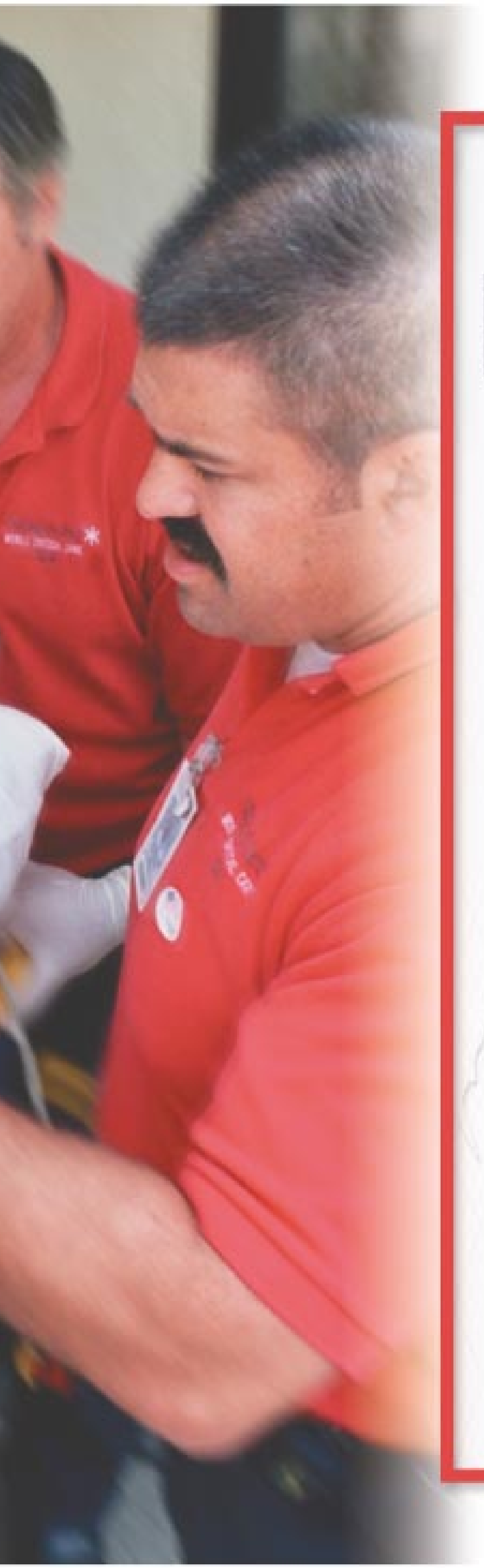
PHOTO JULIE MACIE



BY THE NUMBERS

Prehospital cardiac arrest research

By Mike Rubin, BS, NREMT-P

It is precisely 6:07 a.m. You know that because it's no easier to ignore the crimson, digital display beside your bed than it is to pretend that the tones in the bunkroom didn't abruptly terminate the only 40 minutes of REM sleep you've had during this overnight shift. You and your paramedic partner, Paul, exchange "Why us?" glances, then proceed to your ambulance. Paul pauses to confirm the location at the in-house CDT.

"Unconscious, not breathing, 47 Mill Town Lane," Paul reports as he settles behind the wheel, and eases into traffic. One left and two right turns later, you spot the BLS ambulance parked in front of a brick ranch home.

An average-size, 59-year-old male is supine on the floor of a small, neat bedroom. He's wearing an unbuttoned white dress shirt, underwear, dark socks and no pants. His face is pale but not cyanotic. You're not surprised to find CPR in progress.

The BLS crew explains that the patient was getting dressed for work when he collapsed and that no shock was indicated after an AED assessment. You confirm the absence of a carotid pulse. Your protocols dictate that you leave the AED in place until you've attached the monitor leads. You do so, and Paul prepares to intubate.

You expect asystole, but the ECG reveals the narrow complexes of a sinus rhythm in the 70s. Paul inserts an 8.0 tube while you check again for a pulse. Nothing. Hmmm. … Resume CPR.

"PEA," you announce to Paul who, after verifying and securing the airway, squirts two 10 mL syringes of 1:10,000 epinephrine down the tube. You're already working on the IV when Paul announces that the patient is now in VFib. You notice that he's transferred the AED pads to your monitor and is charging to 200 joules. His clearing chant interrupts your hurried application of a Veni-Gard; you have a strong preference for dodging defibrillation attempts intended for a patient.

You clear from the patient, and that shock plus another one at 300 joules leave him asystolic with occasional agonal complexes. After another milligram of epinephrine and one of atropine, it's time to get moving. St. Stephen's hospital is four to five minutes away.

Nothing changes for the better en route. Your patient is another example of chemical futility and is pronounced after one round of medications in the emergency department (ED). After-the-fact discovery of the patient's aortic aneurysm history does not make you feel any better about the pulseless, narrow complexes that you witnessed. Your feeling of uneasiness about what you saw and did lingers.

Sudden death

Of 250,000 out-of-hospital cardiac arrest victims in the United States each year, approximately 240,000 die before reaching an ED. Only half of the remaining 10,000 patients will survive to discharge.[1] The results are poor because the majority of cardiac arrests aren't completely linked to the "chain of survival": early access to 9-1-1, early CPR, early defibrillation (if indicated) and early advanced cardiac life support (ACLS).[2] It's estimated that 40,000 lives could be saved annually by making realistic improvements to anticipation and management of ventricular fibrillation[1] (VFib) (see "Cardiac Arrest Rhythm Primer," p. 75).

Efforts by large, metropolitan EMS systems, such as Boston, Houston, Seattle and Kansas City, to collect cardiac arrest data are well documented.[3] However, politics and bureaucratic inertia often discourage progress, and most systems lack the requisite feedback loop that would allow evaluation and enhancement of current practices.

This article summarizes the commitment of Stony Brook University Hospital (SBUH) and Suffolk County EMS (SCEMS)—two Long Island, N.Y., institutions—to design and implement prospective cardiac arrest research in a primarily volunteer environment. The SBUH/SCEMS initiative could serve as a template for both small and large EMS organizations eager to assess performance.

Getting started

Suffolk County, a 1,000-square-mile area with 1.4-million residents, has been actively engaged in cardiac arrest research for three years. Led by Mark Henry, MD, chair of SBUH's ED, and Jeanne Alicandro, MD, SCEMS medical director, this suburban region in the eastern half of Long Island has played an innovative role in cardiac arrest research, despite some unique challenges.

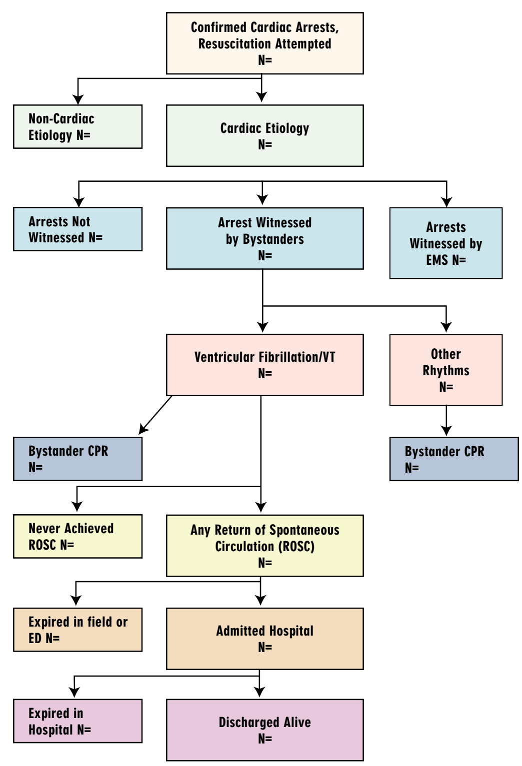
With more than 100,000 EMS calls handled annually by approximately 100 independent volunteer fire and rescue services, SCEMS faces territorial and geographical obstacles unprecedented in the United States.

SCEMS maintains oversight through daily monitoring of calls and periodic review of agencies and their members. Written patient care reports, online consultation with medical control, and off-line accounts of prehospital intervention are key elements of the system's quality assurance. SBUH has a contract with SCEMS to provide medical control and most of the day-to-day information management.

With an average of two to three cardiac arrests occurring daily, Suffolk County is fertile ground for research. County protocols echo ACLS recommendations to hunt for a shockable rhythm, initiate CPR, secure the airway and administer rhythm-specific medications. However, Suffolk County had no evidence that any of these interventions routinely saved lives. With guidance from Henry and Alicandro, SBUH and SCEMS began a methodical study of cardiac arrests.

FIGURE 1

Ütstein Template for Reporting Cardiac Arrest



Initial hypotheses were aligned with ACLS tenets:

PHOTO BILLY GUTH

Fifty to 70 percent of all cardiac arrests begin as VFib.

FIGURE 2: SBUH/SCEMS Cardiac Arrest Data Elements

I. Patient
- A. Name
- B. Address
- C. Phone
- D. Age
- E. Sex
- F. Medical history

II. Responding Agencies
- A. Agency ID
- B. Unit or vehicle
- C. Response times
  1. Dispatched
  2. En route
  3. On scene
  4. To hospital
  5. At hospital

III. Scene
- A. Case ID
- B. Case date
- C. If witnessed, by whom?
- D. Location type
- E. Patient's initial condition
- F. Time of collapse
- G. Time CPR initiated

IV. Treatment
- A. Sequence and/or time
- B. Device
- C. Dose
- D. Intervention
- E. Rhythm

V. Prehospital Outcome

VI. Hospital
- A. Destination
- B. Outcome
- C. Etiology

1. Cardiac arrest survival depends on rapid identification and prompt defibrillation of ventricular fibrillation (VFib) or pulseless ventricular tachycardia (VTach);
2. Access to ALS improves the chances of a favorable outcome, no matter which rhythm presents; and
3. In the absence of clearly identifiable causes, the prognosis is poor when a patient presents in pulseless electrical activity (PEA) or asystole.

You will see, not all of these assumptions were validated.[2]

The biggest challenge was data collection. Although Suffolk County ALS interventions must be reported to medical control in real time, BLS crews have no such requirement. Further, BLS resuscitation attempts might include not only EMS personnel, but also police and lay rescuers. Some cardiac arrests involve all three.

There's an understandable desire to minimize the workload of volunteers who leave their homes or jobs to answer calls. SBUH and SCEMS administrators felt that a brief, verbal report from field technicians (techs) and police officers at the conclusion of each prehospital cardiac arrest would be the least intrusive approach.

Each cardiac arrest would be assigned a unique identification number, and the consolidation of data would be the responsibility of medical control. Ütstein-style guidelines would be used for data collection.[4] The Ütstein template is a proven method to standardize cardiac arrest reporting across diverse domains (see Figure 1, p. 70). Different versions of the template apply to prehospital, in-hospital and laboratory studies.

Figure 2 (left) shows the details collected by medical control from SCEMS prehospital personnel to satisfy Ütstein criteria. Not all of the desired information was available for every case. Times associated with patient collapse, initial EMS notification and prehospital interventions are particularly difficult to capture. In many cases, caregivers were asked for their best estimate. The sequence of ALS treatment is often substituted for the times of each intervention.

Patient outcome is the cornerstone of a results-oriented approach to cardiac arrest research. It's not uncommon to hear the word *save* applied to some cardiac arrests, but what constitutes a save? Return of spontaneous circulation (ROSC)? Hospital admission? Discharge? Long-term survival? Much of the research concerning antiarrhythmics, such as amiodarone and lidocaine, has accentuated the difference between survival to *admission* and survival to *discharge*. Both the ARREST (Amiodarone in Out-of-Hospital Resuscitation of Refractory Sustained Ventricular Tachyarrhythmias) and the ALIVE (Amiodarone vs. Lidocaine in Prehospital Refractory Ventricular Fibrillation Evaluation) trials concluded that amiodarone improved the odds of survival to hospital admission, but not to discharge.[6,7]

SBUH/SCEMS assigns both a prehospital *and* a hospital outcome to each patient, according to the list in Figure 3.

To determine the hospital outcome, SBUH follows up with health-care facilities, patients and family members. The latter can be awkward. After a patient is discharged, the researcher calls the patient or family and inquires about how the patient is doing—never pressing for details if there is any reticence. Occasionally, such conversations become a component of closure for patients and their families. The caller must have good listening skills.

Etiology, although included in the Ütstein template, usually cannot be determined in the field. When it became obvious that techs could only guess at the cause of most cardiac arrests, we reassigned the source of that data element from the field to the receiving hospital.

Initially, cardiac arrest reports were transcribed to dedicated forms that were filed separately from the associated run reports. A time-consuming manual exercise was required to match documents whenever there was an interest in viewing up-to-date statistics. Limited clerical resources made it difficult to compile more than one or two data extracts a year. Clearly, a less labor-intensive alternative was needed.

After two years of experimenting with computerized input and output tools, SBUH developed a PC-based database management system, known as CASS (Cardiac Arrest Survival Statistics). CASS allows for the storage and retrieval of cardiac arrest data using customized, user-friendly screens and reports (see sidebar article, p. 74). Details are entered once and then summarized by the software in a variety of formats. Survival, for example, can be correlated to agencies, response times, presenting rhythms, interventions and destinations. Finally, we had an automated way to manage cardiac arrest information.

The payoff

More than 2,000 non-traumatic cardiac arrests reported to Suffolk County medical control during a 30-month period yielded the following preliminary conclusions:

PEA: The probability of prehospital ROSC is much greater when the patient presents to ALS providers in PEA than in other pulseless arrhythmias. This is particularly noticeable in the setting of prehospital defibrillation (39% for PEA vs. 16% for VFib/VTach and 9% for asystole), but is also evident without prehospital defibrillation (17% for PEA vs. 6% for asystole).

Comments: ACLS literature distinguishes between PEA and pseudo EMD (electro-mechanical disassociation).[2] The

FIGURE 3

Prehospital Outcomes
- CPR continued
- ROSC, sustained
- ROSC, brief
- Termination
- DNR
- DOA
- Unknown

Hospital Outcomes
- Expired in ED without ROSC
- ROSC, then expired in ED
- DNR presented in ED
- Admitted, then expired
- Admitted, still in-house
- Transferred to another facility
- Discharged
- Discharged, then expired
- Discharged, alive at one year
- Unknown

latter produces ventricular contractions that are not strong enough to be palpated or measured by sphygmomanometers. We might be able to improve survival to discharge (2.2% of PEA cases) by treating selected instances of PEA as profoundly symptomatic brady- or tachycardia. A supporting Helsinki study found PEA to be the most survivable unwitnessed prehospital cardiac arrest rhythm.[8] SCEMS has added transcutaneous pacing to its PEA protocol as a medical control option.

Prehospital defibrillation: Not surprisingly, the chances of prehospital ROSC and survival to discharge are significantly greater in the presence of prehospital defibrillation (18% and 5%, respectively) than without prehospital defibrillation (8% and 1%, respectively). In the presence of prehospital defibrillation, there is a greater chance of prehospital ROSC with ALS than with BLS only (19% vs. 17%), but a higher probability of survival to discharge among prehospital ROSC cases with BLS only than with ALS (29% vs. 24%).

Comments: Improved survival to discharge with BLS-only after ROSC might indicate the limits of prehospital definitive care and the importance of rapid transport in the post-arrest setting. Also, prehospital intervention may be timelier when there is no delay for ALS.

Non-shockable rhythms: Without prehospital defibrillation, there is a greater chance of prehospital ROSC with ALS than with BLS only (9% vs. 3%). Among ALS cases without prehospital defibrillation, prehospital ROSC is more likely with endotracheal intubation (11%) than without (6%).

Comments: Survival of patients in PEA or asystole occasionally depends on prompt treatment of the underlying cause (e.g., hypoxia, hypovolemia, hyperkalemia, etc.). In general, BLS providers are not equipped to provide such intervention.

ALS vs. BLS: Prehospital ROSC is more likely with prehospital endotracheal intubation (14%) and/or prehospital medication (13%) than with BLS only (7%). However, the probability of survival to discharge among cases of prehospital ROSC is much higher with BLS only (25%) than with prehospital intubation (9%).

Comments: The success of prehospital intubation depends greatly on the experience of the practitioner.[2] It may be best to expedite transport to a facility where advanced airway management is ensured.

Gender: Survival to discharge is skewed

PHOTO MAURA CASEY

Cardiac arrest survival depends on rapid identification and prompt defibrillation of ventricular fibrillation (VFib) or pulseless ventricular tachycardia (VTach).

toward males (22% of prehospital ROSC cases vs. 11% for females). Interestingly, only 38% of reported non-traumatic arrests involved females, although 49% of patients registered through Suffolk County medical control are female.

Comments: An earlier study by SBUH showed a slight bias toward treating men for acute coronary syndromes prehospitally, compared with treatment of women. Perhaps earlier recognition of ACS signs and symptoms by family members and by-

Tracking Cardiac Arrests with CASS

CASS (Cardiac Arrest Survival Statistics) is a database management system (DBMS) that uses Microsoft Access as its platform. A DBMS stores information efficiently so it can be viewed by the user in many different formats without duplicating data entry. A DBMS is more adept at validating and maintaining relationships between disparate data elements than a spreadsheet or a word processing document. Menus, screens and reports can be tailored to the needs of the user or agency.

Easy entry: CASS makes it easy to enter and view cardiac arrest data. The top half of the data entry screen displays potential selections on how the patient was found and when resuscitation was initiated. Pull-down lists eliminate the need for users to remember codes associated with types of arrests, locations, initial conditions, etc. Tabs at the bottom of the screen separate patient demographics, medical history, responding agency, treatment and outcome sections.

Patient data: The patient tab contains fields for name, address, phone, age and sex. Because the latter two are particularly important, built-in queries correlate age and sex to outcome. The telephone number is useful for follow-up calls regarding long-term survival.

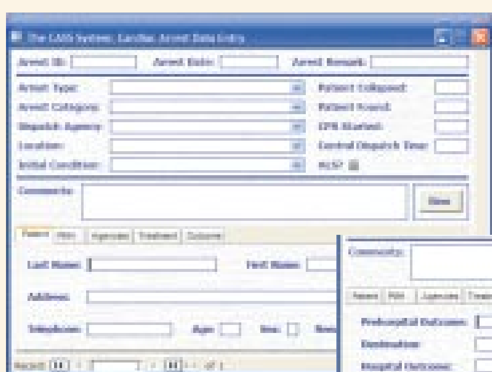
Agencies: The agencies tab focuses on response times: dispatch, en route, on scene, to hospital and arrival at hospital. Not surprisingly, the time from dispatch to arrival on scene ("arrival time") is an important predictor of outcome. CASS is able to group agencies according to affiliation (e.g., EMS, police, public access), geography, level of care and other parameters. Multiple responding agencies may be reported for each case.

Treatment rendered: CASS tracks treatments associated with presenting and ensuing rhythms and makes correlations between specific interventions (e.g., defibrillation, endotracheal intubation, epinephrine administration) and prehospital ROSC. If intervention times are not available, the user can load the treatment sequence.

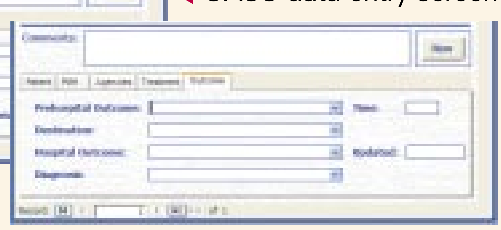
A particularly powerful aspect of CASS is its ability to analyze survival with respect to dynamic ECGs and interventions. CASS helps the user answer such questions as how survival is affected by early advanced airway management in the setting of PEA.

Outcomes: Prehospital and hospital outcome are accessed by use of the final tab. CASS encourages differentiation between short-term and long-term survival. Details not known at the time of initial entry can be added later.

Reports: Data entry serves no purpose unless meaningful information can be retrieved quickly and easily. CASS has robust reporting capabilities. A pull-down menu shows the data reports that are frequently used by SBUH/SCEMS. Specific, customized queries can be created on demand and can be saved for future data extraction and comparison.



◀ CASS data entry screen



▶ Patient outcome screen

Cardiac Arrest Rhythm Primer

Ventricular fibrillation (VFib): Electrical impulses originating from multiple ventricular sites, causing "quivering" of the heart, rather than organized contractions. VFib is always pulseless. It's estimated that 50–70% of all cardiac arrests begin as VFib.[5]

Ventricular tachycardia (VTach): Three or more consecutive ventricular complexes at a rate exceeding 100 beats per minute, caused either by enhanced automaticity or re-entry. If VTach is sustained at more than 150 BPM, the ventricles will not have time to refill before each contraction, and the patient may suffer from inadequate perfusion. VTach may be pulseless or may deteriorate into VFib. Most cardiac arrests that lead to sudden death are thought to originate as VFib or VTach.[1]

Pulseless electrical activity (PEA): The presence of electrical activity (other than VFib or VTach) on an ECG, without a palpable pulse. PEA may be slow, fast or in between, with either narrow or wide QRS complexes. Such conditions as hypoxia, hypovolemia and electrolyte imbalances can cause PEA. The rate, morphology and history may give clues about the etiology.

Asystole: The absence of all electrical activity. Usually a sign of irreversible death, asystole occasionally can be resolved by discovering a treatable underlying cause.

standers would improve survival of female cardiac arrest victims. Further study is needed concerning the disproportionate number of men suffering cardiac arrests prehospitally.

Arrival times: Of 12 agencies with at least 30 cases and above-average ROSC rates, nine (75%) had faster-than-average arrival times (from time of dispatch to time of arrival on scene). Of 14 agencies with at least 30 cases and below-average ROSC rates, nine (64%) had slower-than-average arrival times.

Comments: Three links in the Chain of Survival—early CPR, early defibrillation and early ACLS—frequently depend on the prompt arrival of trained personnel.[2] SCEMS has taken an aggressive approach to reducing response times by working closely with participating agencies. The goal is to get an ambulance to the scene within nine minutes for 90% of calls.

Poor correlation: The SBUH/SCEMS study showed insufficient evidence that any of the following factors affected patient outcome:

- Age;
- Cardiac history;
- On-scene times (from arrival on scene to departure);
- Patient contact times (from arrival on scene to arrival at a hospital);
- Transcutaneous pacing; and
- Online medical control contact.

Fine-tuning

SBUH/SCEMS cardiac arrest research is a work in progress. There's always room for improvement, such as refinement of the following components:

Capture of 9-1-1 activation times: A gap exists from the time the patient collapses (not known in unwitnessed arrests) and the time that EMS is dispatched. It would be worth learning more about that first step in the Chain of Survival.

Design and approval of prospective studies: As discussed above, patients may benefit from a modified approach to PEA. Real-time interpretation of ECGs by medical control and consideration of more aggressive, rate-related treatment modalities for pulseless patients could lead to improved outcome for many patients presumed to be in cardiac arrest.

Recorded times of treatment: Although CASS permits each prehospital intervention to be time-stamped, there is insufficient manpower and automation at many Suffolk County cardiac arrests to permit concurrent, detailed data collection by prehospital providers. Research would benefit significantly by trapping not just the sequence of interventions and outcomes, but the intervals between interventions and outcomes.

Cases with incomplete data: Occasionally, it's difficult to consolidate reports from multiple agencies concerning the same case, especially if post-call reporting requirements are delayed or overlooked

PHOTO RAY KEMP

Three links in the Chain of Survival—early CPR, early defibrillation and early ACLS—frequently depend on the prompt arrival of trained personnel.

by techs. More follow-up by researchers is needed.

Assignment of etiology: Case-by-case feedback from hospitals is not always specific enough to determine cardiac arrest etiology. Closer cooperation between SBUH and other hospitals is indicated.

Uncertain medical history: Patient medical history is another independent variable worth further scrutiny. Unfortunately, prehospital workload during a cardiac arrest rarely permits thorough investigation of PMH.

Summary

The paramedics in the opening scenario could have considered undetected perfusion when they discovered a pulseless, narrow complex sinus rhythm. Their patient's leaking aortic aneurysm might have been better treated with fluid than with epinephrine. Such guidance can be a benefit of cardiac arrest research.

The development of CASS represents a commitment to ongoing research by Stony Brook University Hospital and Suffolk County EMS. Database management systems like CASS offer rational, uncomplicated methods of storing and analyzing information. The SBUH/SCEMS discovery of PEA's surprisingly high ROSC rates is an example of provocative results that beg for further study.

New trends will, no doubt, emerge. Assisted by imagination, organization and automation, any EMS system can contribute to a burgeoning body of knowledge that supplements the doctrine of ACLS. JEMS

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Acknowledgments: The author thanks Mark Henry, MD, Jeanne Alicandro, MD, and Eric Niegelberg for their encouragement and guidance.

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