relationship between length of OST and mortality.

Methods

Study Design. The study was a trauma registry study using regression analysis to compare EMS to EMS/HEMS-treated patients.

Setting. The study patients were those at trauma scenes in the area served by HEMS based out of Rotterdam, in The Netherlands. Patients were transferred to a high-level trauma center (Erasmus University Hospital).

Time Frame. Study patients were cared for between January 2002 and 2004.

Patients. Study patients were all ($n = 1,457$) adult (>15 years old) trauma scene transports to Erasmus during the study period: 260 (18%) in the HEMS group and 1,197 (82%) in the EMS group.

Analysis. Mean prehospital on-scene times between groups were compared using Student's *t*-tests. A custom-fitted regression model was defined to compensate for potential selection bias. All commonly used predictive variables were evaluated for their contribution to the model. The variables-Revised Trauma Score (RTS), age, Injury Severity Score (ISS), whether the trauma occurred inside or outside the uniform daylight period, and mechanism of injury were found to have significant predictive value and were fitted into the model. Logistic regression models were used to analyze the influence of OST on mortality.

Results. The number of trauma patients included for analysis was 1,457. HEMS patients had longer mean OSTs (35.4 versus 24.6 minutes; $P < 0.001$). After correction for patient and trauma characteristics (including RTS, age, ISS, daytime/nighttime, mechanism of injury), the difference in OSTs between the groups was 9 minutes ($P < 0.001$). Unadjusted logistic regression suggested a 20% higher chance of dying associated with increased OST by 10 minutes (OR, 1.2; $P = 0.001$). However, adjusted analysis found that for HEMS-attended patients the effect of OST on mortality was eliminated (OR 1.0, $P = 0.89$).

Authors' Conclusions. Combined EMS/HEMS assistance at an injury scene is associated with longer OST, but this prolongation of OST did not have the anticipated (undesirable) effect on mortality. HEMS response to a trauma scene is associated with earlier provision of critical care interventions that, while increasing prehospital time, provide more rapid "golden hour" procedures that improve mortality and eliminate adverse effect from prolonged OSTs.

Commentary. This paper, from well-published and methodologically accomplished investigators in The Netherlands, addresses HEMS outcomes in an indirect manner. The arrangement of HEMS response and subsequent ground transport, unusual in the U.S., has been shown to work well in these authors' country [7]. Regardless of how patients get to the hospital, the important HEMS intervention is—in the judgment of the study authors—getting the experienced crews to the patients. The fact that the provision of advanced care in the prehospital setting negated the adverse outcomes expected due to prolonged on-scene time could be interpreted in two ways. It could be said that the savings of the time associated with more prehospital procedures would get the patients to the trauma center faster, and their "golden hour" interventions could be instituted earlier. This argument may hold true for patients whose ground transport times would be anticipated to be shorter than the 9-minute time prolongation associated with HEMS crew interventions. For other patients, however, the authors' results do seem to make the case that a little prolongation of on-scene time in their setting allows for earlier institution of life-saving interventions.

9.4. Cudnik MT, Newgard CD, Wand H, Bangs C, Herrington R. "Distance impacts mortality in trauma patients with an intubation attempt", *Prehosp Emerg Care,* 2008; 12 : 459–466.

Objective. Out-of-hospital endotracheal intubation (ETI) has been associated with adverse outcomes; whether transport distance changes this relationship is unclear. The authors sought to determine whether there was an association between transport distance and prehospital ETI's impact on outcome.

Methods

Study Design. The study was a retrospective analysis of a consecutive-case adult cohort.

Setting. The study covered 19 counties in Oregon's northwestern portion (including the greater Portland metropolitan region).

Time Frame. Study patients were accrued to cover 2000–2003.

Patients. Study patients were consecutive ($n = 8,786$) adult (>14 years old) trauma scene transports to the study center over the study years. Of these patients, 534 (6%) underwent prehospital ETI, 307 (57.5%) with rapid-sequence induction (RSI), and 227 (42.5%) without RSI.

Analysis. Multivariate logistic regression analysis was used to evaluate the association between prehospital ETI and mortality, and also to assess for effect modification (i.e., statistical significance of an interaction term) between transport distance and ETI. The authors used propensity scoring (for ETI likelihood) and adjusted for potential patient and injury-type confounders, creating estimates for ETI-associated mortality odds ratios (ORs).

Results. Of 8,786 patients analyzed, 534 (6%) underwent prehospital ETI. Helicopter transport was used for 962 (10.9% of 8786) patients; 211 of 962 (21.9%) were intubated by HEMS crews. Patients requiring ETI tended to have lower GCS scores, higher injury acuity, and worse outcomes than nonintubated patients. After adjusting for potential confounders and the propensity to be intubated, the authors found prehospital ETI to be associated with an increased mortality (OR 2.1, 95% CI 1.3–3.2) and increased risk of complications (OR 2.1, 95% CI 1.5–2.9). The authors found an association between transport distance and ETI-associated mortality: shorter transport-distance patients had the highest ETI-associated odds of death (OR 4.0, 95% CI 2.1–7.6) and risk of complications (OR 4.1 CI 2.4–7.1). More importantly for this review, the authors found a strong across-the-board (i.e., ETI and non-ETI patients) association between HEMS (versus ground) transport and improved survival (OR 0.3, 95% CI 0.2–0.5).

Authors' Conclusions. Prehospital ETI is associated with an increase in mortality among trauma patients at all distances from Level 1 trauma centers, with the greatest prehospital ETI-associated mortality risk increase occurring for patients who are relatively close to the trauma center. Helicopter transport is associated with improved survival in trauma patients, even after adjustment for ETI status and transport distance.

Commentary. As noted in previous reviews of the HEMS literature, studies like this one—those that were never intended to assess HEMS' impact on survival—are a double-edged sword. It is vital to avoid overinterpretation of a "secondary" result that was outside the *a priori* intent of the study design. However, the consistently strong association (in these authors' regression models) between survival improvement and HEMS transport should not be ignored. The finding may have been "incidental," but the HEMS term's statistical and clinical significance in such a methodologically sound study is noteworthy—and perhaps even more given the low likelihood of author bias toward either side of the HEMS debate.

9.5. Shepard M, Trethewy C, Kennedy J, Davis L. "Helicopter use in rural trauma", *Emerg Med Australas,* 2008; 20 : 494–499.

Objective. This study's main objectives were descriptive. The investigators also set out to assess whether there were any time savings or outcome advantages accrued by HEMS use or physician staffing, respectively.

Methods

Study Design. This study was a retrospective medical records review.

Setting. The study patients were transported by the Hunter New England Rescue Helicopter Service, which serves the areas northwest of New South Wales in Australia. The HEMS staffing model usually comprises nonphysician prehospital personnel, with the addition of physician crew based upon pretransport judgment that patients might need more advanced care. The physicians who participated in HEMS transports were specially trained doctors with prehospital experience. Patients were transported to Tamworth Rural Referral Hospital in New South Wales.

Time Frame. The study included all HEMS trauma missions from January 2004 through November 2006.

Patients. Study patients included 129 HEMS scene transports, nearly all for blunt trauma. Of these patients 50 (29%) had an ISS >15 and the average ISS for the study cohort was 12.3.

Analysis. The analyses included descriptive approaches as well as univariate assessments. In order to determine whether physician staffing was appropriately triaged, ISS scores were compared between physician-staffed and nonphysician-staffed flights. There were insufficient deaths (2) for meaningful mortality analysis. For the endpoint of transport time, Global Positioning System (GPS) devices were used to estimate road travel times. Times were then compared using Student's *t*-test, within three one-way transport distance categories (<50 km, 50–100 km, >100 km).

Results. There was no significant difference between ISS for patients on physician-staffed versus nonphysician-staffed transports. Overall, the average time from dispatch to trauma scene arrival was 48.6 min and the average on-scene time was 50.3 min. The average distance from scene back to the receiving hospital was 160.4 nautical miles. When the times required for HEMS versus (calculated) ground vehicle transport times were compared in the three *a priori*-defined distance groups, the only subcategory with a HEMS time advantage was for distance exceeding 100 km. For transport distances of 50–100 km, there was no time difference between HEMS and ground transport; ground transport was significantly faster when transport distances were less than 50 km.

Authors' Conclusions. The conclusions most relevant to this review were as follows: (1) addition of a physician to a HEMS crew has no mortality impact, and (2) HEMS response to a trauma scene within 100 km of the receiving hospital does not result in faster time-to-trauma center.

Commentary. The ability to draw definitive conclusions from this dataset is limited by a number of factors. There is potential for selection bias. Furthermore, the very low mortality of the HEMS patients was correctly identified by the authors as problematic. First, there is the obvious fact that such a low death rate indicates room for improvement in triage. Second, the low mortality precludes meaningful assessment of associations between survival and time-distance or staffing variables. The pitfalls of using computers to retrospectively estimate ground transport times have been iterated in previous discussions [3]. Overall, the study should prompt further consideration as to whether HEMS is really necessary for responses within 100 km, in areas that are similar to the study region.

9.6. Berlot G, La Fata C, Bacer B, et al. "Influence of prehospital treatment on the outcome of patients with severe blunt traumatic brain injury: a single-centre study", *Eur J Emerg Med,* 2009; 16 : 312–317.

Objective. This study's objective was to compare the outcomes of TBI patients who were transported by HEMS versus ground ambulance.

Methods

Study Design. This was a retrospective medical records review.

Setting. This study took place in northeastern Italy in a region called Fruili-Venezia Giulia (FVG), with a population of about 1.5 million. Patients with TBI were delivered to one of two regional neurotrauma centers. HEMS operates during daylight hours, with a crew of two nurses and an anesthesiologist with prehospital experience. The comparator ground ambulance service, staffed by two nurses (with occasional addition of a nonspecialized physician), covers a much more limited geographic area around Trieste, the capital of FVG.

Time Frame. This study included patients transported from January 2002 to December 2007.

Patients. Study patients were 194 cases of scene response to patients who were ultimately found to have ISS at least 15 and a head abbreviated ISS ($aISS_{head}$) of at least 9. The HEMS and ground ambulance groups consisted of 89 and 105 patients, respectively.

Analysis. Initial univariate analyses were performed to assess for baseline differences between HEMS and ground patients. Subsequently, the primary study outcomes of mortality and discharge condition were assessed for HEMS versus ground. The discharge conditions were divided *a priori* into 3 groups: (1) alive with no deficit or minor neurological symptoms, (2) alive with severe neurological disabilities (e.g., persistent vegetative status, hemiplegia), and (3) deceased. Secondary outcomes included (among others) prehospital times, hypotension upon arrival at the receiving hospital ED, in-hospital times (including time from receiving hospital arrival to arrival at ICU or operating suite), and ICU and hospital lengths of stay. Statistical analyses included Student's *t*-test and the Wilcoxon rank-sum test for continuous variables, with employment of chi-square analysis and Fisher's exact test for categorical variables.

Results. Univariate analysis identified no statistical differences between HEMS and ground groups with respect to on-scene GCS, ISS, $aISS_{head}$, or age. The primary endpoints of mortality and neurological outcome both favored HEMS. Overall, air-transported patients had significantly lower mortality than ground transported patients (21% versus 25%). HEMS patients also had better neurological outcome. Within the group of surviving patients, HEMS patients were significantly less likely than ground patients to have severe neurological deficit (25% versus 31%). Analysis of the secondary endpoints showed that HEMS patients had significantly longer prereceiving center times (66 versus 38 minutes), but that receiving center stabilization time (i.e., time in ED pre-ICU or preoperating room) was significantly shorter for HEMS patients (99 versus 115 minutes). HEMS patients were significantly more likely to undergo prehospital intubation (82% versus 38%) and had twice as many intravenous lines placed on a per-patient basis. In terms of minimizing potential for secondary brain injury, ED arrival blood pressure was significantly higher in the air-transported cohort (mean 133 versus mean 110, $P < 0.001$). There were no differences between air and ground transported patients, with respect to number of neurological procedures, duration of intubation, or ICU or hospital lengths of stay.

Authors' Conclusions. The authors believe that the better outcomes, in terms of both survival and neurological condition, that were seen in the HEMS group were due largely to enhanced skills and experience of the air medical teams. Longer prereceiving center times for HEMS patients were offset by the increased number of interventions provided during the prehospital phase. In patients with severe TBI, the concept of the "golden hour" should be modified to adjust for interventions that occur during that critical time period.

Commentary. This study, like some others from the same region of Italy [8–10], makes a strong case for HEMS' salutary outcome effect in an "apples-to-oranges" assessment (of greater capability HEMS versus lesser capability ground EMS). The study has limitations—among them the lack of multivariate analysis and the nonadjustment for prehospital times in the reporting of some EMS interventions (i.e., reporting of total volume of fluid resuscitation, rather than volume per hour). In terms of secondary outcomes, the potential for secondary brain injury (which is indeed an important surrogate marker) may have been better evaluated by assessing incidence of hypotension rather than mean blood pressure. Overall, however, the reduction in mortality and the favorable effects of HEMS upon neurological outcome combine effectively with other data suggesting that HEMS improves outcome in TBI patients [11, 12].

9.7. Brown JB, Stassen NA, Bankey PE, Sangosanya AT, Cheng JD, Gestring ML. "Helicopters and the civilian trauma system: National utilization patterns demonstrate improved outcomes after traumatic injury", *J Trauma,* 2010; 69 : 1030–1036.

Objective. This study's objective was to compare outcomes between helicopter transport (HT) and ground transport (GT) of injured patients from the scene of injury.

Methods

Study Design. This was a retrospective study using the National Trauma Databank version 8.

Setting. The patient sample was nationwide.

Time Frame. Data from 2007 were analyzed.

Patients. Patients transported directly to a trauma center from the scene of injury by HT or GT were included. Interfacility transfer patients and patients who were dead on arrival were excluded.

Analysis. Stepwise logistic regression was used to determine whether transport modality was a predictor of survival or discharge to home. Stepwise univariate analysis identified all covariates for inclusion in the regression model.

Results. In this study, 258,287 patients were transported by helicopter (16%) or ground (84%). Mean ISS was higher in HT patients (15.9 ± 12.3 versus 10.2 ± 9.5, $P < 0.01$), as was the percentage of patients with ISS >15 (42.6% versus 20.8%; OR 2.83; 95% CI 2.76 to 2.89). HT patients had higher rates of intensive care unit admission (43.5% versus 22.9%; OR, 2.58 with 95% CI, 2.53 to 2.64), mechanical ventilation (20.8% versus 7.4%; OR, 3.30 with 95% CI 3.21 to 3.40), and requirement for emergent surgical intervention (18.9% versus 12.7%, OR 1.60; 95% CI 1.56 to 1.65). 14.7% of HT subjects versus 25% of GT subjects were discharged alive within 24 hours of admission to the hospital. However, HT became an independent predictor of survival (OR 1.22, 95% CI 1.17 to 1.27) and discharge to home (OR, 1.05, 95% CI 1.02 to 1.07) when compared with GT after adjustment for patient, injury, and hospital covariates.

Authors' Conclusions. HT increased the likelihood of survival and discharge to home after treatment; thus air medical transport has merit and improves outcome. The authors also state that patients being selected for HT "are appropriately sicker and are more likely to use trauma center resources than those transported by ground ambulance." In addition, the authors note that because the injury severity drops off more drastically for HT than GT as the transport time increases, other factors such as distance and geography rather than injury severity alone are influencing the decision to use HT. The authors conclude that although overtriage continues to be an issue requiring attention by individual trauma systems, it is not as profound a problem as previously reported.

Commentary. The largest study in the HEMS literature (HEMS *n* 41,987, GEMS *n* 216,400), this analysis of National Trauma Data Bank (NTDB) data identified a 22% improvement in mortality associated with HEMS as compared to ground transport, for scene trauma patients of all ages/ mechanisms (only dead-on-arrival patients were excluded). The study was able to incorporate a broad array of covariates: age, gender, insurance status, mechanism of injury, prehospital times (calculated for HEMS due to straight-line travel and assuming 150 mph transport speed; unavailable for GEMS), Injury Severity Score (ISS), Glasgow Coma Score (GCS), admission systolic blood pressure and respiratory rate, hospital and intensive care unit admission and length-of-stay, mechanical ventilation duration, Emergency Department (ED) and hospital disposition, and hospital trauma center designation. In addition to the outcomes advantage, significant findings included high acuity for HEMS patients nationwide (nearly half requiring ICU, a fifth intubated for an average of a week, a fifth requiring urgent operative intervention)—the authors write that "On a national level, patients being selected for HEMS are appropriately sicker and are more likely to use trauma center resources than those transported by ground ambulance." The study also found, in terms of triage, that ISS dropped off only as distance from the trauma center increased—so HEMS is being appropriately used to get patients in timely fashion, to trauma centers, for logistics reasons when this is necessary. The study reported a last counterargument to "overutilization" that <15% of HEMS patients nationwide were discharged within 24 hours.

9.8. Nakstad AR, Strand T, and Sandberg M. "Landing sites and intubation may influence helicopter Emergency Medical Services on-scene time", *J Emerg Med,* 2010; Aug 23 (epub ahead of print).

Objective. The purpose of this study was to evaluate how landing site and rapid sequence intubation (RSI) affect on-scene time (OST).

Methods

Study Design. This was a prospective observational study.

Setting. The Oslo University Hospital HEMS is an anesthesiologist-staffed service that operates in a mixed urban and rural area in southern Norway. The HEMS does not operate with fixed landing sites. A landing site is chosen by HEMS that is as close to the scene of the accident as possible.

Time Frame. Data were gathered from January 1 to December 31, 2002.

Patients. All trauma mission patients were included in this study. Interhospital transports of trauma patients and primary missions to trauma patients in which the crew responded by the rapid-response car were excluded from this study. Indications for RSI were actual or potential airway compromise, ventilatory failure, or a Glasgow Coma-Scale score of <9 secondary to head injury. Ketamine was used as the induction agent followed by succinylcholine. Tube position was verified clinically and by capnography.

Results. During the study period, HEMS executed 252 trauma missions involving 298 patients. Information regarding the landing site was available for 214 (84.9%) of the missions. Landing closer than 50 m from the accident was possible in 75% of recorded cases. In 18% of the missions, the helicopter landed between 50 and 200 meters from the accident. The distance exceeded 200 m in 7% of the cases, and additional ground transport was used in most of those cases. The HEMS anesthesiologist performed RSI in 48 patients before the start of transport. Head injury with Glasgow Coma-Scale score <9 was the indication for RSI in 56.3% of the cases. The median OST was 14.5 min when the patient was not intubated and 22.7 min for HEMS-intubated patients. The difference between the mean on-scene times was 8.2 min ($P < 0.001$). The NACA (National Advisory Committee of Aeronautics) revealed a marked difference in severity between the injured patients who were endotracheally intubated on-site and the spontaneously breathing patients who were transported by HEMS.

Authors' Conclusions. The author states that unpublished results from the Oslo University Hospital HEMS show that transfer of a patient between ground ambulance and helicopter takes between 5 and 10 min. Thus, the potential 5–10 min delay is avoided in a large majority of cases (when helicopters land close) since ground transport is unnecessary. This is an argument against the use of fixed, predetermined landing sites. Furthermore, the increased OST of 8.2 min is on the same order of magnitude as found in other studies. The time required for other prehospital procedures such as positioning, suctioning, and establishing intravenous access cannot be separated because an RSI is never performed in isolation. If an RSI had not been performed, it would have been necessary to manage the patients' airways by other means such as supraglottic device or bag-mask-ventilation. Both of these methods not only may shorten OST but also may increase the risk of airway compromise.

Commentary. On-scene time is an important "outcome" for prehospital studies (including HEMS investigations) and minimization of on-scene time is a laudable goal. The use of on-site helipads for receiving hospitals has received attention from organizations such as the National Association of EMS Physicians (NAEMSP). On-site hospital helipads are preferred due to both the savings of time (the endpoint of the current study) and also the elimination of an extra physical transfer of the patient. This study makes a strong case that the extra transport leg associated with HEMS landing distant from trauma scenes is just as undesirable as is the aircraft's landing at a remote helipad at the receiving hospital end. Of course, the reason for predetermined landing zones is largely related to safety, and any adjustment of scene landing sites must take this all-important variable into account.

9.9. Littlewood N, Parker A, Hearns S, Corfield A. "The UK helicopter ambulance tasking study", *Injury,* 2010; 41(1): 27–9.

Objective. The aim of this study is to establish and compare the tasking criteria, dispatch arrangements, and crew configuration for all helicopter ambulance services in the United Kingdom.

Methods

Study Design. The authors employed a structured telephone interview of all the helicopter ambulance services in the United Kingdom. Information was gained from the duty paramedic or doctor and was supported by hard copy documentation for each service's tasking criteria by 14 of the 16 services surveyed. Key types of information requested included number of helicopters, annual number of missions, crew configuration, dispatcher type, existence of dedicated HEMS tasking desk in ambulance control center, and tasking criteria.

Time Frame. The interviews were conducted in the spring of 2008.

Results. All 16 helicopter ambulance services responded and all information requested from each was complete. The services operate between 1 and 3 helicopters each and have an annual mission frequency between 620 and 2000. Of the 16 services, nine are crewed by paramedics, three have a doctor full-time, and four have a paramedic crew with a doctor on board for a variable proportion of missions. Only six of the 16 have dedicated helicopter ambulance dispatch desks. Only two of the services have medically trained dispatchers (both are paramedics). A total of 67 tasking criteria were identified and divided into six groups: mechanism of injury, anatomical injury type, physiology of injured patients, nontraumatic medical conditions, location, and miscellaneous.

Authors' Conclusion. Wide variation in criteria for tasking, crew configuration, and dispatch arrangements exist between the helicopter ambulance services in the UK. These variations may be due to local geographic factors, economic issues, or the availability of a flight crew doctor. The lack of a formal audit or validation criteria may also play a role in the variability observed. The authors cite a lack of evidence-based guidelines for HEMS as another possible reason for the nonuniformity observed in their survey results. They also argued that tasking for paramedic-only crewed aircraft should be focused on remote or inaccessible locations where prolonged ambulance access times would hinder patient care. In order to develop helicopter ambulance service tasking criteria, the cases currently being attended need to be analyzed in terms of shortened response times and improvements in direct triage to definitive care. For physician-crewed aircraft, the incidence of critical care interventions should be analyzed along with the tasking criteria utilized in their activations to determine the most efficient use of those specially trained crews. A nonstandardized approach to air ambulance dispatch criteria and crew configuration is concerning given the financial implications of unwarranted air ambulance use along with the physical risks of aeromedical transport.

Commentary. This paper actually focuses on dispatch. It is included in an "outcomes" overview because of its mention of "lack of evidence-based guidelines for HEMS" as a potential explanation for nonstandardized HEMS dispatch. The paper's authors correctly point out that nonstandardization of HEMS use is not defensible. While the available evidence for HEMS suffers from much the same imprecision as do the data addressing many other prehospital (and in-hospital) interventions, it is clearly the case that some level of dispatch standardization, is better than none. The available HEMS outcomes evidence as discussed in this overview (and its preceding editions) is *prima facie* evidence that there are *some* data upon which to base determinations as to how to appropriately use HEMS. The argument that "there's no evidence" can no longer be accepted as a basis for failure to establish guidelines for utilization of the HEMS resource.

9.10. Sullivent EE, Faul M, Wald MM. "Reduced mortality in injured adults transported by HEMS", *Prehosp Emerg Care,* 2011; 15 : 295–302.

Objective. This study's objective was to determine whether the mode of transport of scene trauma patients affects mortality.

Methods

Study Design. This is a retrospective study using the National Sample Program of the 2007 National Trauma Data Bank.

Setting. The patient sample was nationwide.

Time Frame. Data from 2007 were used.

Patients. Patients transported directly to a trauma center from the injury scene were included. Interfacility transfer patients, patients aged <18, and patients transported by means other than helicopter or ground ambulance (fixed-wing, walk-in, private vehicle, public transportation, law enforcement) were excluded. Only records from facilities in which ≥80% of the patients had all three Revised Trauma Score (RTS) physiologic data were included.

Analysis. Standard logistic regression model without stepwise procedures was used to assess the association of mortality with mode of EMS transport after controlling for potential cofounders. The variance inflation factor test was used to detect multicollinearity among all of the dependent variables. Subanalyses of those aged 18–54 years and those aged 55 years were performed to assess outcome differences.

Results. In this study, 56,744 patients were transported by helicopter (17.7%) or ground (82.3%). The odds of death were 39% lower in those transported by HEMS compared to those transported by ground ambulance (OR = 0.61, 95% CI 0.54 to 0.69). Among those aged 18–54 years the odds of death were 49% lower among helicopter-transferred patients compared to those transferred by ground ambulance

(OR = 0.51, 95% CI 0.44 to 0.60). Among those aged ≥55 years, the odds of death were not significantly different (AOR = 0.92, 95% CI 0.74 to 1.13). Among all transports, male patients had a higher odds of death compared to female patients (OR = 1.23, 95% CI 1.10 to 1.38).

Authors' Conclusions. The use of HEMS for the transport of trauma patients is associated with reduced mortality in adult patients under age 55 years. The 39% reduction in odds of mortality in adults transferred by HEMS compared to ground ambulance is greater than the 20–30% reduction in mortality reported in most of the previous studies. However, HEMS did not improve mortality in adults aged ≥55 years. Based on this latter finding, the authors suggest that the transport mode may not provide a positive effect on mortality in injured older adults. The establishment of a method for selecting those patients who would most benefit from helicopter transfer is expected to enhance the reduction in mortality shown in this study.

Commentary. These authors analyzed the 2007 NTDB data, although the overall *n* was slightly different from the Brown et al.study above due to differing methodology (e.g., different treatment of cases with missing data). Multivariate logistic regression adjusting for age, gender, ISS, and RTS identified a 39% reduction in mortality associated with HEMS. Since the data analyzed were a large subset of the same database used in the study published a few months earlier by Brown et al., this study's findings are confirmatory, if unsurprising. Noteworthy for this study is that when analysis focused on older adults (age >55), the statistical significance of HEMS' mortality benefit was lost (odds ratio 0.92, 95% CI 0.74–1.13). It is quite premature to conclude that HEMS should not be used for older patients, but the finding of limited benefit in those over 55 should spur further investigation of air medical deployment for geriatric trauma.

9.11. Stewart KE, Cowan LD, Thompson DM, Sacra JC, Albrecht R. "Association of direct helicopter versus ground transport and in-hospital mortality in trauma patients: a propensity score analysis", *Acad Emerg Med*, 2011; 18: 1208–1216.

Objective. The study's goal was to determine whether, for scene trauma transport, there was an association between air versus ground transport mode and mortality.

Methods

Study Design. This was a retrospective consecutive-case review of records from a statewide trauma registry (with mandatory data submission for all hospitals). Propensity scoring developed with logistic regression was used to account for variables potentially confounding the association, which was tested with a Cox proportional hazards model. The model included propensity scores as well as ISS, initial RTS, and transport distance. The authors' endpoint analysis focused on 2-week mortality.

Setting. This was a statewide study, conducted in the U.S.' southwestern state of Oklahoma. HEMS services operating in the state were RN/EMTP-staffed.

Patients. Patients were 10,184 scene patients, transported 2005 through 2008, by either ground (*n* 7467) or air (*n* 2717) EMS, directly to either the state's single Level I trauma center (in Oklahoma City) or to one of the state's two Level II centers (100 miles from Oklahoma City, in Tulsa).

Results. The overall hazard for 2-week mortality was 33% lower in HEMS as compared to ground EMS patients, when adjusting for propensity, ISS, RTS, and transport distance. The benefit was greatest in patients with mid-range RTS (39% mortality reduction for RTS between 3 and 7). For the 75% of patients who had normal vital signs at the scene, the hazard ratio point estimate for mortality reduction was 35% but statistical significance was not reached due to this group's overall low mortality (and wider confidence intervals). In the patients with very poor RTS scores (3 or less), there was no difference in mortality between HEMS and ground transport.

Authors' Conclusions. After controlling for a number of factors, and using a model which appeared to account for multiple potential confounders, HEMS use was associated with a mortality reduction of 33%.

Commentary. Propensity scoring is an increasingly-used method to allow for assessment of transport mode and trauma outcome. One of the attractions of the technique, is that overall mortality is often sufficiently low that incorporation of myriad covariates stretches the mathematical capabilities of generalized linear modeling. As the authors point out in a lucid explanation, propensity scoring allows for control of multiple confounders with a single term in the model. The model can then incorporate "standard" covariates (ISS, RTS, distance) and generate a fairly robust estimate for HEMS impact. It is noteworthy that, regardless of the fact that this study's methodology differs from most of the studies in the HEMS literature, the general estimate for scene mortality improvement falls very close to the most commonly encountered range (in the literature as a whole) of 25–30%.

10. Trauma-Scene and Interfacility

10.1. Mitchell AD, Tallon JM, Sealy B. "Air versus ground transport of major trauma patients to a tertiary trauma centre: A provincewide comparison using TRISS analysis", *Can J Surg*, 2007; 50 : 129–133.

Objective. The study's objective was to compare the outcomes of blunt trauma patients transported by HEMS, as compared to ground EMS, in a primarily rural, provincewide integrated trauma system with a single tertiary receiving center.

Methods

Study Design. The study was a retrospective trauma database review.

Setting. The setting was the Queen Elizabeth Health Sciences Centre and Dalhousie University, Halifax, Nova Scotia. The HEMS unit is staffed by a nurse/paramedic team and operates around the clock.

Time Frame. Study patients were those who arrived at the study hospital between 1998 and 2002.

Patients. Study patients were all (n = 791) adult (>15 years old) blunt trauma scene transports to the study center during the study period, with ISS being at least 12; 237 (30%) were transported by HEMS and 554 (70%) were transported by ground EMS. Median ISSs for air and ground patients were 25 and 20, respectively. Only 16% of HEMS transports came directly from the scene to the study center; 56% of ground EMS patients were scene transports.

Analysis. The analysis used TRISS. Importantly, there was a ground control group; so the performance of HEMS and ground EMS could be compared against TRISS-predicted, as well as against each other. This is important, given the opposite directionality of air and ground EMS effects on outcome (see the following).

Results. As compared to TRISS-predicted survival, HEMS patients had significantly better outcome—a 25% improvement in mortality as compared to predicted. Ground EMS-transported patients not only failed to have improved outcome over TRISS-predicted but also actually had significantly *higher* mortality than predicted by TRISS; in this study ground transport equated with a 10% increase in mortality. With a W score of 6.4, HEMS was found to result in 64 lives saved per 1000 transports. The negative W score of −2.4 for ground EMS indicated that there were 24 unexpected *deaths* per 1000 ground ambulance transfers. In *post hoc* analysis excluding falls, the deleterious effects of ground EMS transport disappeared: outcomes in the nonfall group for ground EMS were equal to TRISS-predicted. In the nonfall group, however, HEMS patients still had a significantly improved outcome over TRISS-predicted (W of 6.6 indicating 66 lives saved per 1000 transports).

Authors' Conclusions. This first provincewide study, focusing on a rural area, finds that HEMS transport of patients with ISS at least 12 is associated with significantly improved outcomes as compared with ground transport.

Commentary. As the authors themselves are quick to note, their methodology benefits from the availability of a single trauma database covering the entire province. All of the system's trauma patients are thus captured in the analysis, and the authors thus avoid the selection bias that cripples some HEMS studies [13]. In essence, the authors have conducted a population-based study, with minimization of confounding variables, in a setting ideal for detecting a HEMS benefit (a rural, maritime province with a single tertiary trauma center). If the benefit of HEMS is assessed as the difference in outcome as compared to ground transport, this study demonstrates that—in a setting admittedly ideal for HEMS benefit—air medical transport saves 88 lives per 1000 transports and decreases mortality 35%. Importantly, the study's external generalizability is improved by the fact that both scene and interfacility transports were assessed.

10.2. Schiller J, McCormack JE, Tarsia V, Shapiro MJ, Singer AJ, Thode HC, Henry MC. "The effect of adding a second helicopter on trauma-related mortality in a county-based trauma system", *Prehosp Emerg Care,* 2009; 13 : 437–443.

Objective. The aim of this study is to compare the outcomes of adult trauma patients within a county-based trauma system, using a "natural experiment" design enabled by addition of a HEMS unit.

Methods

Study Design. The study was a before-and-after trauma database review.

Setting. The setting was in the state of New York. The area of interest encompasses the eastern end of Long Island, including a population of 500,000 and an area of 450 square miles. The eastern end of the service area, in the "before HEMS" period, was effectively uncovered by HEMS (due to the stationing of HEMS resources 30 miles away). In the "after" period, the county's HEMS coverage increased to include an aircraft stationed in the eastern end of Long Island. The HEMS unit is staffed by a nurse/paramedic team and operates around the clock.

Time Frame. Study patients were those who were injured during the 10-year period 1996–2006; the time period was split in half by the addition of the second HEMS unit in 2001.

Patients. Study patients were all (n = 1551—roughly half in each period) adult (at least 14 years old) blunt trauma patients in the county trauma registry during the study period.

Analysis. The primary analysis consisted of a straightforward comparison of mortality rates. Importantly, the mortality rates for all patients were assessed (including those who were not transported from the community hospitals in either period). The authors also carefully tracked, for each study period, numbers of patients who were kept in the nontrauma center hospitals and also the transport modality for those undergoing interfacility transport.

Results. The main study result was overall mortality, which decreased significantly in the HEMS era (dropping from 16.2% down to 11.9%, P = 0.02). Additionally, air transport to the regional trauma center increased by 130%, with a commensurate decrease in community (nontrauma center) hospitals' providing care for injured patients. Interestingly, interfacility HEMS transports from the community hospitals remained stable (i.e., there was no increase in HEMS utilization for interfacility transport; the increased utilization was for scene flights). The overall acuity (as measured by ISS) was not different for the HEMS period. Severely injured patients (defined by ISS at least 16) were significantly more likely to undergo HEMS transport in the HEMS period.

Authors' Conclusions. Introduction of a second HEMS unit to the a previously undercovered area of a county-based trauma system was associated with significantly lower trauma mortality.

Commentary. In a natural experiment paper covering a relatively discrete population, the authors performed an informative analysis of trauma patient care and outcomes before and after addition of dedicated HEMS to an area. The authors' methodology and discussion included many details relevant to their geography, and this paper must be read in full for an appreciation of its details. For the purposes of adding to the HEMS literature, it is a fair summary to state that the addition of HEMS resources to previously under- or uncovered areas reduces trauma mortality even in a fairly well-developed trauma system. It is more than interesting to note that the point estimate for trauma mortality reduction (26.5%) is remarkably consistent with the point estimates most often reported in other HEMS trauma literature reported on herein.

10.3. McVey J, Petrie D, Tallon J, Malay S, Colpitts K. "Air versus ground transport of the major trauma patient: A natural experiment", *Prehosp Emerg Care*, 2009 (e-published ahead of print—the manuscript appeared in the print edition of *PEC,* 2010; 14 : 45–50).

Objective. The aim of this study is to compare the outcomes of adult trauma patients transported to a Level 1 trauma center by helicopter versus ground ambulance, using a unique "natural experiment" design to obtain the ground comparison group while reducing potential confounders.

Methods

Study Design. The study was a retrospective analysis of data in two databases (the HEMS database and a provincewide trauma registry). The adult trauma patients were split into 3 groups. *Group 1* consisted of adult trauma patients transported to a tertiary care trauma center by air transport. *Group 2* patients were those triaged to HEMS (i.e., accepted by the online Medical Control Physician for air transport) but transported by ground due to aviation issues. *Group 3* included "all other" adult trauma patients transported by ground ambulance.

Setting. The study was a retrospective study from the largely rural Province of Nova Scotia. There is a single helicopter which serves the entire province (population about one million), executing about 600 missions per year. All provincial patients go to a single trauma center. The HEMS unit is staffed by a nurse/paramedic team and operates around the clock.

Time Frame. Study patients were those transferred between July 1, 1997 and June 30, 2003.

Patients. The study included 397 adult (at least 16 years of age) trauma patients flown by LifeFlight (*Group 1*), 57 ground-transported patients initially triaged to HEMS (*Group 2*), and 1195 patients who were initially triaged to, and subsequently transported by, ground EMS (*Group 3*).

Analysis. The primary outcome of interest of this study was mortality. The analyses that were performed used TRISS-based methodology.

Results. There was no statistically significant difference between *Group 1* and *Group 2* with respect to mean age, gender, percentage with blunt injury, AIS, and ISS; *Group 3* was of lesser acuity. There was no difference in the time between injury and trauma center arrival, between *Group 1* and *Group 2*. *Group 1* patients had a proportion of scene calls (20%) that was higher than that of *Group 2* (7%); *Group 3* patients were mostly (58%) scene transports which were related in part to their being more urban in nature. As compared to *Group 2* patients (whose mortality was equal to TRISS-predicted), *Group 1* status was associated with statistically significant survival improvement (5.61 more lives per 100 transports). *Group 3* patients had the worst outcome, with a survival *less* than that predicted by TRISS ($W = -2.02$).

Authors' Conclusions. This unique natural experiment led to methodological improvement in matching air versus ground cohorts and reduced confounding. Using naturally assigned patient groups, air transport of the adult major trauma patient in Nova Scotia is associated with significantly improved survival as compared to ground transport of similar patients.

Commentary. Although the study has some limitations (as reported by the authors), its message is potent given the methodological strengths of the approach and the fact that it extends (by both methodology and date) the study of Mitchell et al. from the same area [14]. First, some of the study's shortcomings should be acknowledged. The study area is largely rural, with prolonged prehospital times and only a single tertiary trauma center. The results, however internally valid they may be, are thus of uncertain external validity when considering more urban areas. The authors also identify imperfections associated with TRISS use, although they correctly point out the lack of a preferable alternative. In any even, given the particular natural experiment design used in this study, any analytic technique would have to be truly biased (e.g., give an unfair advantage to HEMS as compared to ground EMS patients) in order to lead to spurious results. There is no reason to believe that TRISS would be biased in this population.

What does this study add to the (few dozen) TRISS studies that suggest some HEMS-associated outcomes improvement? While the authors' point estimate for lives saved per 100 transports is remarkably consistent with that of the preponderance of the literature [2–4, 15], there are aspects to the current study that set it apart for methodological interest and excellence.

First, this is a provincewide study, population-based. In such a relatively small population (with only one major trauma center), this means that the selection bias that plagued some other HEMS natural experiment studies in trauma [13] and nontrauma [16] is substantially reduced. Second, the authors' concurrent natural experiment design is unique in the trauma literature and superior (in its minimization of selection bias) to the only similar study—of cardiac patients—in the HEMS nontrauma literature [16].

The use of concurrent design, in which the triage decision-making was the same for *Group 1* and *Group 2*, is powerful. The "before-and-after" approach characterizing the other HEMS natural experiment trauma studies is useful, but potentially limited by non-HEMS trauma system changes [13, 17, 18]. The strength of the current study is enhanced by the facts that the system and patients were served by only one helicopter, with one dispatch center, and by one tertiary trauma center.

The fact that the pretrauma center times were similar in *Group 1* and *Group 2* may or may not mean that the HEMS logistics contributions were minimal in every case. However, the similarity in pretrauma center times does indicate that the time variable was not likely an overriding factor in overall survival benefit.

11. Trauma-Interfacility

11.1. Brown JB, Stassen NA, Bankey PE, Sangosanya AT, Cheng JD, Gestring ML. "Helicopters improve survival in seriously injured patients requiring interfacility transfer for definitive care", *J Trauma,* 2011; 70 : 310–314.

Objective. This study's objective was to assess whether helicopter transport (HT) was associated with a survival benefit when compared with ground transport (GT) in a population of patients requiring interfacility transfer for definitive management of traumatic injury.

Methods

Study Design. This was a retrospective study using the National Trauma Databank version 8.

Setting. The patient sample was nationwide.

Time Frame. Data from 2007 were analyzed.

Patients. Patients transferred from a referring hospital (RH) to a trauma center by helicopter or by ground ambulance were included. Patients transferred by fixed wing aircraft were excluded.

Analysis. A forward stepwise logistic regression model was used to determine whether transport modality was an independent predictor of survival after adjustment for covariates. Regression analysis was repeated in subgroups with Injury Severity Score (ISS) ≤15 and ISS >15. Survival was compared in both univariate and multivariate regression analyses.

Results. In this study 74,779 subjects were transported by helicopter (20%) or ground (80%). Mean ISS was higher in HT patients (17 ± 11 versus 12 ± 9, $P < 0.01$), as was the percentage of patients with ISS > 15 (49% versus 28%; OR 2.53, 95% CI 2.43 to 2.63). HT had higher rates of intensive care unit admissions (54% versus 29%; OR 2.86, 95% CI 2.75 to 2.96), mechanical ventilation (25% versus 9%; OR 3.49, 95% CI 3.33 to 3.66), and requirement for emergent surgical intervention (19% versus 13%; OR 1.52, 95% CI 1.43 to 1.60). Univariate analysis showed that overall survival was lower in HT patients as compared to GT patients (92% versus 96%, $P < 0.01$). In subgroup analysis overall survival for transfer patients with ISS ≤15 was also slightly lower in the HT group (98% versus 99%; $P = 0.01$). Overall survival for transfer patients with ISS >15 was again lower in HT group (85% versus 90%; $P < 0.01$). However, HT became an independent predictor of survival to discharge after adjusting for covariates (OR 1.09, 95% CI 1.02 to 1.17, $P = 0.01$) in patients with ISS >15.

Authors' Conclusions. In this first national-level study to compare HT and GT with respect to interfacility trauma patients' outcomes, HT appears to convey a survival benefit in those patients who are more severely injured. HT was an independent predictor of survival in patients with ISS >15. However, HT was not an independent predictor of survival in less severely injured patients (ISS ≤15). HT offered shorter transport and overall prehospital times. Those patients being transferred by helicopter had consistently higher injury severity markers. HT patients utilize a higher level of hospital resources and the data support a contention that, at a national level, providers are triaging more severely injured patients for HT.

Commentary. The largest ground-versus-air transport comparison in the interfacility trauma literature (HEMS n 14,771, GEMS n 60,008), this analysis of National Trauma Data Bank (NTDB) data followed the same general lines as a scene trauma paper by the same authors (published a few months earlier, in December 2010's *J Trauma*); the difference was that this paper assessed interfacility transports. The authors' overall multivariate analysis incorporated the myriad covariates described above for the scene run paper. Multivariate regression reported was reported as negative for demonstrating HEMS survival benefit; the point estimate of 6% improvement in OR (point estimate 1.06) was associated with a 95% CI that just crossed the null value (0.99 to 1.13, $P = 0.07$). The authors also executed an *a priori* planned subgroup analysis on those patients with ISS below and those with ISS above, a cutoff of 15. For those patients with lower ISS, HEMS was (unsurprisingly) associated with no survival benefit (OR point estimate and 95% CI: 1.06, 0.92 to 1.24, $P = 0.42$). For patients with more serious injury—which group constituted 49% of all HEMS transports—there was a significant mortality improvement associated with air medical transport (OR 1.09, 95% CI 1.02 to 1.17, $P = 0.01$). HEMS patients were far more severely injured (e.g., intra- and early posttransport deaths 10x higher) and required substantially more resources (e.g., 50% more likely to need emergency operation), than those transported by ground EMS. The study's broad array of covariates and the clear demonstration of improved outcome in a group (those with ISS exceeding 15) comprising half of the air-transported cohort adds to the strength of the study message. The study's authors pointed out additional interesting facts addressing logistics and utilization (e.g., only 8% of HEMS patients were discharged within 24 hours). Among the study weaknesses acknowledged by the authors was the failure to account for possible morbidity improvements that could benefit patient with lesser injury acuity.

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Review Article

Helicopter EMS: Research Endpoints and Potential Benefits

Stephen H. Thomas and Annette O. Arthur

Department of Emergency Medicine, University of Oklahoma School of Community Medicine, OU Schusterman Center, 4502 East 41st Street Suite 2E14, Tulsa, OK 74135-2553, USA

Correspondence should be addressed to Stephen H. Thomas, stephen-thomas@ouhsc.edu

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Patients, EMS systems, and healthcare regions benefit from Helicopter EMS (HEMS) utilization. This article discusses these benefits in terms of specific endpoints utilized in research projects. The endpoint of interest, be it primary, secondary, or surrogate, is important to understand in the deployment of HEMS resources or in planning further HEMS outcomes research. The most important outcomes are those which show potential benefits to the patients, such as functional survival, pain relief, and earlier ALS care. Case reports are also important "outcomes" publications. The benefits of HEMS in the rural setting is the ability to provide timely access to Level I or Level II trauma centers and in nontrauma, interfacility transport of cardiac, stroke, and even sepsis patients. Many HEMS crews have pharmacologic and procedural capabilities that bring a different level of care to a trauma scene or small referring hospital, especially in the rural setting. Regional healthcare and EMS system's benefit from HEMS by their capability to extend the advanced level of care throughout a region, provide a "backup" for areas with limited ALS coverage, minimize transport times, make available direct transport to specialized centers, and offer flexibility of transport in overloaded hospital systems.

1. Introduction

This discussion strives to overview potential benefits accrued by utilization of helicopter EMS (HEMS). The goal will be to outline the major HEMS-associated gains accrued by patients, EMS systems, and healthcare regions.

The existence and degree of benefits from HEMS use have been debated for years. Unfortunately, it is not possible to know, at the time of vehicle triage, precisely which patients will benefit from HEMS. On the other hand, there are systematic reviews of the literature which strongly suggest that HEMS accrues benefits for at least some types of patients [1–3]. An example review is found in a 2007 report from the independent Institute of Health Economics, prepared for the Canadian health ministry in Alberta. These authors, after reviewing all available studies from the year 2000, concluded: "Overall, patients transported by helicopter showed a benefit in terms of survival, time interval to reach the healthcare facility, time interval to definite treatment, better results, or a benefit in general." [4]

Since few would argue that HEMS benefit is always predicated solely on time and logistics, any consideration of HEMS outcomes must include broader considerations of out-of-hospital care (for purposes of consistency within this paper, "prehospital" is interchangeable with "out-of-hospital" in order to encompass both scene and interfacility transports). The HEMS crews' extended practice scope offers circumstances well suited for assessing high-level advanced life support (ALS) care and its potential benefits [5]. For example, studies assessing prehospital intubation (ETI) have provided important—if unintended—insight into HEMS' salutary impact on outcome [6–8].

Many questions remain unanswered about HEMS. However, there is a growing body of evidence addressing HEMS' potential benefits. This paper aims to assist those working toward proper deployment of air medical resources. The discussion also aims to aid those planning further HEMS outcomes research.

2. Outcomes Assessment in HEMS

Various outcomes will be visited in detail later in this paper, but it is appropriate to commence with a brief word on what constitutes an "outcome." This paper will address primary, secondary, and surrogate outcomes.

2.1. Primary Outcome Variables: Survival and Functional Outcome. The most important outcome for HEMS studies is that of functional survival. This is the primary outcome addressed in most studies referenced in this paper. Since survival to hospital discharge in a persistent vegetative state is different from functional survival, consideration of neurological condition should be (and usually is) incorporated into survival definition.

Discussions of HEMS' potential utility often mention safety. The line of thinking, usually advanced by those who believe that HEMS is significantly overused, is that against any potential benefit accrued by HEMS should be weighed the risks associated with air transport. The importance of safety as the prime consideration in HEMS is undeniable, but the subject is beyond the scope of this paper. Readers are directed to other expert resources, who have assessed prehospital air and ground vehicle safety [9, 10].

2.2. Secondary and Surrogate Outcome Variables. These variables either explore possible mechanisms for morbidity/mortality reduction (e.g., peri-intubation physiology), or assess parameters that are indirectly linked to outcomes improvement (e.g., time to cardiac catheterization).

One outcome of increasingly recognized importance is relief of pain. Though listed here as a secondary variable, pain relief has been considered by many EMS experts as a stand-alone (i.e., primary) outcome for prehospital care [11].

An additional set of secondary variables encountered in the medical literature deals with lengths of stay in various hospital departments (e.g., ICU stay). The problems attendant to use of these endpoints are well known to clinical researchers; length of stay is impacted by many factors well downstream from transport modality. Nonetheless, at least one HEMS study [12] suggests that, as compared with ground-transported cardiac patients, those transported by air had a 2-day decrease in hospital length of stay due to improved myocardial salvage. That study is the exception to a general rule that HEMS literature focuses more on mortality and other surrogate endpoints (see below) rather than addressing hospital lengths of stay.

Studies assessing HEMS' impact on surrogate endpoints constitute an important set of contributions to the literature. Surrogate variables tend to be physiologic (e.g., hypoxemia, hypercapnia, hypotension) or logistic (e.g., prehospital time, time to advanced care) parameters with evidence basis for delineation as endpoints. Some surrogate outcomes are not likely to be testable in terms of precise mortality benefit; an example would be the ability of highly trained HEMS crews to streamline interfacility transports of ruptured abdominal aortic aneurysm patients by taking them directly to receiving hospitals' operating rooms [13]. Some secondary and surrogate endpoints may lack universal acceptance as impacting functional outcome, but others (e.g., hypoxemia in brain-injured patients) are solidly evidence based [14].

An emerging view is that patient safety initiatives in HEMS have resulted in low incidence of adverse events during air medical transport. Given the importance of patient safety, and the increasing attention to this as an "outcome," preliminary work such as that by MacDonald et al. [15] is of vital import. Assessment of patient safety and adverse events is in early stages, but HEMS investigators deserve credit for focusing on this measure.

2.3. Nontrauma Outcomes Analysis. Nontrauma outcomes studies are limited largely for two reasons: (1) experts in many countries, even where there is debate over HEMS' effectiveness, are in agreement that a randomized controlled trial of HEMS versus ground transport is not currently feasible, and (2) since HEMS-triaged patients tend to be of higher acuity than ground-transported patients, outcomes analysis has to be acuity adjusted; however there is no consistently reliable means of adjusting for acuity in HEMS-transported nontrauma patients.

Another issue with nontrauma outcomes studies is that the transport population comprises disparate diagnostic groups (e.g., pregnancy, acute coronary syndromes, epiglottitis, stroke, poisoning). Such disparity translates into small numbers for a single diagnosis, leading to biostatistical difficulties in detecting a small but clinically important benefit in the less commonly encountered patient types.

As a result of the issues noted above, use of HEMS for nontrauma patients has an evidence base that is, compared to that for trauma transport, less concrete. Nonetheless, there is evidence of various sorts. Absent controlled trials, some consideration should be given to expert opinion and even (for unusual diagnoses) case reports. These reports are often based upon time savings accrued with HEMS. Some examples follow, for cardiac, stroke, and "sporadic-use" cases.

An editorial [16] appearing in Chest, the journal of the American College of Chest Physicians, observed that "in many communities, emergency air medical systems have become an integral part of the practice of cardiology and critical care medicine." The authors go on to aver that "we firmly believe that air medical transport is a safe means for transport of cardiac patients and should be considered for patients who require transfer to more specialized centers for additional diagnostic and therapeutic interventions." Reports outlining extension of percutaneous coronary intervention to community hospitals include incorporation of HEMS into systems planning, as a necessary backup in cases where urgent CABG is required [17]. It is increasingly well known that time savings—in the manner that may be achieved by judicious HEMS use—can be helpful: each 30 minutes' additional ischemia time increases mortality by 8–10%. [18] Additionally, work from the TRANSFER-AMI group suggests that expedited transfer for mechanical intervention after community hospital lysis is associated with a 50% reduction in the 30-day composite endpoint (death, reinfarction, recurrent ischemia/reinfarction, CHF, or shock) [19]. It seems likely that HEMS will occasionally be a valuable option for some patients receiving this combined-therapy approach.

Similar to the situation with integration of HEMS into cardiac care systems is the rapidly solidifying role for air transport in stroke care. A Resource Document for a position statement of the National Association of EMS Physicians recommends air transport of stroke patients if the closest fibrinolytic-capable facility is more than an hour away by ground [20]. The American Stroke Association Task Force on Development of Stroke Systems [21] identified HEMS as an important part of stroke systems. The report states "air transport should be considered to shorten the time to treatment, if appropriate." Authors writing about the utility of HEMS in stroke (and also cardiac) care systems generally refer to the ability, addressed in detail later in this discussion and bolstered by logistics studies, of HEMS to "extend the reach" of tertiary care centers providing time critical care [22, 23]. A potential role for time critical transport in improving stroke outcomes is suggested by the pooled analysis revealing a stepwise outcomes improvement associated with each 90-minute improvement in lysis time (to 270 minutes) [24].

Another type of difficult-to-categorize (and equally hard to research) "outcomes" publication is the case report. As an example of many such reports, there is a description [25] of lifesaving HEMS use in a 32-year-old ARDS patient who received inhaled prostacyclin during an air medical transport that was deemed to be critical to that patient's survival. Others, in both the U.S. and abroad, have highlighted the occasional utilization of HEMS (scene runs) to enable stroke patients to reach specialized care centers in time to receive outcome-improving lytic therapy [26, 27]. Recently, a Canadian group described use of air transport to get critically needed antidotes (fomepizole in one patient, Digibind in another) to patients up to 6 hours faster than would have been the case had therapy been delayed to ultimate arrival at receiving centers [28].

2.4. Trauma Outcomes Analysis. Trauma outcomes analysis has a major advantage over nontrauma outcomes analysis in that there are more transported patients with trauma; this allows for more robust statistical methods. Also, there are many scoring systems (e.g., Glasgow Coma Score [GCS], Trauma Score [TS], Injury Severity Score [ISS]) that can be used to stratify patient acuity.

The capability of scoring systems to adjust, at least partially, for differences in patient acuity translates into an improved ability to combine patients from many HEMS programs and thus conduct multicenter research. Since most (though not all) HEMS programs transport a majority of trauma patients, the larger numbers for injured patients mean that it is easier to conduct outcomes research on trauma patients than on other populations.

The reader is expected to be familiar with most of the simple scoring systems, such as GCS and TS, but one subject—TRISS—is more complicated. Since TRISS is frequently encountered in the HEMS literature, and since its application (and misapplication) has important implications for appropriate interpretation of many trauma outcomes studies, readers are referred to a more definitive source such as the work of Boyd et al. [29]. For the purposes of this paper, it is noteworthy that TRISS, while prone to misapplication (e.g., employment of nonstandardized analysis in a patient population with inappropriately low M statistic), remains the gold standard for predicting outcomes in trauma patients [30–32].

3. Potential HEMS Benefits to Patients

3.1. Mortality Improvement as an Endpoint. This seems like the most obvious potential benefit upon which to focus, and in fact survival improvement has been the main endpoint of most of the major HEMS studies. Mortality is a relatively concrete endpoint (the only vagaries being introduced by a postincident time demarcation, such as 30- or 60-day mortality). Mortality is also relatively easy to address in the large, retrospective study designs (usually registry based) that comprise much of the HEMS outcomes literature. [6, 33, 34] As a dichotomous, easily ascertained endpoint, mortality can also be assessed with novel techniques. One example is the artificial neural network methodology reported by Davis et al., who identified HEMS (as compared to ground transport) as saving a statistically significant 3.6 lives per 100 transports of brain-injured patients with head AIS of at least 3 (when analysis focused on patients with GCS 3–8, 7.1 lives were saved per 100 transports) [5].

There are some potential weaknesses to use of the mortality endpoint. For example, the time frame is often not clearly laid out in HEMS studies, and the mortality timeline can be defined arbitrarily (e.g., 30 or 60 days). Additionally, though mortality is undoubtedly the most important clinical endpoint, it is difficult to assess unless there are large patient numbers and some means of matching acuity in air- and ground-transported patients. Finally, most HEMS study designs performing isolated assessment of mortality do not isolate the mechanism (e.g., streamlined prehospital times, improved airway management) for HEMS benefit.

3.2. Morbidity Improvement as an Endpoint. Since mortality assessment provides an incomplete picture, it makes sense to ascertain whether any nonmortality endpoints are affected by transport mode. Even if HEMS does impact mortality, it likely does so at a sufficiently low frequency that detection is difficult (given methodological issues and need to control for acuity). It is possible that nonmortality endpoints are reached with greater frequency than survival improvement, and thus nonmortality endpoints may be easier to detect. Additionally, nonmortality endpoints may provide clues to the mechanism by which HEMS improves survival (e.g., decrease in aspiration pneumonia implying improved airway management).

There are weaknesses associated with assessing morbidity. Heterogeneity is one. Depending on disease process, a myriad of nonmortality endpoints could theoretically be assessed. The potential utility of the "strength in numbers" argument (i.e., that nonmortality endpoints occur more frequently than survival accrual) is somewhat offset by the fact that assessment of many nonmortality endpoints requires analysis of a subgroup of patients in a certain diagnostic category; such limitation of the focus of a study results in lower numbers of patients with the endpoint in question. (Sometimes there are still enough numbers for functional outcomes assessment. For head injuries there is clear evidence that HEMS improves these nonmortality outcomes [6, 35]).

The literature includes some studies which address nonmortality endpoints such as quality-of-life and Glasgow neurological outcome score. It is fair to point out that those considering the weight of the evidence in favor of HEMS' improvement of trauma mortality have also stated the naturally following conclusion that HEMS improves morbidity, writing that appropriate air medical utilization will result in "lives saved and disabilities prevented" [36].

3.3. Secondary Endpoints. Secondary endpoints are myriad. The most useful are those with high clinical relevance. Examples are provided in this section.

Physiologic parameters are frequently used as secondary endpoints in HEMS studies. As mentioned earlier in this discussion, HEMS airway management for head injured patients has been shown to be associated with improved patient outcome [6, 37]. Investigators have addressed the intermediate mechanism for outcome improvement. It appears to be related to improved oxygenation and ventilatory practices, as reflected in peri-ETI (i.e., before and after ETI) physiologic parameters such as end-tidal CO_2, which may be frequently disrupted during ground EMS ETI [38], whereas they are much less during HEMS ETI or even with HEMS transport postground ambulance ETI [39–42]. Evidence demonstrating deleterious impact of peri-ETI physiologic disruptions (in head injury patients, at least) is sufficiently compelling that studies, showing less such derangement in HEMS patients, should be considered as highly relevant to the outcomes debate. Recent analyses also demonstrate improved hemodynamic management, with investigators concluding that improved blood pressure management by HEMS was partially responsible for improved head injury outcome [35].

The next major secondary endpoint is pain control. After being neglected for too long as a priority for acute-care (and prehospital) medicine, the subject of pain care is finally receiving its due. Experts in prehospital care have written that pain care is a valid endpoint in and of itself [11, 43, 44]. Furthermore, the fact is that HEMS providers tend to be more diligent in assessing and treating pain, than ground EMS providers [11, 45].

While HEMS patients are different from ground EMS patients, the studies of patients with suspected isolated fractures result in substantial differences in analgesia rates (ranging from 1.8–12.5% for ground EMS, to over 90% for HEMS as outlined in detail in another review [43]). In fact, EMS experts writing about pain management have acknowledged the better HEMS performance with respect to analgesia provision, stating that (as compared with ground EMS) HEMS is characterized by a "population of patients and providers very different from ground EMS-transported patients" [46].

As HEMS researchers try and extend their outcomes assessments beyond mortality, pain assessment and care represent a fertile ground for (partial) justification for use of HEMS. In some patient populations, such as those with suspected myocardial infarction, pain control is a paramount clinical goal. Thus, assessment of potential benefits of HEMS should take into account studies finding better pain control in HEMS-transported cardiac patients—who are of higher acuity with commensurate increased likelihood of refractory pain—than those transported by ground [12]. It is easy to argue that good pain care can be brought to bear by ground EMS (i.e., analgesia is allowed for in protocols), but the existing evidence on what is done is consistent with a HEMS pain management benefit.

3.4. Surrogate Endpoints. Distinction between endpoints that are secondary (as outlined above) and those that are surrogate (defined in this discussion as indirect mediators of improved outcome) can be tricky. The delineation is in some cases semantic. Examples of surrogate endpoints are provided in this section.

Earlier ALS care is one surrogate endpoint. Especially in rural or isolated areas, HEMS may represent the best means to get ALS to patients within a reasonable time frame. The significant improvement in "time to treatment" associated with HEMS utilization has been noted in systems throughout the world [47]. Though there is little data to actually prove that ALS improves outcomes, many EMS experts—and most systems benchmarkers—believe this to be an important goal for optimizing care of many types of patients. Furthermore, given the extant data showing that at least one ALS intervention—ETI—improves outcome when provided by HEMS, it naturally follows that the earlier provision of such an intervention will often be in the patient's best interests. More recent data, especially focusing on patients with severe trauma including head injuries, suggests that the earlier arrival of those capable of providing ALS-level airway and hemodynamic support translates into improved overall outcome and better neurological function [35]. Authors of case series demonstrating high rates of neurologically intact survival in diagnoses such as drowning also make strong arguments for the advantages of dispatching experienced ALS-level crews to areas in which such coverage (by ground EMS) is lacking [48]. Trauma specialists assessing nationwide data indicating HEMS outcomes improvement have written that although HEMS' logistics advantages may be uncommon in some areas, there are definitely regions within the US at least, where the access provided by HEMS is life saving [49].

A second surrogate endpoint is the extension of critical care experience and capabilities, throughout a region. In many regions, HEMS providers have pharmacological and procedural capabilities that outstrip the tools available to ground EMS. The differences in care capabilities can be dramatic. A report from the UK contended that patient outcomes were improved by performance of field thoracotomies [50]. Trauma surgeons reinforcing the concept of providing critical interventions during the "golden hour" have written that HEMS response to trauma scenes allows for provision of this life-saving care in timely fashion [51, 52]. Recent analysis of US data from the National Trauma Data Bank (NTDB) prompted authors to conclude that, on a nationwide level, one of the major advantages of HEMS is the higher level of care often provided by air medical crews [49].

In terms of air medical crew capabilities, the situation in the area served by Mayo Clinic in Minnesota may be reflective of what occurs in many areas. Ground EMS providers carry 20 different drugs but HEMS crews carry three times that number and can provide therapy such as blood transfusion and antibiotics for patients with open fractures [53]. Prehospital providers from some HEMS programs can provide advanced interventions such as tube thoracostomy; available evidence suggests that HEMS crew-placed chest tubes are as effective as, and no more likely to be associated with complications than, those placed in the hospital setting [54].

Especially in rural areas, the only prehospital care available may be BLS level [53]. It has been noted that since "HEMS brings a level of care to a trauma scene or small referring hospital that is over and above care rendered by an ALS ground ambulance," many procedures such as intubation (even for patients transferred from referring hospitals) are deferred to the HEMS crew [53]. Thus, HEMS is an important mechanism for getting to the patient medical crews that bring important expertise to both trauma scenes and small community hospitals. For example, HEMS crews using neuromuscular blockade have long demonstrated ETI success rates that rival those achieved in the E.D., whereas outcomes with ground EMS ETI (even with neuromuscular blockade) tend to be worsened [6, 14, 37, 42, 53, 55–57]. It seems likely that poor results from ground ETI (as assisted by neuromuscular blockade) are related in part to provider inexperience and differences in training for HEMS as compared to most ground providers [6, 53, 58, 59]. As another example, critical care transport teams (that use both helicopter and ground vehicles) have reported sophisticated ventilatory and other advantages accrued with application and use of $ETCO_2$ monitoring in pediatric and adult patients [40, 53, 60].

As mentioned previously, there is increasing evidence that better airway management skills are responsible for better outcomes in at least some patient groups. While this HEMS discussion is not the place for a detailed analysis of airway management issues, it is undoubtedly the case that failure to obtain or maintain a trauma patient's airway is a significant cause of preventable death [61].

For patients with head injury, there are now large-scale studies identifying markedly improved outcome for HEMS patients, as compared to ground ambulance transports, for those undergoing prehospital ETI [6, 37, 42]. Technically, ETI is better considered as an "ALS" level intervention, rather than an expanded practice scope maneuver. However, it is unrealistic to expect that the airway management expertise possessed by busy HEMS providers can be easily attained by practitioners with less experience and less rigorous training [58]. (What only the future can tell is whether HEMS crews will maintain their proficiency and high ETI success rates. There are few data, but anecdotal evidence suggests the possibility of skills dilution due to burgeoning numbers of air transport services and increasing difficulties in obtaining ETI experience in settings such as the operating room).

The improved outcomes for head-injury patients transported by HEMS have also been suggested to be associated with other traditional ALS-level maneuvers that are simply performed better by highly trained air medical crews. In a discussion of possible explanations for HEMS-associated improved mortality and neurologic outcomes for HEMS (as compared to ground ALS), an Italian group [35] noted that not only were airways more commonly managed, but that IV access and fluid resuscitation were handled significantly better by HEMS.

In addition to ETI capabilities, HEMS crews operate with benefit of experience dealing with critically ill and injured patients; the HEMS crews may in fact have more comfort with high-acuity patients than even physicians at a referring hospital [53, 61]. Analyses of HEMS systems have consistently revealed a relationship between crews' advanced training/experience and performance of critical tasks. In this era of focus on medical errors, it is noteworthy that recent studies (particularly in the pediatric population, but also in adults) have strongly suggested that errors (e.g., missed esophageal intubations, inadvertent extubation, incorrectly sized, or too-deeply-placed endotracheal tubes) are more likely in ground as compared to HEMS-transported patients [62]. There has been little concrete correlation between such findings and mortality, but the common-sense implications are difficult to refute.

3.5. Streamlined Prehospital Times for Scene Missions. It is well known that, particularly for rural locations, prolonged EMS response/transport time results in increased trauma mortality [63]. Shorter transport duration would seemingly be a "given" for HEMS use, but ever since early HEMS studies (e.g., Baxt and Moody [64].) found that HEMS did not save time; this supposed HEMS benefit has been subject to debate. Studies conducted from regions as disparate as California and the Netherlands clearly demonstrate HEMS mortality benefit, yet find similar scene-to-trauma center times for ground and HEMS transports [65, 66]. One study from a well-developed HEMS and trauma system in the Netherlands finds that (physician-staffed) HEMS crews' scene times are about 10 minutes longer than those for ground EMS crews (25 versus 35 minutes in a system in which HEMS crews stabilize patients prior to ground transport to Level I care) [51]. The prolongation in scene times was accounted for by patient acuity and casemix, and adjusted analysis showed no effect of on-scene time on survival (OR 1.0, $P = .89$) [51]. In fact, the traumatologists assessing the slight prolongation in on-scene times associated with HEMS argue that bringing advanced interventions to the scene was actually a benefit to survival—the HEMS crews' interventions had sufficient salutary impact as to completely negative the well known adverse impact of prolonged prehospital times, on outcome [61].

The consideration of urban scene HEMS use is problematic. On the one hand, HEMS transport from areas close to a trauma center does not make much sense as a time saver since distances are short. On the other hand, such areas tend to be particularly prone to traffic congestion and transport delays (depending on the time of day). Since most studies focusing on transport times tend to have the times for one vehicle type or the other "estimated" it is easy for bias to be introduced. The fact that such transport times for either air or ground EMS are estimated retrospectively (i.e., lacking information about traffic or weather or other conditions) further dilutes the value of these estimates.

Faster transport time is, in some cases, potentially life saving—the premise that faster transport improves trauma mortality is widely accepted based upon available evidence. Authors focusing on logistics studies support the notion that time to definitive care is an appropriate primary endpoint, writing that "The correlation between length of time to definitive care and outcome has been well established in the literature, so the premise that faster transport is better seems justifiable[67]." The authors of a Pennsylvania trauma registry-based head injury study, in noting that HEMS was associated with improved survival and functional outcome, noted that their results could have "simply reflected the effect of [faster] transport time to trauma center" [6]. Furthermore, the impact of logistics on trauma mortality has been argued in a 2005 JAMA study which found that HEMS represented the only mechanism by which 27% of the US population had timely Level 1 or 2 trauma center access (within an hour of receipt of emergency call) [68]. Put another way, HEMS has been estimated to be the only mechanism by which 81.4 million Americans have timely (<1 hour) access to Level 1 or Level 2 trauma centers [68]. The authors concluded that new helipad placements and additional HEMS programs "could be an important, and practical, means of extending trauma center access to populations that currently have none." Since the JAMA study group comprised both clinical and epidemiologic trauma systems leaders, their paper—with its assumption that HEMS is useful from a time-distance perspective—is a useful complement to the HEMS utility dialogue. The fact that HEMS provides the only timely access to high-level trauma care is particularly noteworthy, given recent large-scale studies finding that Level I trauma care results in a distinct outcomes benefit as compared to other levels of trauma care; [69, 70] for at least a quarter of the US population, helicopters thus represent the only mechanism for rapidly accessing life-saving care for injuries.

Related conclusions about the critical utility of air medical transport for the US population have emanated from burn investigators. While there is no "golden hour" for burn patients, epidemiologists and clinicians writing in a JAMA study point out that early care (in the first few hours) at a burn center improves outcome and that HEMS is the sole mechanism by which millions of Americans have access to burn center care within 2 hours of injury [71].

3.6. Rapid Transport for Interfacility Missions. The idea of HEMS utilization to expedite care for patients with time critical injury and illness is not new. There is a significant body of literature addressed in this monograph and elsewhere, that demonstrates HEMS utility for time savings (and mortality advantage) in secondary (interfacility) trauma transport [72]. Recent nationwide database analysis reveals that HEMS use in the US is associated with significant time savings. Loss of HEMS availability has been recognized as a potentially important factor causing increased trauma mortality in patients presenting to non-Level I centers [73].

Besides use for trauma diagnoses, there is growing emphasis on employment of HEMS to expedite care for patients with time critical nontrauma illness. The utility of HEMS' logistics/speed capabilities to extend the reach of Level I centers' time-windowed advanced cardiac and stroke care has been the subject of increasing attention, with particular emphasis being given on the ability of HEMS to expedite care of these time-sensitive diagnoses [74, 75]. The use of air medical resources to rapidly move patients to specialized centers is gaining increasing attention in part because of the ever-growing realization that "time is myocardium", "time is brain tissue", and so forth [74, 76, 77].

In terms of cardiac patient transports and time savings, there is increasing emphasis on getting patients with myocardial infarction to primary PCI as the treatment of choice if a 90 minute first-door-to-balloon time can be met; expedited prehospital care—including HEMS—will play an important role in cardiac care systems [78, 79]. The 90-minute "window" is not absolute. Emergency Medicine experts have written that the maximal benefit of primary PCI is accrued in the initial 60 minutes [80]. In fact, it is known that each 15-minute decrement in time to PCI, from 150 minutes down to <90 minutes, is associated with 6.3 fewer deaths per 1000 patients treated [81]. Given these findings, it is hard to dispute the importance of data such as those from a rural setting in Pennsylvania. Investigators instituted a streamlined HEMS transport program for community hospitals to get patients into receiving center PCI, and tracked the proportions of patients with community hospital door to wire-crossing times under 90 minutes and 120 minutes. For both time frames, the proportions of patients meeting the timing endpoints increased significantly (under 90 minutes, from 0% to 24%; under 120 minutes, from 2% to 67%) [75]. Complementary to the results in Pennsylvania are data from Ohio, that demonstrate that having HEMS transport cardiac patients is no guarantee of arrival to cath labs within recommended time frames [82]. HEMS is potentially important as a part of a cardiac care system, but the air medical resource must be used wisely.

Cardiac patients are not the only nontrauma diagnosis for which time is critical. Considered in one easily understood way, each hour of ischemic stroke results in neuronal damage approximating 3.6 years of normal aging [77]. Furthermore, ED specialists have noted with concern the consistency of reports finding that nearly 1 in 5 patients receiving lysis for "stroke" based upon CT reading in fact have nonstroke "mimics" of acute thromboembolic CVA [83]. The increasing awareness that advanced imaging optimizes accuracy and safety, combined with the current (and likely near-future) lack of round-the-clock availability of such imaging [83], has high potential to translate into a major role for early and rapid HEMS transport for stroke. These time critical findings emphasize the importance of integrating HEMS into stroke care networks. Addition of air medical resources into logistics calculations halves the numbers of Americans who lack timely (within one hour) access to a primary stroke center (from 136 million to 63 million) [84].

Sepsis, a long-recognized disease process, has not generally been considered "time critical." This view has changed, with the advent of studies demonstrating improved outcome associated with goal-directed therapy. Recent reviews of sepsis care have emphasized the importance of the six-hour goal for institution of high-level sepsis care [85]. Though many patients with sepsis do not undergo transport at all, HEMS may in some cases provide a useful mechanism for rapidly getting patients to appropriate, time critical, goal-directed therapy.

HEMS has also long been known to allow for maternal (and fetal) outcome benefits for high-risk obstetrics transports that simply would not have occurred (due to physician unwillingness to have prolonged transport times) in the absence of air transport [86]. More recently, a group from Florida [87] has reported that scene transports for suspected stroke patients resulted in extension of their stroke care to patients previously outside of the "logistics envelope", and others have reported that HEMS is useful to expedite interfacility stroke and cardiac transports [88, 89].

One approach currently in investigative use in Boston incorporates the twin novelty of prehospital EKG triggering of both HEMS dispatch and activation of the receiving hospital's cardiac cath lab. The aircraft thus arrives at the (non-PCI-capable) community hospital within minutes of the patient's arrival by ground EMS [90]. After the community hospital's ED physician quickly confirms the diagnosis based upon review of the prehospital 12-lead EKG, the tertiary center's cardiac catheterization laboratory activation is confirmed, and the helicopter (either already at, or very close to, the community hospital) completes rapid transport directly to the cath lab. Initial experience with this protocol has found it saves about 10–20 minutes. Such a time saving initially appears modest. In fact, it is at least as much time has been saved by other prehospital and hospital practices—associated with time savings of 8–19 minutes—that have been judged to be significant contributors to efforts to meet a 90 minute door-to-balloon deadline [91]. There is growing recognition of importance of transporting ST-elevation myocardial infarction (STEMI) patients for primary percutaneous intervention (PCI). For example, a consortium US panel of US EMS medical directors has recently been identified as an evidence-based benchmark for quality prehospital care, the transport of STEMI patients to primary PCI within 90 minutes of EKG diagnosis [92]. Recent meta-analysis confirms the substantial outcomes benefits, in terms of both mortality and morbidity (including from stroke), of timely transfer of STEMI patients for mechanical reperfusion [93]. It is clear that, for some regions and their patients, HEMS provides a vital capability to meet this benchmark.

The authors of a logistics study from the University of Wisconsin [22] noted that HEMS and fast transport are occasionally critical even for patients who are not profoundly unstable, but who may need time-windowed cardiac or stroke therapy. In assessing average transport times from their 20-hospital network, the investigators found that for all hospitals, the average HEMS total transport time over the study period was at least as good as the best ground transport time, and this took into account the fact that for many hospitals ground EMS was on site at the time of transport. Furthermore, the authors found that there were clinically significant time savings for all institutions: patients at close-by hospitals accrued an average of 10 minutes' time savings, while those from further-out hospitals had HEMS transport times of up to 45 minutes shorter than achievable by ground transport.

3.7. Minimization of Out-of-Hospital Time. As an additional facet to the time issue, the issue of "out-of-hospital" time (for interfacility transports) should be considered separately from the general issue of "pretrauma center time." Even if a HEMS service takes longer than local ground units to respond to a community hospital patient requiring transport to a tertiary care center, in most cases the actual time spent in patient transport is much less for HEMS patients. In one study, for instance, even though the overall time characteristics of HEMS were not significantly better than ground EMS performance, the actual out-of-hospital time saved by HEMS use averaged 20 minutes (58 minutes for HEMS versus 78 minutes for ground transport) [67]. In some patients—especially those who are in tenuous condition or who may require difficult interventions in the event of deterioration—the minimization of time spent in the relatively uncontrolled out-of-hospital transport environment is an admirable goal. As an example, in some areas high-risk obstetric patients are often transported by air (helicopter or fixed wing) to minimize out-of-hospital times (and decrease the chances of intratransport delivery). In Japan, for instance, reduction in out-of-hospital times averaged over 100 minutes for high-risk obstetric patients transported by air as compared to ground; the reduction in out-of-hospital times was theorized by the authors to contribute to good maternal and fetal outcomes in their transported population [94].

3.8. Direct Transport to Specialized Centers (for Primary/Scene Missions). As considered from the point of view of the patient, the benefit of direct transport to specialized centers relates to the debate about whether community or tertiary care hospitals provide better care. For some diagnoses, such as trauma or acute coronary syndromes, a strong argument can be made for bypassing community hospitals in favor of direct transport to larger, higher-volume centers (and perhaps more capabilities such as primary percutaneous coronary intervention) [95]. For areas in which there is no trauma center, air medical scene response for direct transport to the trauma center is often the best course [31]. In fact, there is strong evidence basis to suggest that, for blunt trauma patients, bypassing community hospitals (including HEMS-executed bypass) in favor of direct transport to Level I trauma centers has a significant and positive impact on outcome [70, 96–102]. Experts with no interest in the HEMS debate have noted that "it is beneficial for a patient to be taken to a designated trauma center rather than a nontrauma community hospital" [99]. More recent evidence finding a clear correlation between trauma center status (Level I or Level II) and adherence to well-accepted Traumatic Brain Injury Guidelines concludes that direct transport for brain-injured patients to trauma centers will improve outcome [103]. There are also substantial implications for HEMS in the (controversial) studies that reveal a distinctly improved outcome from transport to Level I (as compared with Level II) trauma centers [70].

The most notable recent paper in the HEMS literature, a nationwide study of over 250,000 adult and pediatric scene trauma transports from the National Trauma Data Bank (NTDB), is also tied to the Level I versus other-level trauma centers [49]. The paper's finding that HEMS was associated with a 22% improvement in mortality was discussed by the authors as possibly indicating that HEMS afforded access to Level I (and to a lesser extent, Level II) trauma center care. A few months after the publication of the NTDB study by Brown et al., the results were confirmed in a study of the same NTDB 2007 dataset, from the Centers for Disease Control; the fact that the CDC study focused only on adults probably explains its larger point estimate (39%) for HEMS-associated mortality benefit [104]. The very large-scale aspect of the NTDB studies that make results so compelling renders it impossible to tease out specifics—but even if HEMS transport was nothing more than a marker for capability to get patients to high-level trauma care, the results remain compelling in the "real world."

As a general rule, use of HEMS for direct transport to tertiary care is commonly used for trauma patients and less commonly used for other patient categories. Data from the Centers for Disease Control and elsewhere has confirmed that, for the general population of injured patients, trauma center care (i.e., appropriate triage) results in substantially reduced mortality [69, 105]. In a study focusing on the subset of patients with severe traumatic brain injury, and with methodology adjusting for hypotension, age, GCS, and pupillary reactivity, a group of investigators from New York State found that direct transport to a trauma center provided a clear outcomes benefit [106]. Authors of that study point out that the Guidelines for Prehospital Management of Traumatic Brain Injury call for direct transport to high-level care, when severe brain injury is present (GCS < 9) [107]. It is also well known that delays at nontrauma centers, which can result from a variety of factors such as specialist nonavailability, prolong pretrauma center times and worsen injured patients' outcomes [108–111]. Such reports may be reasonably expected to increase utilization of HEMS for such "direct" transfers from scenes to trauma center care. Trauma triage and systems experts have found that patients with head injuries, and those patients with physiologic findings meeting trauma triage criteria, had significantly better outcome when treated at regional centers as compared to area (Level 2) trauma centers or nontrauma centers [112, 113]. For adult and pediatric trauma patients who are initially treated at nontrauma centers, transfer to Level I centers is associated with substantial improvement in outcome (mortality odds ratio 0.62 as compared to patients kept at nontrauma centers); thus interfacility transfer (which will occasionally be via HEMS) is warranted and appropriate [102]. Henry et al. write "the considerable improvement in survival raises the question of whether patients meeting these physiologic criteria with improved outcomes should be transported directly to regional centers, even if that means bypassing an area trauma center" [112].

On the nontrauma front, suggestion of potentially growing indications for HEMS "scene" transports of noninjured patients is provided by an evolving literature consisting of both case series (e.g., for primary percutaneous intervention) and sporadic reports (e.g., scene transport to neurological centers for lytic therapy for ischemic stroke) [27, 47, 114]. A Japanese report finds that, compared to ground ambulance transport, HEMS use in their particular system is associated with a half-hour's decrement in times to angiographic evaluation and intervention [114]. A recent preliminary report on simultaneous HEMS dispatch and tertiary care hospital cardiac cath lab activation, by ground prehospital providers diagnosing STEMI during transport to a community hospital, found that the time at the referring hospital was reduced from 79 to 31 minutes [115]. The economic factors driving the growing trend towards regionalization of many critical care services will continue to spur investigation into routine use of HEMS for indications that would be considered novel in past years. Early indications that outcomes are improved with stroke care in specialized centers may add to the efforts to integrate transport plans into regional care for this disease [116].

While the integral nature of HEMS as part of a system may make it difficult to delineate the specific outcomes contribution made by the helicopter, the HEMS effect is no less important. When considering a report [117] that HEMS integration into a cardiac care system allows for diagnostic catheterization to be performed at community hospitals, with rapid air transport for interventional procedures when needed, it is not easy to either prove or refute the critical nature of HEMS for patient outcomes. Similarly, it is not easy to discount the potential benefit to stroke patients, when reviewing a study from north Florida demonstrating the effective integration of HEMS into the stroke system, with resultant extension of the "reach" of advanced stroke care such as thrombolytic therapy [87]. The same logic holds true for injured patients undergoing air transport to Level I centers [118]. In these cases, direct transport to specialized centers likely benefits many patients. Additionally, the judicious integration of HEMS into a system of care has high probability of accruing benefits to the region itself. These benefits are among other "systemwide" benefits of HEMS, and are considered in the next section.

4. Possible HEMS Benefits to Systems

It goes without saying that if HEMS is associated with mortality (or significant morbidity) improvement, then it benefits a regional EMS system to have access to such a service. Whether the EMS region is dealing with increased interfacility transports as a result of implementation of "inclusive" trauma systems [100] or more frequent HEMS use for stroke patients, air medical transport clearly has a vital role in regionalization of care. While patient-centered thinking should be paramount, some logistic and economic considerations represent very important potential utilities for HEMS services.

4.1. Extension of Advanced Level of Care Throughout a Region. Some of the above-mentioned benefits to patients also apply as advantages to regions and EMS systems. For example, HEMS may allow an EMS system ability to provide for early ALS in isolated and/or difficult-to-reach areas which otherwise would be poorly covered. In pointing out that HEMS can cover roughly the geographic area of seven ground ALS ambulances, Hankins [53] has written that "this kind of coverage, in many areas of the country, provides advanced care where it is not otherwise available." Others, considering the US trauma system as a whole, have agreed that at least in some areas of the US, the extension of trauma regional care provided by HEMS is critical [49]. Analysis of the economics of covering a widespread region using a small number of aircraft, as compared to a large number of ground vehicles dispersed in such fashion as to assure equivalent response times, is complex; preliminary analysis has suggested that HEMS is actually no more expensive than the multiple-ground-unit alternative.

In fact, limitation of the HEMS versus "highly trained ground EMS" argument to economic considerations ignores the fact that EMS cannot simply fiat into the ground personnel "high level of training" that comes with concentrated training and experience accorded to HEMS crews. Recent literature suggests that even with major emphasis on training, some ground EMS systems have had efficacy difficulties when neuromuscular blockade-assisted ETI protocols were instituted. In at least two regions, neuromuscular blockade-assisted intubation by ground EMS was sufficiently problematic that the practice was discontinued. Contrasting this with the 95–98% intubation success rates regularly reported by HEMS services, HEMS proponents make sound arguments that HEMS is a reasonable means for a given EMS region to provide a high level of care to a large area.

HEMS may offer benefits even to patients already at (smaller) hospitals [33]. This is most likely true in rural settings in which local facilities may be staffed by individuals with relatively little experience with trauma or other critical illnesses [32]. In trauma, for instance, the lack of ready availability of surgical subspecialists (e.g., neurosurgeons) is translating to an increasing inability of non-Level I centers to care for injured patients [108]. Trauma triage experts have labeled as "undertriage" any instance of transporting to any hospital lacking emergency access to neurosurgeons, a traumatic brain injury patient with potential for requiring neurosurgical monitoring or craniotomy [108].

The issue of regionalization of trauma care is well known to acute care physicians, but recent data have clarified the importance of capabilities to get injured patients to a trauma center. In fact, a 2008 consortium panel of US metropolitan EMS medical directors emphasized the importance of transporting patients for trauma center care if they have ISS > 15 (number needed to treat to save one life: 11) [92]. As trauma systems mature, there is obviously a role for HEMS in the occasional transport of patients to insure that life-saving care is available to more patients throughout a region.

4.2. Provision of ALS "Backup" for Parts of an EMS System Which Have Limited ALS Coverage. In addition to providing ALS-level care to geographically remote areas, HEMS can offer a means for relatively isolated areas to get patients to tertiary care centers without necessitating removal of scarce ground ALS resources from the region. At least one paper [119] has specifically identified that one major reason rural areas use HEMS is that they perceive they are unable to cope with losing their limited ground ALS coverage for what can be a 5-hour round trip. For better or for worse—use of HEMS for patients with noncritical illness or injury may not be in the best interest of the system as a whole—some regions have come to rely on HEMS as a means to assure that they will not lose ALS coverage for hours, every time a patient requires ALS-level transport to a distant receiving hospital. As an added benefit, the use of helicopters for longer-distance transports of critical patients can reduce the risks associated with prolonged red-lights-and-siren ground EMS transports [53].

4.3. Minimization of Transport Times. The utilization of HEMS for some transports, and its resultant streamlining of out-of-hospital times, can benefit EMS systems as well as individual patients. Examples of such benefits include faster turnaround and greater availability for transport. The overall transport time minimization discussed earlier, with respect to trauma, cardiac, and stroke care, should also be viewed as a system benefit. It should be kept in mind that the total time savings accrued by HEMS are not just beneficial for scene flights; interfacility patients also get to definitive care more quickly with HEMS [22, 72].

4.4. Direct Transport to Specialized Centers. Like some of the other advantages potentially accrued by individual patients, this benefit can also be said to be accrued by an EMS system. One purpose of the EMS regional authority is to provide the optimal prehospital and out-of-hospital transport setup; so patients can get to where they need to be. In many cases, this will be the closest facility; in such circumstances ground transport will usually be a preferable alternative. However, some patient populations have definite, probable, or possible indications for direct transfer to a specialized center with bypassing of community facilities. Despite the ongoing debate with respect to "inclusive" versus "exclusive" trauma systems—a debate which entails points outside the scope of this discussion—the fact remains that care at Level I centers improves morbidity and mortality outcomes for many patient types [69, 73, 120–122]. Furthermore, HEMS studies commonly identify significant mortality benefit from direct transportation from scenes to tertiary care (rather than initial ground transport to a "stabilizing" hospital first) [101]. Emerging literature makes compelling arguments, from perspectives of both outcomes and cost (e.g., preventing dual workups), for direct transport of pediatric trauma patients to specialized centers [123].

As regionalization of care continues to evolve, EMS systems will doubtless play a major role in both primary (i.e., scene) and secondary (i.e., interfacility) transport of an increasing number of patients requiring specialized care. In fact, a 2010 study revealed that centralization of cardiac catheterization resources, with appropriate buildup of EMS transfer systems, is significantly more cost effective than construction of multiple cardiac catheterization centers; the same authors note that 20% of Americans live more than an hour away (by ground) from a cardiac catheterization center [124]. HEMS' role in such regionalization is not yet fully characterized, but the existing literature renders clear the fact that air medical transport does have some role in optimizing regionalization.

4.5. Transport Flexibility in Overloaded Hospital Systems. The helicopter offers advantages of being flexible with respect to receiving center; not much time is lost in changing the receiving hospital destination if it is close by, and the helicopter's speed and "legs" can often bring relatively distant hospitals into play if local facilities are overloaded. Though the obvious benefit to this (for EMS systems) relates to unusual circumstances such as disasters [125, 126], the current environment of hospital and E.D. overcrowding renders the receiving hospital flexibility of HEMS a potentially useful thing.

With the advent of increasing problems due to ambulance diversion, the transport flexibility provided by HEMS has additional advantage. Since ambulance diversion problems can often result in a given ground EMS unit being out of service for an extended period (i.e., while it is performing a longer-distance transport) [99], the aircraft may be able to "back up" the ambulance by either performing the transport or being available while ground EMS is out of service. With increasing evidence demonstrating trauma mortality rates increasing when trauma centers' EDs are on diversion [127], the HEMS unit can serve as a life-saving method for "decompressing" the overtaxed ED. In fact, the utility of HEMS to distribute the patient load, already noted for its potential value in disaster and mass casualty incidents, may be applicable in some areas' Level I trauma centers on an increasingly frequent basis [125]. The loss of availability of rotor-wing transport has been recognized as a potential mediator of increased mortality due to decreased capability to execute interfacility transports [73].

4.6. Ability to Perform Unusual and Ad Hoc Activities . While noone questions the flexibility and capabilities of ground EMS units, the nature of the helicopter lends itself to utility in unusual circumstances. For example, in the unusual case where a medical expert or team needs to be transported to the patient, the speed and logistical capabilities of the helicopter may be useful [128]. The utility of HEMS in disaster and mass casualty incidents is well described [125, 129]. In fact, during the London subway bombings of 2005, the London HEMS aircraft flew at least 25 missions—none of them patient transports, but rather transportation of medical care teams to incident sites. Given the traffic situation in London at that time, the HEMS was judged to be a vital part of the emergency response (personal communication, Dr. David Baker of the UK's Health Protection Agency, 21 June 2007).

Additional reports from around the world outline unusual use of HEMS resources, which do not justify expense for an aircraft, but which nonetheless represent (in conglomeration) a potentially significant illustration of HEMS' ad hoc utility. For example, the French have reported HEMS response to cruise ships at sea, enabling time critical and successful lytic therapy for stroke [130].

In addition to transporting people, helicopters have been occasionally used to rapidly transport vital supplies or equipment (e.g., prostaglandins to a neonate with a ductus-dependent lesion). Another "unusual" activity that may for some regions be appropriate for HEMS is performance of research in the out-of-hospital setting. Particularly in rural regions, where the HEMS crews arrive at patients (both at scenes and at referring hospitals) long before the patient will get to Level I care, it has been suggested that a small cadre of air medical personnel can be trained to intervene/enroll patients in clinical studies with a narrow time window [74, 131].

5. Conclusion

This paper has attempted to overview the important questions of HEMS' possible benefits to patients and to healthcare systems. The potential benefits of HEMS must be considered by policymakers and others providing HEMS use guidance, with other parameters not discussed in this paper (e.g., triage, utilization review, cost effectiveness, and safety).

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Clinical Study

Can Peak Expiratory Flow Measurements Differentiate Chronic Obstructive Pulmonary Disease from Congestive Heart Failure?

John E. Gough and Kori L. Brewer

Department of Emergency Medicine, Brody School of Medicine, Greenville, NC 27834, USA

Correspondence should be addressed to John E. Gough, goughj@ecu.edu

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Dyspneic patients are commonly encountered by Emergency Medical Service (EMS). Frequent causes include Chronic Obstructive Pulmonary Disease (COPD) and Congestive Heart Failure (CHF). Measurement of peak expiratory flow rate (PEFR) has been proposed to help differentiate COPD from CHF. This prospective, cohort, pilot study was conducted to determine if PEFR in patients with an exacerbation of COPD were significantly different than CHF. Included were patients presenting with dyspnea plus a history of COPD and/or CHF. A PEFR was measured, values were compared to predicted average, and a percentage was calculated. Twenty-one patients were enrolled. Six had a diagnosis of COPD, 12 CHF; 3 had other diagnoses. Mean percentage of predicted PEFR with COPD was 26.36%, CHF 48.9% ($P = 0.04$). Patients presenting with acute COPD had significantly lower percentage of predicted PEFR than those with CHF. These results suggest that PEFR may be useful in differentiating COPD from CHF. This study should be expanded to the prehospital setting with a larger number of subjects.

1. Introduction

Dyspnea, a common cause of Emergency Medical Service (EMS) calls, can result from problems involving many organ systems. Some of the more frequently encountered scenarios are Chronic Obstructive Pulmonary Disease (COPD) and/or Congestive Heart Failure (CHF) which have different treatment regimens [1]. It is estimated that approximately 14 million Americans have COPD and five million carry the diagnosis of CHF [2]. These patients require rapid and accurate evaluation in order to provide the proper course of treatment. Studies have shown that physical examination alone is not always sufficient to determine the underlying cause of the patient's dyspnea. Both diagnoses may present with similar physical findings such as wheezing, rales, and jugular venous distension [3]. In the Emergency Department (ED), physicians have access to several diagnostic aids to assist in determining the cause of the dyspnea that are not available in the EMS setting. Peak expiratory flow meters are small, inexpensive, and accessible devices used to measure the peak expiratory flow rate (PEFR) after maximal inspiration. They are commonly prescribed for asthma patients but have shown promise in assessing COPD [4, 5]. Peak expiratory flow is not part of the standard protocol for gauging CHF patients, although several studies have suggested that PEFR may be useful in helping to differentiate cardiac from pulmonary causes of dyspnea [3, 5]. The purpose of this study is to determine if peak expiratory flow meters are effective in assisting EMS personnel in differentiating the respiratory and cardiovascular etiologies of dyspnea, and if so, to what extent. We hypothesize that the measured peak expiratory flow value calculated as a percentage of an established predicted value will be significantly lower in patients whose respiratory symptoms represent an exacerbation of COPD as opposed to CHF. As an initial step in testing this hypothesis, the authors chose to perform a data collection in the ED to determine if use of the PEFR may be useful in the prehospital setting.

2. Materials and Methods

This prospective, cohort, pilot study was conducted in the ED over a two-month period. A convenience sample of patients were enrolled based on their chief complaint and suspected history as recorded in triage or by EMS. Only

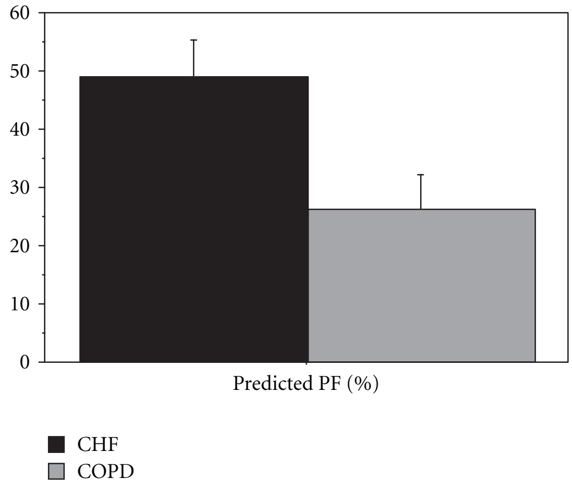

Figure 1: % Predicted peak flow measurement: COPD versus CHF.

those patients who presented with a history of COPD or CHF were included in the study. Patients were excluded if they were unable to cooperate with peak flow testing, or if any interventions, other than oxygen administration, were initiated by EMS, nursing or medical staff prior to obtaining the PEFR measurements. Once the patient was placed in a room, investigators obtained informed consent and a brief history. The patient was then given instructions on how to perform the peak expiratory flow test, and three attempts were made. The peak flow measurements were taken by one of the authors (J. E. Gough) or one of the study assistants trained in measuring PEFR. The treating physicians were blinded to the results of the PEFR testing. The highest peak expiratory value was recorded and considered the patient's best effort. This value was then compared to a standard predicted value based on the patient's height and age. A percentage of predicted value was calculated and used for the purpose of statistical analysis [6]. The patient's history, previous diagnoses, and discharge diagnosis were confirmed using medical records at a later date. The means of the percentages of predicted values were calculated and compared among the COPD and CHF subgroups. Statistical significance was determined using an unpaired t-test with $P = 0.05$ indicating a significant difference.

3. Results

Twenty-one total patients were enrolled in the study. The mean age for the patients enrolled was 61 ± 12.27 years. Six had a final diagnosis of COPD, 12 had a final diagnosis of CHF, and 3 had a different diagnosis. The mean % of predicted PEFR for patients with a history of COPD was 26.4 ± 14.3. For patients with CHF, it was 48.9 ± 22.6. The P value was calculated as 0.04 (Figure 1). Only those with diagnoses of CHF or COPD were included in the data analysis (Table 1).

There were 6 patients enrolled which had a known history of COPD. These patients had a mean PEFR of 35.8%; all received a final diagnosis of COPD. There were twelve other patients with no history of COPD, and these patients had a mean PEFRF of 40.1%. There was no significant difference in peak flow between patients with a history of COPD and those without ($P = 0.65$).

Table 1: Patients enrolled in study.

Age	Predicted peak flow	Measured peak flow	% Predicted	Discharge Dx
64	550	132	24.0%	CHF
33	650	420	64.6%	CHF
87	402	175	43.5%	CHF
66	430	190	44.2%	CHF
41	650	370	56.9%	CHF
71	552	240	43.5%	CHF
71	416	70	16.8%	CHF
73	410	325	79.3%	CHF
57	605	180	29.8%	CHF
59	542	310	57.20%	CHF
59	542	310	57.20%	CHF
60	591	200	33.84%	CHF
65	550	125	22.7%	COPD
52	466	225	48.3%	COPD
64	572	85	14.86%	COPD
55	418	60	14.35%	COPD
50	602	240	39.87%	COPD
67	554	100	18.05%	COPD

Of the twelve patients with a known history of CHF, the PEFR of 48.8%, and 11 received a final diagnosis of CHF. The six patients enrolled who had no history of CHF had a mean PEFR of 26.3%. Those without a history CHF had a significantly lower PF than those with a history of CHF ($P = 0.05$).

One patient had a history of both CHF and COPD. The PEFR for this patient was 79.3%, and the diagnosis for this visit was CHF exacerbation.

4. Discussion

Respiratory distress and shortness of breath are frequent complaints which account for approximately 13% of EMS transports [1]. Early appropriate treatment can significantly impact the patient's comfort as well as help prevent further deterioration and adverse outcomes. Studies have shown that both emergency physicians and EMS personnel can, in the majority of cases, make appropriate determination of the etiology of the patient's dyspnea on the physical exam findings. However, in approximately 30% of patients, the physical examination alone is not sufficient to identify the cause of the distress [3, 7]. Similar physical findings such as dyspnea, tachypnea, wheezing, cough, rales, and jugular venous distension may be seen in patients with both cardiac and pulmonary etiologies of dyspnea [3, 8]. Obtaining a past medical history from the patient and reviewing their medications may also yield clues. However, many patients carry multiple diagnoses. Studies have noted the prevalence of COPD to be as high as 20–32% in patients with known CHF [2]. This makes the distinction difficult, particularly in the prehospital environment. Making the appropriate assessment may be crucial, as incorrect treatment may lead to adverse outcomes for the patient. Diuretics used to treat cardiac dyspnea may cause electrolyte disturbances (mainly potassium and magnesium) and fluid loss [9]. Sympathomimetic amines and beta-agonists can cause tachycardia, increased QTC inducing arrhythmias, and hypokalemia. In the presence of underlying cardiovascular disease, these medications may increase the risk of heart failure and ischemic events including MIs [10].

Utilization of a peak flow test has been proposed as a simple, low cost, and time-effective instrument to help differentiate COPD from CHF as a cause of dyspnea [3, 4, 11]. In this paper the authors examined the mean percentage of predicted PEFR which was a different variable than in previous studies. While no absolute cutoff has been identified, these data support these previous studies' findings demonstrating that PEFR is significantly lower in patients undergoing a COPD exacerbation than that in those experiencing shortness of breath due to CHF. There was only one patient enrolled in this study with both COPD and CHF diagnoses previously documented. The PEFR in this patient was not significantly reduced (79.3%). This was consistent with the final diagnosis of CHF not a COPD exacerbation.

Limitations of this study include a small number of patients enrolled and the ED setting rather than EMS environment. The authors first sought to determine if the PEFR would potentially be useful before expanding the study to the prehospital setting. Study enrollment was limited by several factors, the first of which was the sampling method utilized as patients were only enrolled when one of the study investigators was present in the ED. Furthermore, a number of patients had interventions such as nebulizer treatments or medications initiated prior to obtaining PEFR. These limitations preclude the authors from determining how many patients were lost to enrollment. Although peak flow meters are easy to use and interpret, a major limitation to their use is that results are dependent on patients' understanding and effort [3, 5].

5. Conclusions

The results of this study demonstrate that in this population there is a difference between the PEFR values among patients with COPD as compared with CHF. Although the sample population is small, these data suggests that COPD patients show a lower percentage of predicted value for peak expiratory flow than those with CHF. This study should be continued in the prehospital setting with a larger sample size to better assess the utility of using this method among EMS personnel.

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Review Article

Measuring Quality in Emergency Medical Services: A Review of Clinical Performance Indicators

Mazen J. El Sayed

EMS and Prehospital Care Program, Department of Emergency Medicine, American University of Beirut Medical Center, P.O. Box 11-0236, Riad El Solh, Beirut 110 72020, Lebanon

Correspondence should be addressed to Mazen J. El Sayed, mj_sayed@hotmail.com

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Measuring quality in Emergency Medical Services (EMSs) systems is challenging. This paper reviews the current approaches to measuring quality in health care and EMS with a focus on currently used clinical performance indicators in EMS systems (US and international systems). The different types of performance indicators, the advantages and limitations of each type, and the evidence-based prehospital clinical bundles are discussed. This paper aims at introducing emergency physicians and health care providers to quality initiatives in EMS and serves as a reference for tools that EMS medical directors can use to launch new or modify existing quality control programs in their systems.

1. Background

Measuring quality in emergency medical services (EMSs) is important since EMS is the practice of medicine in the prehospital setting. At its earliest developmental stage, an EMS system is a system of emergency care that functions to reduce death and disability usually resulting from two epidemics: trauma and cardiac arrest. In the United States, EMS systems have witnessed a major transformation since the EMS program was first established in 1966 in the Department of Transportation through the Highway Safety Act. The expansion in EMS scope and increase in the range of medical interventions performed by prehospital providers were paralleled with an increased scrutiny of the value and effectiveness of the services deployed in the prehospital setting [1, 2]. The need for increased coordination in patient care and higher quality care at lower costs has made it essential for EMS agencies to have in-place quality control or quality improvement programs that rely on key performance indicators to continuously monitor the system's overall performance and the effectiveness of the different prehospital interventions.

The Institute of Medicine (IOM), in a report entitled "Emergency Medical Services at the Crossroads" and published in 2006, recommended the development of "evidence based performance indicators that can be nationally standardized so that statewide and national comparisons can be made" [3]. The development and implementation of these indicators would enhance accountability in EMS and provide EMS agencies with data to measure their system's overall performance and to develop sound strategic quality improvement planning. The objective of this paper is to introduce emergency physicians and other healthcare providers to the concepts of quality measurement in EMS with a focus on clinical performance indicators currently used by EMS agencies in the USA and by ambulance services in other countries such as the United Kingdom and Australia.

2. Quality Care in EMS: Definition and Challenges

A central premise is that the same principles of healthcare quality apply to EMS. Many definitions of quality in health care exist (Donabedian and the American Medical Association definitions of quality) [3, 4]; however the most widely cited one and most applicable to EMS systems is the definition formulated by the IOM. The IOM defined quality as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge" and described six dimensions of quality care: a care that is safe, effective, patient centered, timely, efficient, and equitable [5]. When applied to EMS, the IOM concepts on quality care therefore entail a system design with a specific arrangement of personnel, facilities, and equipment that functions to ensure not only effective and coordinated delivery of health care services under emergency conditions but also high quality appropriate care. This ideal system design is nonexistent since most EMS systems evolved as a response to the communities' needs for emergent health care services (military conflicts, major highways trauma, and nontraumatic cardiac arrest) rather than as an a priori designed EMS infrastructure. This resulted in heterogeneity of existing EMS systems designs [6, 7] making EMS systems complex and difficult to evaluate or compare.

Other EMS-specific challenges to systems evaluation include the lack of uniformity in data collection and the lack of agreement over the validity of the performance indicators or assessment measures used in EMS research [8, 9]. Adding to that, the existence of a broad range of EMS conditions (i.e., conditions that cause EMS activation) and the challenge of isolating the prehospital care effect from that of the emergency department and hospital care increase the complexity of measuring quality in EMS [10, 11].

3. Approaches to Quality Measurement

Initiatives to incorporate quality assessment in EMS, similar to other healthcare settings, have adopted the frameworks and principles of quality management systems used in the business industry. The goal is to improve the end product and the customer's satisfaction. In EMS, the end product is the care provided to patients in the prehospital setting. Quality programs usually range from basic traditional Quality Assurance (QA) to Continuous Quality Improvement (CQI) and complex Total Quality Management (TQM). Quality assurance is the static and retrospective review or inspection of services to identify problem areas [12, 13]. Quality improvement requires a continuous study and improvement of a process, system, or organization [13]. Total Quality Management is the most advanced and most comprehensive since it involves the whole organization. Elements of TQM consist of leadership commitment to quality, use of reliable indicators of quality, and involvement of front-line workers in quality improvement efforts [12]. The shift in quality management paradigm in EMS from pure quality assurance programs towards quality improvement took place after the adoption of CQI concept by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) in 1992. EMS quality assessment focused more on improving patient care through continuous measurements and inputs using key performance indicators [14].

4. EMS System Performance Indicators: Structure-Process-Outcome Model

Performance indicators are measurement tools that should be "specific, measurable, action oriented, elevant and timely" [15]. Three types of indicators are used to measure quality in patient care: Structure, process and outcome indicators (Table 1) [16–19]. EMS system performance indicators follow the same classification.

Structural data are attributes of the setting in which care is provided [17]. These usually refer to the characteristics of the different components of an EMS system including facilities, equipment, staffing, knowledge base of providers, credentialing, deployment. Most structure indicators reflect standards developed at a local, regional, or national level through consensus building or by EMS organizations, administrators, or authority. These indicators provide an indirect measure of quality and are difficult to relate to outcomes in patient care [19]. Since EMS systems designs are diverse as discussed above, these indicators may not be applicable to all systems. Emergency vehicle response time standard is the most commonly used structure measure in EMS. The goal is to respond to 90% of priority 1 calls (life threatening and highly time dependant) in less than 9 minutes [22]. Several EMS systems designed ambulance deployment strategies to meet this standard despite conflicting results from several studies about the effect of short response times on patient outcome in trauma [23–25] and the need for even shorter EMS times (around 4 minutes) to impact survival in out-of-hospital cardiac arrest [26, 27]. In the United Kingdom, the adoption of a similar time target structure measure (8-minute response time for 75% of category A or emergency calls) by the National Service Framework for coronary artery disease as the main performance indicator was criticized and described by the paramedics as a poor quality indicator that is "too simplistic and narrow" and that is putting patients and ambulance crews at risk [28].

Another type of measures is process data. These are the components of the encounter between the prehospital provider and the patient. It is an evaluation of the steps of the care provided. A process is the repeatable sequence of actions used across all EMS levels to produce good patient outcome [19]. Process measures are more sensitive to differences in quality of care [29]. In contrast to structure and outcome measures that provide an indirect approach to quality measurement, process measures allow for a direct assessment of quality of care. The inputs from process measures are very useful for quality improvement programs since they are easy to interpret and act on [30, 31]. One disadvantage of using process measures to monitor quality is that they can become very complex with increased clinical sophistication of the medical services provided in the prehospital setting. In the USA, EMS medical directors commonly use process measures when performing a structured implicit review of prehospital records (run sheets) to evaluate compliance with medical protocols and appropriateness of the treatment provided. One example would be collecting specific data points on the process of endotracheal intubation performed by EMS providers to monitor the success rate of this procedure. A medical director can evaluate the technical skill of providers performing this procedure and their compliance with preestablished criteria and decide which specific elements will need improvement such as mandating tube placement verification with End Tidal CO2 waveform documentation.

A third type of measures is outcome data. These evaluate the change in patient's subsequent health status in response to a clinical intervention. Numerous prehospital

Table 1: Structure-Process-Outcome Model for EMS systems PIs.

Indicator Type	Definitions	EMS systems PI examples	Advantages	Limitations
Structure	Characteristics of the different components of the system	(i) Facilities (ii) Equipment (iii) Staffing (iv) Knowledge base of providers (v) Credentials (vi) Deployment (vii) Response times	(i) Standardized structural data allows for comparison between systems structure	(i) Indirect measure of quality (ii) Difficult to relate to outcome (iii) Problematic with EMS system design diversity
Process	Combination or sequence of steps in patient care intended to improve patient outcome	(i) Medical protocols (ii) Medication administration (iii) Transport to appropriate facility	(i) Direct measure of quality (ii) Specific input for improvement (iii) Easy to understand and to evaluate (iv) Does not require Risk adjustment (v) Easy data collection (vi) Best for technical skill evaluation (vii) Short-term evaluation	(i) Strict criteria for generalization (ii) Can become very complex with more advanced care (i.e., complex processes)
Outcome	Changes in health and well-being related to antecedent care *6 D's** (i) *Death* (ii) *Disease* (iii) *Disability* (iv) *Discomfort* (v) *Dissatisfaction* (vi) *Destitution*	(i) Out of hospital cardiac arrest survival (ii) Patient Satisfaction (iii) Improvement in pain score	(i) Easy to understand (ii) Feedback about all aspects of care provided (iii) Long-term outcomes	(i) Indirect measure of quality (ii) Requires Risk adjustment and standardization of data collection

* EMS outcomes defined by Emergency Medical Services Outcomes Project (EMSOP).

interventions are not yet evidence based [2, 31–33]. Outcome research in EMS focuses on determining the effectiveness of some of these interventions and showing the true value of an EMS system since it offers feedback on all aspects of care. Outcome data is easy to interpret and easily understood by the different stakeholders (policymakers, patients, EMS providers, public, etc.) and can be used to compare EMS systems. The adoption of pure outcome data as performance indicators is not however straightforward. For outcome data and more specifically clinical outcome data, to be relevant performance indicators, accurate risk adjustment, standardization of definitions, and development of research models for each measured outcome are required [11, 29, 30]. Four explanations for the source of variation in outcome were described by Mant: these include differences in type of patient (patient characteristics), differences in measurement, chance (random variation), and differences in quality of care [30]. Adding to these challenges are the degree of sophistication of some prehospital treatment technologies, the operational complexity of the prehospital environment, and the difficulty in isolating the prehospital effect from the emergency department and hospital effect [11]. In an effort to overcome the barriers to outcome research and the adoption of outcome data as performance indicators for EMS systems, the US National Highway Traffic Safety Administration (NHTSA) launched in 1994 the EMS Outcomes Project (EMSOP) [10]. This project identified the priority conditions that should take precedence in EMS outcomes research based on impact and frequency and defined six outcome categories (6D's): survival (death), impaired physiology (disease), limit disability (disability), alleviate discomfort (discomfort), satisfaction (dissatisfaction), and cost-effectiveness (destitution) [10]. Two framework models were also proposed to facilitate outcome measurement in EMS: the "Episode of Care Model" and the "Out-of-Hospital Unit of Service Model" [11]. The first model is used for high-priority conditions (highly time dependent) to measure long-term outcomes (survival, physiologic derangement,

Table 2: Comparison of EMS clinical performance indicators.

US clinical performance indicators*						
Clinical condition	ST Elevation Myocardial infarction (STEMI)	Pulmonary Edema	Asthma	Seizure	Trauma	Cardiac arrest
Indicators or bundle elements	(1) Aspirin (2) 12 lead Electrocardio-graph (ECG) (3) Direct transport to percutaneous cardiac intervention (PCI) interval from ECG to balloon <90 minutes	(1) Nitroglycerin (2) Noninvasive positive pressure ventilation	(1) β_2 agonist administration	(1) Blood Sugar measurement (2) Administration of a benzodiazepine	(1) Entrapment time <10 minutes (2) Direct transport to trauma for patients meeting criteria	(1) Response interval <5 min for basic CPR and Automated external defibrillators (AEDs)
Outcome	NNT = 15 Harm avoided: A stroke, 2nd myocardial infarction, or death	NNT = 6 Harm avoided: need for an endotracheal intubation	Not Specified	NNT = 4 Harm avoided: persistent seizure activity	NNT = 3 or 11 depending on criteria used Harm avoided: one death	NNT = 8 Harm avoided: one death
UK clinical performance indicators#						
Clinical condition	STEMI	Stroke/TIA	Asthma	Hypoglycemia	Trauma	Cardiac arrest
Indicators or bundle elements	(1) Aspirin (2) Nitroglycerin (3) Recording pain score (before and after treatment) (4) Pain medication (5) Transfer targets for thrombolysis/PCI	(1) Recording of Face Arm Speech Test (FAST) (2) Recording of blood sugar (3) Recording of blood pressure	(1) Recording of respiratory rate (2) Recording of Peak Expiratory Flow Rate (PEFR) (3) Recording of SpO_2 (4) β_2 agonist (5) Oxygen	(1) Recording of blood glucose before treatment (2) Recording of blood glucose after treatment (3) Recording treatment (4) Direct referral to appropriate health professional	Pilot indicators available only for patients with severe trauma (Glasgow Coma Score, GCS < 8) (1) Recording of blood pressure (2) Recording of respiratory rate (3) Recording of SpO2 (4) Recording of pupil reaction	(1) Return of Spontaneous circulation (ROSC) on arrival to hospital (2) Presence of defibrillator on scene (3) ALS provider in attendance (4) Call to scene response ≤4 min
Outcome	Improved assessment and management of STEMI with increased survival	Improved assessment and management of stroke	Improved assessment and management of asthma	Improved assessment and management of hypoglycemia	Not specified	Improved response to and survival from cardiac arrest

*Source: [20].
#Source: [21].

long term disability). The second one is used for low-priority conditions (minor trauma) to measure short- or intermediate-term outcomes (patient satisfaction, relief of pain). Examples of core risk adjustment measures (RAMS) that are common to all EMS conditions (e.g., age, gender and vital signs) and specific RAMS (e.g., peak flow measurement for asthma exacerbation) were also described [34]. All these steps were designed to facilitate outcome research and the adoption of outcome measures in evaluating quality in EMS.

Internationally, out-of-hospital cardiac arrest (OHCA) survival is the most common outcome measure used to compare EMS systems. Standardized risk adjustment measures and data collection forms are well defined (Utstein template) [35]. The incorporation of these elements in quality programs would enable EMS administrators and medical directors to compare outcomes with other systems, to identify the specific components of the system that are functioning properly and those that are not and how changes can be implemented to improve cardiac arrest outcomes.

5. Transitioning from Theory to Practice

Relying on only one type of performance measures (structure, process, or outcome) can yield a very narrow perspective on quality care in EMS. The complexity of EMS systems requires a more comprehensive evaluation of the different components of the system.

One approach is to use a set of mixed indicators that cover different aspects of an EMS system. Several EMS stakeholders in the USA have proposed comprehensive sets of indicators: one set was proposed by the International Association of Firefighters in the National Fire Protection Association (NFPA) in several publications on standards of emergency medical operations (NFPA 1710), criteria for response times (NFPA 1720), and dispatch standards (NFPA 1221) [36]. Another set of 35 consensus-based indicators was proposed by the National Association of EMS Officials (NAEMSO) in 2007 at the end of the EMS Performance Measures Project in an effort to identify a common set of specifically defined measures of EMS system performance [37]. A tool was also proposed for EMS agencies to properly measure these indicators. Other sets of indicators are used by international ambulance services such as those used by the South Australian ambulance services and which are part of performance framework encompassing "operational, managerial and strategic level" indicators [38]. The validity and practical application of these indicators are yet to be tested.

Another approach is to focus on few high impact clinical conditions and to use bundles of measures that are disease or condition specific in order to evaluate quality in the overall system. Evaluating the system's response to few high-priority clinical conditions considered "tracer conditions" can help predict performance of same elements in response to other clinical entities [39–41]. "Tracer conditions" such as trauma or cardiac arrest are clinical entities with high impact (mortality and morbidity, cost and frequency) and potential for improved outcome [10, 40, 42]. The bundles of measures are similar to composite measures that link structure and process to outcome. The elements of the bundle are evidence-based measures that would lead to improved patient outcome when combined together. One example of evidence-based treatment bundles is the set of clinical performance indicators proposed in 2007 by the US Consortium of Metropolitan Municipalities EMS directors [20]. Six EMS priority conditions were selected based on available supporting evidence of an effective prehospital treatment and on a consensus of EMS experts. Specific outcomes were described in the form of number needed to treat (NNT) and the harm avoided if the bundle measures were met in each case. A similar approach was used by the UK Care Quality Commission in proposing a different set of evidence-based indicators following the recommendations of Joint Royal Colleges Ambulance Liaison Committee (JRCALC) in 2006 [21]. Comparing the US and UK sets reveals overlap between some of the clinical conditions and the indicators that are proposed (Table 2). The outcomes that were defined by the UK set were however less specific than those of the US set. The goal of these bundles, when used in combination with standardized outcome categories, is to establish evidence-based benchmarks or best practices for EMS systems or ambulances services and to allow comparison of performance between different systems [20, 43]. Prerequisites for the use of these bundles for performance comparison between EMS systems include but are not limited to similarity in infrastructure and clinical sophistication of the prehospital services and standardized data collection.

6. Implications for the Future

The ultimate goal of performance indicators in EMS is to measure the true value of the system. A lot of work has been done to find the right system metrics for EMS system's evaluation. Evidence-based bundles can be good measures of the effectiveness of the system when it comes to specific clinical conditions and patient outcome. These however represent only one perspective of what good quality prehospital care means. Different stakeholders have different perspectives on quality care [44, 45]. A transition towards "Whole System Measures" defined by the Institute for Healthcare Improvement (IHI) as "balanced set of system level measures which are aligned with the Institute of Medicine's (IOM's) six dimensions of quality and are not disease or condition specific" can help overcome some of the challenges of evaluating quality in EMS [46]. Patient satisfaction with care score, rate of adverse events, incidence of occupational injuries and illnesses, and healthcare cost per capita are some examples of these whole systems measures [46]. These measures would be part of a balanced score card or measurement dashboard with specific set goals for improvement that are communicated across all levels of the EMS system from prehospital providers to leadership and policy makers. This integration of whole system measures into EMS system evaluation can help answer the question: what value is the system adding to patient care and what is the quality of the services provided?

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