Part 12: From Science to Survival
Strengthening the Chain of Survival in Every Community

ECC in the Community: How to Ensure Effectiveness

Many clinicians, administrators, and researchers have recognized the need to improve community systems of ECC to optimize patient survival. In 1992 this section of the guidelines described in detail the structural components of a “Chain of Survival.” Eight years later the same systematic, organized, coordinated effort in a community remains the strongest recommendation we can make to save more people from out-of-hospital cardiac arrest. The metaphor of links of a chain has proved successful across many aspects of resuscitation and ECC. For example, the Utstein guidelines for evaluating outcomes from in-hospital cardiac arrest and examining pediatric cardiopulmonary emergencies were developed from the Chain of Survival perspective. As originally formulated, the out-of-hospital Utstein guidelines were intended to provide a structure to evaluate an emergency system. The usefulness of the Utstein template has been confirmed by the many communities that have identified weaknesses in the “links” of their ECC system. Communities continue to implement modifications and optimize treatment for their critical out-of-hospital patients.

The central question to be answered is whether a community’s ECC system provides optimal patient survival. Achieving the optimal survival rate for out-of-hospital cardiac arrest in every community is the challenge now and in the future. What is optimal in one community, however, may not be possible in all communities. Early reports of high survival in mid-sized cities provided the EMS prototype adopted by most communities. Obstacles to providing care in rural and large metropolitan areas create different challenges for EMS systems. Each community will need to examine and devise its own mechanisms to achieve the goal of optimal patient survival. Traditionally, quality assurance in ECC has measured process variables, but the emphasis of quality assurance for cardiac arrest care should be expanded to examine outcome variables in the entire ECC system. The shift in emphasis on system evaluation is necessary because the Chain of Survival is necessary for optimal outcome.

The Chain of Survival

The 1992 guidelines described early access, early CPR, early defibrillation, and early advanced care as essential components of a series of actions designed to reduce the mortality associated with cardiac arrest (Figure 1). These vital links were echoed by the International Liaison Committee on Resuscitation (ILCOR) advisory statements in 1997.

Survival from cardiac arrest depends on a series of critical interventions. If one of these critical actions is neglected or delayed, survival is unlikely. The American Heart Association has used the term “Chain of Survival” to describe this sequence. This chain has 4 interdependent links: early access, early basic CPR, early defibrillation, and early ACLS. The Chain of Survival concept underscores several important principles:

1. If any link in the chain is inadequate, survival rates will be poor. Weakness in system components is the major explanation for variability in survival rates reported over the past 20 years.

2. Although all links must be strong, the inevitable question always arises: Which link is the most important? Certainly, recognition of the emergency and initiation of the Chain is essential—if no one recognizes the emergency and begins to act, survival will be poor. Because rapid defibrillation is the only “sufficient” intervention (ie, defibrillation and only defibrillation can reverse a ventricular fibrillation arrest), it is often proclaimed to be “the single most important factor in determining survival from adult sudden cardiac arrest.” The truth, however, is even more satisfying and more in keeping with the concept of a “Chain of Survival.” Each link in the Chain of Survival is important (see below).

3. The effectiveness of an ECC system cannot be identified by examining an individual link—the whole system must be evaluated. The survival rate to hospital discharge has emerged as the “gold standard” for determining the effectiveness of treatment of cardiac arrest. Recently, considerable progress has been made in providing clear methodological guidelines for study design, uniform terminology, and reporting of results. This progress should facilitate future research on CPR and implementation of the Chain of Survival in each community. (See Table 1 for definitions of terms.)

At least 2 large-scale studies have investigated which patient variables and which emergency system variables were significantly related to survival to hospital discharge. A number of variables (male sex, age, witnessed arrest, etc) had at least some significant relationship with survival. The investigators tried to identify the fewest variables that could explain the greatest differences in survival rates. Surprisingly, most of the differences in survival were explained by just 2 performance variables: the intervals collapse to CPR and...
**collapse to defibrillation.** These results provided even more support for the Chain of Survival concept when investigators observed that it was the *interaction* of early CPR with early defibrillation that was most powerful: without both factors, (1) CPR starting within 5 minutes and (2) defibrillation occurring within 10 minutes, the value of early defibrillation or early CPR was lost. This interaction becomes dramatically clear in a simple 2×2 table (Table 2).

**TABLE 1. Definitions and Terminology in ECC**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac arrest</td>
<td>Cardiac arrest is the cessation of cardiac mechanical activity. It is a clinical diagnosis, confirmed by unresponsiveness, absence of detectable pulse, and apnea (or agonal respirations).</td>
</tr>
<tr>
<td>Cardiopulmonary resuscitation (CPR)</td>
<td>CPR is an attempt to restore spontaneous circulation through any of a broad range of maneuvers and techniques.</td>
</tr>
<tr>
<td>Basic CPR</td>
<td>Basic CPR is the attempt to restore spontaneous circulation by using chest wall compressions and pulmonary ventilation.</td>
</tr>
<tr>
<td>Bystander CPR, layperson CPR, or citizen CPR</td>
<td>These terms are synonymous; however, bystander CPR is preferred. Bystander CPR is an attempt to provide basic CPR by a person not at that moment part of the organized emergency response system.</td>
</tr>
<tr>
<td>Basic life support (BLS)</td>
<td>BLS is the phase of ECC that includes recognition of cardiac arrest, access to the EMS system, and basic CPR. It may also refer to the educational program in these subjects.</td>
</tr>
<tr>
<td>Advanced CPR or advanced cardiovascular life support (ACLS)</td>
<td>These terms refer to attempts to restore spontaneous circulation with basic CPR plus advanced airway management, tracheal intubation, defibrillation, and intravenous medications. ACLS may also refer to the educational program that provides guidelines for these techniques.</td>
</tr>
<tr>
<td>Emergency medical services (EMS) or emergency personnel</td>
<td>Persons who respond to medical emergencies in an official capacity are emergency (or EMS) personnel. The EMS system has 2 major divisions: EMS dispatchers and EMS responders.</td>
</tr>
<tr>
<td>EMS dispatchers</td>
<td>EMS personnel responsible for dispatching EMS responders to the scene of medical emergencies and providing telephone instructions to bystanders at the scene while professionals are on route.</td>
</tr>
<tr>
<td>EMS responders</td>
<td>EMS personnel who respond to medical emergencies by going to the scene in an emergency vehicle. They may be first-, second-, or third-tier responders, depending on the EMS system. They may be trained in ACLS or BLS. All should be capable of performing defibrillation. Emergency medical technician (EMT) usually denotes BLS training. Paramedic or EMT-P usually denotes ACLS training.</td>
</tr>
<tr>
<td>ECC system</td>
<td>The ECC system refers to all aspects of ECC, including that rendered by emergency personnel. The extended ECC system also includes bystander CPR, rapid activation of the EMS system, emergency departments, intensive care units, cardiac rehabilitation, cardiac prevention programs, BLS and ACLS training programs, and citizen defibrillation.</td>
</tr>
<tr>
<td>Chain of Survival</td>
<td>The Chain of Survival is a metaphor to communicate the interdependence of a community’s emergency response to cardiac arrest. This response is composed of 4 links: early access, early CPR, early defibrillation, and early ACLS. If a link is weak or missing, the result will be poor survival despite excellence in the rest of the ECC system.</td>
</tr>
<tr>
<td>Presumed cardiac cause</td>
<td>Cardiac arrest due to presumed cardiac cause is the major focus of ECC. When reporting cardiac outcome data, studies of cardiac arrest should exclude arrests due to obvious noncardiac causes. Because of practical considerations (lack of autopsy information, cost), all arrests are considered to be of cardiac cause unless an obvious noncardiac cause can be identified. Common noncardiac diagnoses that should be separated during analysis of cardiac arrest outcome include sudden infant death syndrome, drug overdose, suicide, drowning, trauma, exsanguination, and terminal illness.</td>
</tr>
<tr>
<td>Time intervals</td>
<td>The Utstein recommendations have provided a rational nomenclature for important time intervals. Time intervals should be reported as the A-to-B interval, which represents the period that begins at time point A and ends at time point B. These are more informative than imprecise terms like downtime or response time. The following terms, for example, are suggested:</td>
</tr>
<tr>
<td>911-call-to-dispatch interval</td>
<td>The interval from the time the call for help is first received by the 911 center until the time the emergency vehicle leaves for the scene.</td>
</tr>
<tr>
<td>Vehicle-dispatch-to-scene interval</td>
<td>The interval beginning when the emergency vehicle departs for the scene and ending when EMS responders indicate that the vehicle has stopped at the scene or address. This does not include the time interval until emergency personnel arrive at the patient’s side or the interval until defibrillation occurs.</td>
</tr>
<tr>
<td>Vehicle-at-scene-to-patient-access interval</td>
<td>The interval from when the emergency response vehicle stops moving at the scene or address until EMS responders are at the patient’s side.</td>
</tr>
<tr>
<td>Call-to-defibrillation interval</td>
<td>The interval from receipt of the call at the emergency response system center until the patient receives the first shock.</td>
</tr>
</tbody>
</table>
The First Link: Early Access

Early access encompasses the events initiated after the patient’s collapse until the arrival of EMS personnel prepared to provide care. Recognition of early warning signs, such as chest pain and shortness of breath, that encourage patients to activate the emergency response system before collapse is a key component of this link. With a cardiac arrest the following events must occur rapidly:

- Early identification of the patient’s collapse by someone who activates the system
- Rapid notification (usually by telephone) of EMS response team
- Rapid recognition by dispatchers of a potential cardiac arrest
- Rapid dispatch instructions to available EMS responders (first-, second-, and third-tier EMS personnel) to guide them to the patient
- Rapid arrival of EMS responders at the scene
- Arrival of an EMS responder with all necessary equipment at the patient’s side
- Identification of the cardiac arrest

All of these events must take place before defibrillation or advanced care can occur; each of these events is a vital part of the early access link. In most communities responsibility for these events rests with the EMS telephone system, dispatcher, and responders.

The Telephone Call to Activate the Emergency Response System: Key Role of an Area-Wide Dedicated Emergency Telephone Number

Widespread use of a 2- or 3-digit dedicated emergency telephone number has simplified and shortened access to emergency assistance. Many countries have established area-wide emergency telephone numbers. Table 3 displays the emergency telephone number used in many countries throughout the world.17 International travelers can access a website for the emergency numbers of more than 200 countries: http://ambulance.ie.eu.org.

Unfortunately, many communities do not have the service of a single EMS telephone number. Providing emergency response service through a dedicated unique number should be a top priority for all communities. Enhanced EMS phone service is preferable.

The increasing sophistication of telecommunication systems now makes it possible for emergency medical dispatchers (EMDs) to identify the location and telephone number of the incoming telephone call. This invaluable feature (called “enhanced 911” in the United States) requires a costly software and hardware upgrade. Cellular telephone calls to

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**Table 2. Influence of Early CPR and Early Defibrillation on Percent of Survival to Hospital Discharge**

<table>
<thead>
<tr>
<th>Collapse to CPR</th>
<th>Collapse to Defibrillation</th>
<th>&lt;10 min</th>
<th>&gt;10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 min</td>
<td>37%</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>&gt;5 min</td>
<td>20%</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

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**Table 3. Emergency Response System Numbers in Europe**

<table>
<thead>
<tr>
<th>Country</th>
<th>Emergency Telephone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>17</td>
</tr>
<tr>
<td>Argentina</td>
<td>101</td>
</tr>
<tr>
<td>Australia</td>
<td>000</td>
</tr>
<tr>
<td>Austria</td>
<td>144</td>
</tr>
<tr>
<td>Belarus</td>
<td>03</td>
</tr>
<tr>
<td>Belgium</td>
<td>100</td>
</tr>
<tr>
<td>Bosnia</td>
<td>94</td>
</tr>
<tr>
<td>Brazil</td>
<td>192</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>155</td>
</tr>
<tr>
<td>Canada</td>
<td>911</td>
</tr>
<tr>
<td>Chile</td>
<td>131</td>
</tr>
<tr>
<td>China</td>
<td>120</td>
</tr>
<tr>
<td>Croatia</td>
<td>94</td>
</tr>
<tr>
<td>Cyprus</td>
<td>112</td>
</tr>
<tr>
<td>Czechia/Czech Republic</td>
<td>155</td>
</tr>
<tr>
<td>Denmark</td>
<td>122</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>911</td>
</tr>
<tr>
<td>Finland</td>
<td>0112</td>
</tr>
<tr>
<td>France</td>
<td>15</td>
</tr>
<tr>
<td>Germany</td>
<td>112</td>
</tr>
<tr>
<td>Greece</td>
<td>166</td>
</tr>
<tr>
<td>Guatemala</td>
<td>123</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>999</td>
</tr>
<tr>
<td>Hungary</td>
<td>104</td>
</tr>
<tr>
<td>Iceland</td>
<td>112</td>
</tr>
<tr>
<td>India</td>
<td>102</td>
</tr>
<tr>
<td>Indonesia</td>
<td>118</td>
</tr>
<tr>
<td>Ireland</td>
<td>112/999</td>
</tr>
<tr>
<td>Israel</td>
<td>101</td>
</tr>
<tr>
<td>Italy</td>
<td>118</td>
</tr>
<tr>
<td>Jamaica</td>
<td>110</td>
</tr>
<tr>
<td>Japan</td>
<td>119</td>
</tr>
<tr>
<td>Kenya</td>
<td>999</td>
</tr>
<tr>
<td>Korea</td>
<td>119</td>
</tr>
<tr>
<td>Malaysia</td>
<td>999</td>
</tr>
<tr>
<td>Malaysia</td>
<td>999</td>
</tr>
<tr>
<td>Mexico</td>
<td>080</td>
</tr>
<tr>
<td>Morocco</td>
<td>112</td>
</tr>
<tr>
<td>Netherlands</td>
<td>112</td>
</tr>
<tr>
<td>New Zealand</td>
<td>111</td>
</tr>
<tr>
<td>Norway</td>
<td>113</td>
</tr>
<tr>
<td>Philippines</td>
<td>166</td>
</tr>
<tr>
<td>Poland</td>
<td>999</td>
</tr>
<tr>
<td>Portugal</td>
<td>115</td>
</tr>
<tr>
<td>Romania</td>
<td>06</td>
</tr>
<tr>
<td>Russia</td>
<td>03</td>
</tr>
<tr>
<td>Slovakia</td>
<td>115</td>
</tr>
<tr>
<td>Slovenia</td>
<td>94</td>
</tr>
<tr>
<td>South Africa</td>
<td>10177</td>
</tr>
<tr>
<td>Spain</td>
<td>061</td>
</tr>
<tr>
<td>Sweden</td>
<td>112</td>
</tr>
<tr>
<td>Switzerland</td>
<td>114</td>
</tr>
<tr>
<td>Taiwan</td>
<td>119</td>
</tr>
<tr>
<td>Thailand</td>
<td>191</td>
</tr>
<tr>
<td>Turkey</td>
<td>118</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>999</td>
</tr>
<tr>
<td>United States</td>
<td>911</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>94</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>994</td>
</tr>
</tbody>
</table>
emergency medical dispatchers cannot be included in such “enhanced services” because only the location of the connecting cell is identified. The amazing growth in the use of cellular phones, however, demands a solution to this problem. Features may be added to cellular telephones and cellular networks to enable tracking of emergency calls from cellular phones. Such features should be mandatory and widely implemented.

**Emergency Medical Dispatchers and the Emergency Medical Dispatch System**

Rapid emergency medical dispatch has emerged as a critical component of the early access link.\textsuperscript{18–22} Traditionally, however, the dispatchers who answer the emergency calls were simply that—“dispatchers”—identifying the nature of the call (“fire, police, emergency medical”), the location, and then switching to the appropriate service to receive details. All EMS dispatch systems must be able to immediately answer all emergency medical calls, quickly determine the nature of the emergency, identify the nearest appropriate EMS responder unit(s), dispatch the unit to the scene in <1 minute on average, and provide critical information to EMS responders about the type of emergency.

In the late 1980s EMS leaders began to explore whether EMDs could actually stay on the telephone with the callers and offer medical advice to the caller. (See also “Part 3: Adult Basic Life Support.”) This led to the highly successful concept of “prearrival instructions,”\textsuperscript{21,22} in which the EMD quickly interviews the caller to learn more about the emergency. The EMD then offers to give the caller advice or instructions on what to do while waiting for the EMS responders to arrive. Internationally, EMDs now give prearrival instructions, and there is widespread acknowledgment that these instructions have improved outcomes.

Simultaneously with the development of protocols for prearrival instructions, Eisenberg and colleagues, in Seattle–King County, Washington, developed and validated CPR instructions for the dispatcher to offer to the caller.\textsuperscript{23,24} These dispatcher-assisted CPR instructions are now standard practice for dispatch centers all over the globe. The “template” instructions first developed in King County have been translated into >10 languages. Dispatcher-directed CPR requires only 2 to 4 hours of additional dispatcher training, and it has been shown in controlled trials to be feasible and effective.\textsuperscript{24,25,25a}

An article in the *New England Journal of Medicine* in 2000 by Hallstrom and colleagues used EMDs to conduct a prospective, randomized, controlled trial of chest compression–only CPR.\textsuperscript{25a} This work was an indirect confirmation of the success of some of the more controversial instructions in telephone CPR, namely, elimination of the pulse check (too difficult for lay rescuers to perform) and replacing the complicated directions on locating the sternal compression point to a simple “press right between the nipples.” These “controversial” shortcuts in CPR instructions were actually put into service >12 years ago, with no problems resulting from their implementation.

The growth of interest in public access defibrillation (PAD) and the growing use of automated external defibrillators (AEDs) by family members of high-risk cardiac patients led to the inevitable question of EMD-assisted defibrillation. Early work by Doherty and colleagues\textsuperscript{26} in Seattle–King County, Washington, confirmed the ease with which this could be achieved and implemented across large EMS systems. The caller is instructed to place both the AED and the telephone next to the victim. The dispatcher simply listens with the rescuer to the voice prompts of the AED, and together they work through the directions.

**The EMS Responder System**

The EMS responder system is usually composed of responders trained in BLS, ACLS, or both.\textsuperscript{19} The system may provide either a single-tier or multi-tier level of response.\textsuperscript{27} Most 1-tier systems use ACLS-trained responders (paramedics), although some provide only BLS. Two-tier systems generally provide first-responder units staffed with emergency medical technicians or firefighters close to the scene,\textsuperscript{19} followed by the second tier of ACLS responders. Two-tier systems in which first responders are trained in early defibrillation are most effective in providing rapid ACLS.\textsuperscript{6,28}

Once dispatched, EMS responders must quickly reach the site of the cardiac arrest, locate the patient, and arrive at the patient’s side with all necessary equipment. The following are important considerations:

1. **EMS travel interval**—The interval it takes an EMS responder to reach the scene is critical for survival of the cardiac arrest victim. Communities have learned to shorten this interval by adding response vehicles, placing response vehicles strategically, and improving traffic paths. Multi-tiered systems appear to have the fastest response intervals because they have more first-responder units. Many communities report an EMS transit interval of approximately 5 minutes for first responders. This interval is too long when the goal is to provide CPR and defibrillation within 4 minutes of an EMS emergency call. Providing rapid EMS response in rural areas with smaller populations remains a challenge.

2. **Locating the patient**—Few studies have actually noted the time interval from arrival of EMS responders at the scene address until their arrival at the patient’s side.\textsuperscript{29} This interval, previously assumed to be negligible, is difficult to document because most systems have no means of recording this time.

3. **Carrying the correct equipment**—The first EMS responders dispatched to treat a patient with cardiac arrest must carry a defibrillator, oxygen, and airway management equipment.\textsuperscript{30} They must also arrive at the patient’s side in <4 to 5 minutes if defibrillation is to be performed within 5 minutes of the call.

**The Second Link: Early CPR**

Bystander CPR is the second link in the Chain of Survival. CPR is most effective when started immediately after the victim’s collapse. Many studies have confirmed the value of early CPR by lay rescuers.\textsuperscript{15,16,31–35} The probability of survival approximately doubles when bystanders initiate CPR before the arrival of EMS personnel.\textsuperscript{15} The contribution of bystander CPR to survival appears particularly significant for infants and children; the best survival from out-of-hospital
collapse has been documented among infants resuscitated by parents, near-drowning victims who receive immediate CPR, and children resuscitated by bystanders.

The 1992 conference recommended the development of community-wide CPR programs in as many locations as possible, including schools, military bases, housing complexes, work sites, and public buildings. Communities need to remove barriers that discourage citizens from learning and performing CPR. Creating community-wide change, however, can be challenging. Several randomized community intervention trials, including one in which a short CPR training video was distributed to various households, failed to show an increased likelihood of either CPR being performed or EMS being called. Targeting relatives of high-risk persons also failed to show an increased likelihood of CPR being performed in an emergency. In contrast, parents of high-risk infants who learn CPR appear to perform it willingly and successfully.

One significant barrier to CPR performance is the complexity of the CPR skills set as commonly taught. Multiple studies have documented poor skills retention by participants in traditional didactic CPR courses. New approaches to teaching CPR, including a simplified curriculum and practice-while-watching and practice-after-watching videos, have been more successful in teaching core skills to participants than traditional courses. Computerized prompt devices or web-based instruction may offer benefit for teaching or reviewing the skills of CPR. Innovative approaches are necessary to focus on participant skill acquisition.

The Third Link: Early Defibrillation

Early defibrillation is the link in the Chain of Survival that is most likely to improve survival. The placement of AEDs in the hands of large numbers of people trained in their use may be the key intervention to increase the chances of survival of patients with out-of-hospital cardiac arrest. AEDs are computerized, low-maintenance, user-friendly defibrillators that analyze the victim’s rhythm to determine whether a shockable rhythm is present. When the AED detects a shockable rhythm, it charges, then prompts the rescuer to press a shock button to deliver a shock. These devices are highly accurate (sensitivity for VF and specificity for non-VF >95% for virtually all AEDs) and can significantly reduce the time to defibrillation (see “Part 4: The Automated External Defibrillator”).

Early Defibrillation

The AHA, ERC, and ILCOR recommend that every emergency vehicle that may transport cardiac arrest patients be equipped with a defibrillator and that emergency personnel be equipped with, trained to use, and permitted to operate this device. To achieve this goal, the International Association of Fire Chiefs has endorsed equipping fire-suppression units with AEDs.

Several options for rapid defibrillation exist. Although AEDs dominate the BLS level of the EMS market, defibrillation also can be performed with manual or semiautomated external defibrillators. Manual defibrillation requires interpretation of a monitor or rhythm strip and is usually performed by responders trained in ACLS. Even so, manual defibrillation by emergency medical technicians trained to recognize VF improves survival.

The widespread effectiveness and demonstrated safety of the AED have made it acceptable for use by nonprofessional responders. Lay responders must still be trained in CPR and use of the defibrillators. PAD programs, in which AEDs are placed in the hands of trained rescuers, have had initial success in police departments, and airplanes. For early defibrillation programs to be successful, defibrillators must be placed in the hands of rescuers who will arrive before traditional EMS personnel. If time to defibrillation is not shortened, survival will not increase.

With limited EMS resources, defibrillators should be given priority over many other medical devices, such as automatic transport ventilators. The cost of defibrillators has steadily declined, making purchase of these devices more attractive.

Participants in the 1992 Guidelines Conference recommended that

- AEDs be widely available for use by persons who have been appropriately trained
- All firefighting personnel who perform CPR and first aid be equipped with and trained to operate AEDs
- AEDs be placed in gathering places of >10 000 people
- In those states in which it is necessary, legislation be enacted to allow all EMS personnel to perform early defibrillation

Participants in the international Guidelines 2000 Conference expressed the opinion that PAD may prove to be the decade’s most effective and successful improvement in ECC (See Public Access Defibrillation in “Part 4: The Automated External Defibrillator”). PAD programs should include the following:

1. Preparation and planning
2. Establishment of pre-event training and program
3. Post–clinical event monitoring of quality improvement and critical incident stress debriefing

The Fourth Link: Early ACLS

Early ACLS provided by paramedics at the scene is another critical link in the management of cardiac arrest. EMS systems should have sufficient staff to provide a minimum of 2 responders trained in ACLS. Because of the difficulties in treating cardiac arrest in the field, additional responders should be present. In systems with survival rates of >20% for patients with VF, response teams have at a minimum 2 ACLS providers plus 2 BLS personnel at the scene. Most experts agree that 4 responders (2 trained in ACLS and 2 trained in BLS) provide the most effective team in resuscitation of cardiac arrest victims. Although not every EMS system can attain this level of response, every system should actively pursue this goal.

Research Challenges for the Future

The best way to evaluate the Chain of Survival in a community is to assess survival to hospital discharge and
identify delays in activation of the chain. The best way to improve the Chain of Survival is to develop high levels of evidence needed to refine resuscitation guidelines. To meet these goals, clinical research is essential. This research should use common definitions and terminology to allow comparisons and sharing of information across regions and internationally. The Utstein templates (Figures 2 through 4) should be used.3,64,65

The best way to evaluate the strength of the community Chain of Survival is to assess the survival rates achieved by the ECC system. The cost of data collection for a system may be significant, but only through evaluation can systems routinely improve their services. Thus, conference participants strongly endorsed the position that all ECC systems should assess their performance through ongoing evaluation. For evaluation data to be meaningful, it is necessary to compare EMS systems. This in turn requires standardized definitions and terms of reference. Until recently, uniform terminology was not available, producing a cardiac arrest Tower of Babel.5 Survival rates reported in the literature range from 2% to 44%. It is not yet understood whether these profound variations are due to differences in population, treatment protocol, system organization, rescuer skills, or reporting practices.

There is now international consensus on the importance of using standard terminology and methods to evaluate survival and the Chain of Survival. Considerable effort has been directed to create clear, unambiguous terminology, establish a uniform method of reporting outcome data, and improve methods of research in cardiac arrest.2,3,64 Improving the ECC system, however, first requires an accurate measurement of the survival rate for each community. This can be achieved by implementing the following recommendations:

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*VF and VT should be reported separately through template*
In-hospital patients with a pulse
(includes outpatients and ED; excludes patients
admitted for out-of-hospital arrests, who should be
reported separately; actual numbers not required)

Cardiac arrest,
no resuscitation attempted
• Patients designated DNAR, N=____
• Patients not designated DNAR, N=____
• Found dead, N=____
• Considered futile, N=____

Attempted in-hospital
resuscitations
Total, N=____
• Defibrillation only, N=____
• Chest compressions only, N=____
• Airway interventions only, N=____
• Combination interventions, N=____

False arrests
(BLS or ALS actions not needed)
N=____

Denominator Note
Outcome boxes 7-13 can be completed for any
subset of “attempted in-hospital resuscitations”
(box 3), including box 5. For comparison
purposes, however, only outcomes for patients
with initial rhythm VF/VT are recommended.

Non-VF/VT
• PEA, N=____
• Asystole, N=____

Initial rhythm VF/VT
N=____
(see “Denominator Note”)

Never achieved ROSC
N=____

Any ROSC
N=____

Died in hospital
Classify as
• ROSC ≤20 min, N=____
• ROSC >20 min but ≤24 hours, N=____
• ROSC >24 hours*, N=____
• Reattempts/rearrests, N/N=____
Identify patients who had
• DNAR status declared, N=____
• Support withdrawn, N=____
• Brain death established, N=____
• Organ donor status declared, N=____

Discharged alive
N=____
• Alive at 6 months*, N=____

(for 9, 10, 11, 12)

*Functional outcomes
Measure best outcomes at
• Time of discharge
• 6 months
• 1 year

Died within 1 year of
discharge*
N=____

Alive at 1 year*
N=____

Figure 3. Template for reporting results of in-hospital resuscitation. Reproduced with permission from Reference 2.
Figure 4. Template for reporting results of pediatric resuscitation. Reproduced with permission from Reference 3.
TABLE 4. Recommended Clinical Data to Collect*67

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location and time of cardiac arrest</td>
<td>One of the most important pieces of information is the location and time of the cardiac arrest. This includes the exact location (street address, hospital, etc.) and the time it occurred.</td>
</tr>
<tr>
<td>Any precipitating event/obvious noncardiac cause</td>
<td>It is important to document any events or conditions that may have contributed to the cardiac arrest.</td>
</tr>
<tr>
<td>Time of receipt of call for help</td>
<td>The time the emergency call was received is crucial for time calculation.</td>
</tr>
<tr>
<td>Time of dispatch of emergency vehicle</td>
<td>The time the emergency vehicle left the station is important for time calculation.</td>
</tr>
<tr>
<td>Time first-response vehicle stops at scene</td>
<td>The time the emergency vehicle arrives at the scene is important for time calculation.</td>
</tr>
<tr>
<td>Confirmed cardiac arrest, witnessed or unwitnessed</td>
<td>It is important to know if the arrest was witnessed or not, as this can affect the response time.</td>
</tr>
<tr>
<td>Bystander CPR performed and time initiated</td>
<td>The timing of bystander CPR is important for assessment.</td>
</tr>
<tr>
<td>Arrest after arrival of emergency response personnel</td>
<td>The time of arrest after emergency personnel arrival is crucial for survival rates.</td>
</tr>
<tr>
<td>Time of first CPR efforts</td>
<td>The time the first CPR efforts were initiated is important for survival rates.</td>
</tr>
<tr>
<td>Initial ECG rhythm</td>
<td>The rhythm at the beginning of CPR efforts is important for treatment.</td>
</tr>
<tr>
<td>Treatment provided and corresponding times</td>
<td>It is important to record the treatments given and the times they were provided.</td>
</tr>
<tr>
<td>Time of first defibrillation</td>
<td>The timing of defibrillation is crucial for survival rates.</td>
</tr>
<tr>
<td>Return of spontaneous circulation and time</td>
<td>The time return of spontaneous circulation (ROSC) occurs is a critical factor.</td>
</tr>
<tr>
<td>Final patient status at scene</td>
<td>The patient’s condition at the scene is important for further treatment.</td>
</tr>
<tr>
<td>Patient status on arrival in Emergency Department</td>
<td>The patient’s status upon arrival is crucial for survival rates.</td>
</tr>
<tr>
<td>Status after Emergency Department treatment</td>
<td>The status post-treatment is important for outcome assessment.</td>
</tr>
<tr>
<td>Status at hospital admission</td>
<td>The status at hospital admission is important for further survival.</td>
</tr>
<tr>
<td>Status at hospital discharge</td>
<td>The status at hospital discharge is important for final outcome.</td>
</tr>
<tr>
<td>Time of death</td>
<td>The exact time of death is important for final analysis.</td>
</tr>
<tr>
<td>Discharged alive</td>
<td>The status of discharge indicates the patient’s survival.</td>
</tr>
<tr>
<td>Alive at 1 year (if possible)</td>
<td>The status at 1 year provides long-term survival data.</td>
</tr>
<tr>
<td>Neurological assessment (if possible)</td>
<td>Neurological assessment is important for rehabilitation potential.</td>
</tr>
</tbody>
</table>

*Describe the method by which each data point is obtained (estimated or measured).

1. Develop an evaluation process for the ECC system.
2. Include an accurate assessment of survival rate by using standardized terminology and reporting methods. This focus on quality improvement should identify practical goals, given the structure and demographic characteristics of the local system; identify current performance, including survival rate; identify gaps between goals and current performance; identify strategies to improve system performance; and evaluate whether performance improves with these modifications.
3. Design the evaluation specifically to benefit the local community. As a secondary interest, information should be shared regionally and nationally to help other communities develop optimal systems.
4. In assessing survival, integrate evolving concepts of consensus terminology, data collection, system description, and CPR research methods into EMS systems.

Consensus Terminology

The terms and definitions listed in Table 1, referred to as the Utstein style,2,3,64 were developed by a joint task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, the Resuscitation Council of Southern Africa, the Australian Resuscitation Council, and the New Zealand Resuscitation Council. These terms are intended as a starting point for achieving uniform terminology. Collectively they represent a major improvement over past practice. The emphasis has been to develop terms that will have universal applicability and replace the imprecise terms previously used in the cardiac arrest literature. The terms and definitions in Table 1 should be used whenever possible to reduce confusion in reporting cardiac arrest data.

Data Collection

Hundreds of potentially important events start and then stop during the course of a cardiac arrest. Events do not always occur in the same order, nor will all patients experience all events. Despite the complexity of cardiac arrest data, certain minimal data must be gathered (Table 4).

Population Served

It is important to report accurately the size of the population served by the EMS system so that the incidence of cardiac arrest within a community can be calculated (incidence equals number of cardiac arrests per population served per unit of time). Incidence of cardiac arrest may reflect the overall health of a community, which may in turn affect the survival rate. Reporting gender, education, socioeconomic factors, and age allows collection of important epidemiological data and identification of high-risk groups. The level of CPR training in the community also should be reported.

Confirmed Cardiac Arrests Considered for Resuscitation, Resuscitations Attempted, and Resuscitations Not Attempted

The number of unresponsive, pulseless, and breathless persons for whom emergency response personnel are called should be documented. This is the maximum number of cardiac arrest patients to use for analysis. Some patients will be excluded in subsequent analyses (e.g., those with traumatic arrests, those “dead on arrival,” or those in whom resuscitation was not attempted). After these exclusions the total number of cardiac arrests should be categorized as “resuscitation attempted” and “resuscitation not attempted,” and the criteria or rationale for nonattempted resuscitations should be reported.

Arrest After Arrival of Emergency Personnel

Approximately 10% of cardiac arrest patients collapse after the arrival of emergency personnel.7,66,67 During data analysis these cases should be considered separately from unwitnessed and bystander-witnessed arrests, for 2 reasons. First, the presence or absence of bystander CPR and the call-to-arrival interval do not apply to these patients. Inclusion of arrests witnessed by paramedics with other cases would distort tabulation of the percentage of bystander CPR and measurements of the call-to-arrival interval. Second, patients in this category provide important clinical information that deserves separate analysis.

Stopping CPR Efforts in the Field

Many studies have shown the futility of transporting patients to the Accident and Emergency Department if return of spontaneous circulation is not achieved with adequate ACLS in the field.64–70 Some EMS systems routinely terminate unsuccessful CPR efforts in the field, whereas others trans-
port every patient in whom resuscitation is attempted. No one disputes that the survival rate among these patients is dismal low, at <1%. A dilemma remains over how to determine which patients may benefit from additional care. Reported data should include the number of patients for whom efforts were discontinued at the scene and in the Emergency Department and specific criteria for termination of efforts.

**Cardiac Rhythms**

Analysis of cardiac rhythms is complicated because of the many different abnormal ECG patterns and because most patients experience changing rhythms during a cardiac arrest. The distinction between asystole and fine VF should be made for all patients. Deflections on the surface ECG of <1 mm (calibrated at 10 mm/mV) are defined as asystole, whereas ≥1 mm is VF. “Pulseless electrical activity” is a term that includes electromechanical dissociation, pseudo-electromechanical dissociation, idioventricular rhythms, pulseless ventricular escape rhythms, postdefibrillation idioventricular rhythms, and bradyasystolic rhythms. For purposes of uniform reporting, all pulseless rhythms with electrical activity should be included as “other rhythms.” For all cases of cardiac arrest, emergency personnel should report the initial rhythm noted. When a patient arrests after emergency responders arrive, personnel should report the initial rhythm immediately. They should also classify ECG rhythms into 1 term that includes electromechanical dissociation, pseudo-electromechanical dissociation, idioventricular rhythms, pulseless ventricular escape rhythms, postdefibrillation idioventricular rhythms, and bradyasystolic rhythms. For purposes of uniform reporting, all pulseless rhythms with electrical activity should be included as “other rhythms.”

**Outcomes**

In a review of 36 communities, 11 different working definitions of survivor were reported. Four outcomes that provide the most useful information are (1) return of spontaneous circulation, (2) successful hospital admission, (3) successful hospital discharge, and (4) long-term survival with some assessment of neurological function. This data should be reported.

**Time Points and Intervals**

A great deal of confusion has resulted from the use of imprecise terms for the timing of cardiac arrest events. For example, response time, downtime, and time to definitive care have all had a variety of meanings. For clarity, the times at which an event starts and stops should be referred to as *time points*. The interval from *time point A* to *time point B* should be referred to as the *A-to-B interval*.

Lack of accuracy in documenting time is still a problem. Most communities depend on EMS personnel to accurately document the timing of cardiac arrest events. In reality these times are usually estimated by EMS personnel after the patient has arrived in the Emergency Department. This method is inaccurate. Newer defibrillator/monitors with audio event recorders, notebook computers, bar code readers, and other technologies are available to allow EMS responders to document each event. If these devices can be synchronized with emergency response system clocks, they will help provide answers to the many questions posed by researchers and ECC systems in future analyses. The ideal documentation system should be hands-free and should automatically record the time a device is turned on or used. Conference participants recommended the following:

- Recording the best available time points for patient collapse, initiation of CPR, receipt of emergency response system call, rescue vehicle dispatch, rescue vehicle arrival, first CPR by emergency response personnel, first defibrillatory shock, return of spontaneous circulation, and abandonment of CPR (death)
- Describing how time data was documented
- Developing mechanisms to synchronize all emergency response system clocks (those of EMS dispatch centers, dispatchers, and responders)
- Striving to make data collection hands-free and automated

**In-Hospital Data**

The outcome of patients with in-hospital cardiac arrest has not been analyzed extensively. Researchers have noted a number of methodological problems in studying the in-hospital arrest population. The analysis is confounded with comorbid variables, such as terminal diseases and serious underlying illnesses. It has been thought that this would lead to a disproportionate number of deaths. The claim has been that out-of-hospital cardiac arrests represent a more homogeneous population and cannot be compared with in-hospital cardiac arrests.

The facts do not support these concerns, however. Not all in-hospital cardiac arrest patients die, and many out-of-hospital patients also have a terminal disease or underlying illness. In 7 recent in-hospital studies the aggregate survival rate was 11% (of 1804 arrests, 199 hospital discharges), a rate better than the rates achieved in some out-of-hospital studies. Although there may be important differences in the pathophysiological bases of some in-hospital cardiac arrests (a higher percentage of pulmonary embolism, hyperkalemia, etc), the outcomes of in-hospital cardiac arrests appear to be similar to out-of-hospital arrests (see Figure 3).

There are advantages to studying in-hospital patients. Documentation is improved, and arrest-to-defibrillation intervals are shorter. Research protocols and data collection techniques requiring advanced or invasive monitoring are more feasible and can be rapidly implemented in the hospital. Most hospitals have resuscitation teams that respond to all arrests. This consistency in response increases consistency in treatment protocols and documentation. The patient’s medical history and condition leading to the arrest are often documented in medical records. Patients with no-CPR status are clearly identified, eliminating prehospital situations in which emergency personnel are called to attend to a patient who should not receive resuscitative efforts. The complete cardiac arrest history is in the hospital medical record, eliminating the need to merge multiple data sources. A single clock (the hospital clock) runs during the arrest reducing the likelihood of lack of synchronization between time points. In addition, autopsies are performed after many unsuccessful resuscitations. These may provide important additional data. Participants in the national conference recommended encouraging...
research on in-hospital cardiac arrests and applying the prehospital Chain of Survival model to in-hospital cardiac arrest, including activities such as in-hospital early defibrillation programs using AEDs.

A Systematic Approach to Resuscitation Data Collection: The Utstein Template for Out-of-Hospital Cardiac Arrest
The original Utstein template (Figure 2) provides cardiac arrest researchers with a uniform format for data reporting. This is important because of confusion and inconsistencies in survival rate statistics in the past. Some researchers have reported analysis of only favorable subgroups (ie, patients with witnessed VF). Others have excluded from analysis patients pronounced dead at the scene. This variability in reporting practices has produced different denominators for the survival rate and made comparisons impossible. The template approach should facilitate comparisons between communities and reduce confusion about calculation of survival rates. The template provides a uniform method of calculating an overall survival rate and defines a subgroup stratification that can be used for further analysis.

Emergency Medical Dispatch, Emergency Medical Systems, and the Accident and Emergency Department
The 1985 national conference made recommendations for both prehospital and in-hospital ECC units. These guidelines, however, have been implemented in a variety of ways. There are major differences among EMS systems in how they fulfill their responsibilities with dispatching, staffing, training level, equipment, skills (such as defibrillation, tracheal intubation, venous access), communication technologies, administration, and ratio of rescue personnel to population.72 Of even more importance are the variations in how the EMS components coordinate and fit together.

With such wide variation in EMS systems, it is difficult to make comparisons. Investigators have not agreed on the optimal EMS system configuration, but research data has now identified those features common to consistently successful out-of-hospital ECC systems. Analysis of some systems with high survival rates for out-of-hospital cardiac arrest reveals these common effective practices:

- Two-tiered EMS systems have improved survival rates over 1-tiered systems.
- Any system in which the first-responding personnel can use AEDs has better outcomes than systems that do not have first-responder defibrillation.
- Multi-tiered systems using deployment rules based on concepts of priority dispatching are effective.
- Cross-training of personnel in dual-service systems (fire and emergency medical) allows aggressive use of fire department personnel and equipment for emergency medical responses.
- EMS systems with active medical control and supervision (medical supervisors at the scene, in the field) have better outcomes than those with passive medical control (retrospective chart reviews).
- The system has actively involved citizenry, defined as having

- High incidence of citizens trained in CPR
- Training in lay responder defibrillation
- Emergency phone calls made and completed as soon as possible after the witnessed emergency
- On arrival, EMS personnel observe lay responders attempting acceptable CPR on a high percentage of all witnessed arrests

These preliminary findings need confirmation by assorted communities. These communities should possess enough variability and population to identify critical factors leading to the high survival rates. Each part of the system—dispatch and first-, second-, and third-tier responders—must be clearly defined so that we can learn the strengths and weaknesses of different structures.

Analysis will be facilitated by describing the EMS dispatch system in terms of type of communication (eg, 911, enhanced 911, or computer-aided dispatch) and method of dispatch, describing each EMS responder, specifying the number of tiers and the role each tier plays during a cardiac arrest, and listing the major interventions in cardiac arrest treatment and obstacles or delays encountered.

Performing the Outcome Assessment: The Chain of Providers
The Chain of Survival model suggests an important dynamic to consider when performing an evaluation of an EMS system. It implies a chain of providers to treat victims of cardiac arrest. This chain of providers should perform the system evaluation. The long-term goal is not merely to collect data but to improve the ECC system. All members of the chain of providers must be represented in the outcome assessment team because the assessment will naturally evolve into the improvement process.

The outcome assessment team may benefit from having representatives of various health departments, EMS systems, police departments, hospitals, universities, industry, and organizations active in BLS and ACLS training. Often a nonpartisan organization such as a resuscitation council or association can facilitate the genesis of this diverse team and serve as an umbrella over the work to be done. A representative team should assess the Chain of Survival, including all interested providers in the process, and identify (1) current performance, (2) community-specific goals, (3) gaps between current performance and goals, (4) ways to improve the ECC system, and (5) whether performance improves after modifications. This process should be a long-term, ongoing effort in every community.

Design of Cardiac Arrest Studies
In the development of a Chain of Survival assessment, the process of working together may be as important as scientific results. For example, EMS personnel may feel threatened by the review process. ACLS-level providers may question why administrators wish to collect information on how long it takes to defibrillate, or dispatchers may feel that they are being singled out for scrutiny. Hospitals provide much of the outcome data, but they also are reluctant to undergo outside scrutiny. In reality local politics cannot be separated from the
assessment. Most concerns can be addressed, however, and the effort can move forward if the team represents all providers. Each community must develop its own assessment process to evaluate its Chain of Survival.

The National Registry of Cardiopulmonary Resuscitation

The National Registry of Cardiopulmonary Resuscitation (NRCPR) is a national database for collection of information on in-hospital resuscitation interventions. Sponsored by the American Heart Association, the NRCPR, using modified Utstein templates, gathers the information collected by subscribers. Each participating hospital receives quarterly reports comparing its outcome data with that of an appropriate peer group. This information will undoubtedly be of great value for quality-assurance monitoring within participating medical centers. In addition, the registry will yield valuable information about large groups of inpatients, with analysis within subgroups.73

For information about subscribing to the NRCPR, contact www.info@nrsrcpr.org.

Summary

Cardiac arrest treatment continues to evolve. Adequate treatment of the individual patient requires that the whole ECC system function smoothly, consistently, and rapidly. To maximize community-wide survival rates, a careful evaluation of the entire Chain of Survival is necessary, using standard measurements of performance. The challenge for the next decade is to establish this infrastructure and conduct multicenter, prospective, controlled clinical trials to better define the key factors that will improve survival from cardiac arrest in every community.

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