INTRODUCTION
Emergency Medical Services (EMS) can be defined as a system that provides acute, urgent care and transportation for the sick and injured. EMS practitioners include professionals at many levels, both volunteer and paid, who are trained in the operational and clinical aspects of EMS. Physicians, nurses, respiratory therapists, pilots, dispatchers, managers, educators, maintenance staff, information technology professionals and others all contribute to the EMS system. Increasingly, EMS practitioners also work in other settings where their training is an advantage, such as hospital and other clinical settings, military and law enforcement, preventive and follow-up care systems, safety and security.

These activities generate data of interest to many, ranging from traffic safety scientists and automotive engineers to epidemiologists and economists. This article reviews some EMS data sources and tools available with a focus on using cardiac arrest data to improve system outcomes.

EMS DATA SOURCES
Sources of EMS data can be grouped into three categories:
1] Logistic data, such as time, date and location of events, names of practitioners and services, patient demographics, health insurance information, etc.
2] Clinical data, such as patient assessment, vital signs, treatment and response, etc.
3] Operational data, such as response time, transport distance, communications recordings, practitioner skill logs, quality assurance reviews, patient safety audits, etc.

Much of this data is available from EMS ambulance responses as they are recorded electronically, instead of by prior paper and audio recording tape systems. Electronic recording, dispatch, and patient charting systems have been the long-term industry standard in EMS. Software vendors offer systems for computer-aided dispatch (CAD), patient charting, quality assurance review, personnel management, GIS mapping of EMS incidents, and other functions. Digital audio recording software now offers transcription and search functions. These advances make EMS data more available for analysis. For most patients, however, outcome data remains separate from the EMS dataset, and requires abstraction or query from hospital databases.

EMS DATA HISTORY
In 1973, state EMS directors realized that there was no standard format or process for gathering and comparing data from one state, one service, one provider, or one patient to another. There was increasing interest in such comparisons as hospital networks and specialty centers developed, ambulances more often crossed state lines, and large ambulance services formed. The emergency medical services system act of 1973 identified 15 essential components of an EMS system, thus creating a rudimentary framework for EMS data collection.

Some systems began extracting data from paper reports or using early scannable paper database systems. Rhode Island had one of the earliest statewide EMS data systems, starting in the 1990s.

The 1990 Utstein style of EMS data reporting for cardiac arrest patients created a more detailed set of EMS data elements and allowed comparison between systems. In 1994, the National Highway Traffic Safety Administration's Office of EMS (NHTSA EMS) developed a national consensus document that defined the first national prehospital EMS data set, with 81 thoroughly defined data elements. This data set formed the foundation for the National EMS Information System, NEMSIS, which was established in 2001. Version 3.5 of the EMS data dictionary is currently in development and encompasses over 500 data elements. The NEMSIS data registry includes data from over 30 million EMS activations submitted by over 10,000 agencies serving 49 states and territories.

While this is an impressive national data set and a unique healthcare enterprise that can answer many research questions, for privacy and efficiency reasons the national data set does not include many elements that are important at state, regional, or individual service, provider, or patient levels. However, similar software is in use at these levels and allows robust local analysis. As is true with any large database where the information is entered without significant oversight, the NEMSIS dataset contains some inaccurate
data. However, improvements in data entry rules, physician quality assurance review of EMS charts, and increased understanding of the importance of accurate EMS data should gradually improve data quality. Thus, there is an EMS data pyramid, with a broad base representing individual and local data tapering to a smaller but still robust data set at the national level. Topics of particular interest, such as cardiac arrest, highway crash incidents, epidemics, and opiate overdose, merit focused databases.

**CARDIAC ARREST DATA AND CARES**

For cardiac arrest, independent projects to gather data and benchmark using the Utstein guidelines developed, culminating in the Cardiac Arrest Registry to Advance Survival (CARES) in 2004. CARES was formed through collaboration between the CDC and Emory University’s Department of Emergency Medicine. The CARES registry began collecting data in the Atlanta area in 2005 with 600 patients, and has now expanded to statewide data collection in 23 states and 63 community efforts in an additional 18 states, as well as 8 countries outside the US. The registry now includes over 350,000 patients representing the efforts of over 1,400 EMS agencies and 1,800 hospitals. A major use of the CARES registry is benchmarking, as seen in Figure 1, with individual agencies able to perform both internal benchmarking against prior performance as well as comparison with like systems or the registry in general. The project also allows discussion of diversity and location information.

Since the NEMSIS database has evolved to include most of the 66 CARES registry elements, barriers to membership have decreased, but abstraction of hospital data still requires significant personnel effort. CARES membership fees present a significant hurdle to many states and agencies, currently including Rhode Island, as shown in Figure 2. However, the involvement of focused and dedicated data abstraction personnel also means that the CARES dataset is likely more accurate than the NEMSIS data cube.

In Rhode Island, there is interest in CARES enrollment, currently complicated by lack of funding. However, other efforts are underway including inclusion of CARES elements in the RI EMS data set and efforts to search both traditional data and parse narrative data to develop a strong and accurate statewide EMS database for research and quality purposes.

**CASE EXAMPLES**

Several hypothetical case examples illustrate the capabilities and utility of EMS data analysis.

**Case 1: Individual Patient Data**

A 68-year-old male patient has diabetes and congestive heart failure. He lives alone, has poor vision due to diabetic retinopathy. He often has difficulty taking his medication properly but does not qualify for home nursing services. About twice a month, he calls 911 due to symptoms of his chronic diseases, and is often hospitalized. Noting this pattern of readmission, a case management meeting occurred, involving the local EMS agency and their data system. From an analysis of their individual EMS run data, the care team determines that many of his 911 calls have been related to medication errors. With the patient’s permission, he is entered into a community paramedicine program where
members of the EMS agency visit him at home and assist
him with medication dosage and compliance, reducing the
need for 911 calls and re-hospitalization.

Case 2: State System Data Improves Cardiac Arrest Care
A state EMS office receives several complaints about ques-
tionable resuscitation rates in some communities. In a num-
ber of cases during the prior year, patients suffering cardiac
arrest in these communities had long waits for EMS care.
A query of the prior year’s EMS data identifies the set of
patients with witnessed and unwitnessed cardiac arrest, and
identifies those with bystander CPR, including those who
received CPR instructions via 911/Dispatch. After analysis,
there does not appear to be discrimination based on cultural
or ethnic characteristics, place of residence, responding
agency or provider. However, most of the patients in question
had their emergency occur during peak call volume times
of day, contributing to the prolonged response times. After
discussion with several involved providers, the state office
determines that low percentages of bystander CPR and dis-
patcher instruction in CPR via telephone represent a gap in
the current system. Focused efforts in both areas begin, and
resuscitation rates rise compared with prior year baselines.

Case 3: National Data Reveals Health System Patterns
Syndromic surveillance of EMS data in real time by the
National Collaborative for Bio-Preparedness, enabled by
BioSpatial, is currently in place. This capability, dependent
on prompt uploading of individual EMS system data to state
databases and a cooperative agreement between state EMS
offices and BioSpatial, monitors a number of syndromes
of national interest (cardiac arrest, opiate overdose, motor
vehicle crashes, gastrointestinal symptoms, influenza-like
illness, etc.). Data at the national level is scrubbed and aver-
ged to avoid privacy concerns, but at the state and service
level the system allows access to the original data (at the
same level these entities already enjoy). Figure 3 depicts a
year of Rhode Island cardiac arrest data as a heat map – the
southernmost portion of the state not visible due to map
zoom range.

Such EMS data analysis and syndromic surveillance can
be used to uncover clusters of foodborne illness and aid
in tracking the source, find concentrations of opiate over-
dose patients to enable community response, and identify
the location of accident-prone intersections and segments
of highway to facilitate traffic engineering improvements.
Surveillance of cardiac arrest data enables identification of
neighborhoods at risk due to lack of EMS coverage, AED
availability, or low rates of bystander CPR.

SUMMARY
Availability of robust electronic EMS data and tools to share,
analyze, and report these data have profound implications
for the healthcare system, ranging from ability to improve
individual patient disease management to national level
syndrome identification and response. Today’s data systems
and analysis tools, including the NEMSIS Data Cube, the
CARES registry, and the National Collaborative for Bio-Pre-
paredness BioSpatial graphic information system analysis
and mapping capabilities, provide powerful real-time capa-
bilities for understanding EMS data and improving care
across our prehospital system.

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DOA 2/10/2019.

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