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Sudden cardiac arrest – How can we improve results of resuscitation?

Hein J. Wellens

Cardiovascular Research Institute Maastricht, The Netherlands

Abstract

Death from heart disease has continued to diminish during the last two decades, but still half of those deaths are sudden, often occurring unexpectedly outside hospital, claiming at least 250.000 lives in Europe each year. What can we do to prevent this from happening and how can we successfully resuscitate the victim?
When an arrhythmic sudden death occurs outside the hospital, the only chance for survival is recognition of the situation by a witness, the start of cardiac massage and a call to bring a defibrillator and experienced people to the scene as soon as possible. Increasing the number of people trained in resuscitation, and the density of the automatic external defibrillator in the community are important factors to increase the success rate of the resuscitation attempt. However, a real breakthrough requires the development of a device that recognizes cardiac arrest, sounds an alarm, and transmits the location of the victim, thereby shortening the time interval of the different steps in the chain of survival.

Key words: cardiac arrest, resuscitation, sudden death

Although in the western world death from cardiac disease has been diminishing during the last two decades, still one-fifth of all deaths occur suddenly and unexpectedly (1), ventricular fibrillation being a frequent mechanism.

We know that if we are able to restore normal sinus rhythm in that situation by a defibrillation shock many of the victims of cardiac arrest will have many more years of satisfactory living.

The challenge therefore is two fold: “Can we do a better job in the identification of the victim before the event, and can we improve results of the resuscitation attempt?”

Identification of the candidate for sudden cardiac arrest

This is not difficult in case of a previous life-threatening arrhythmia or successful resuscitation from sudden cardiac arrest (SCA). In such patients death from a new arrhythmic episode can be prevented by implanting a defibrillator.

To have an idea of the risk of dying suddenly from cardiac arrest without such a history we can divide the population into four groups: 1) People without a history of cardiac disease, 2) A history of cardiac disease with slight to moderate cardiac dysfunction, 3) A history of cardiac disease and severe cardiac dysfunction, and, 4) Those having a monogenic cause for a life-threatening cardiac ar-

Table 1: Recognition of high risk for SCD

	% SC deaths	Predictability
No history of cardiac disease	45%	poor
Low-medium risk post MI	40%	limited
High risk heart disease (LVEF < 35%)	13%	possible
Monogenic arrhythmic disease	2%	limited

rhythmia. Table 1 shows how these 4 groups contribute to the number of people dying suddenly. The table also gives our ability in the 4 groups to predict the chance of dying suddenly based upon our current methods of risk stratification.

People not known with heart disease contribute almost half of the sudden cardiac arrest victims (2). Attempts to identify risk before the event led to risk scores such as the Framingham one, which includes age, gender, smoking, blood pressure, total and HDL-cholesterol, body mass index, and diabetes (3). The Framingham risk score was followed by other models to predict cardiovascular disease in the general population such as SCORE, PROCAM, and the Reynolds risk score. More recently many biomarkers have been added to these risk scores. Those different biomarkers reflect inflammation, endothelial function, fibrin formation, oxidative stress, renal function, matrix metalloproteinases, ventricular function, metabolomics, proteomics and genetic information. These biomarkers alone or in combinations with conventional risk factors result in only a slight increase to predict future cardiovascular events as compared to the conventional risk factors included in the Framingham risk score (4,5). At this point in time their predictive accuracy is too low to advice specific measures other than a healthy life style and treatment of comorbidities.

The second group are patients who have suffered from a myocardial infarction in the past with residual slight to moderate cardiac dysfunction.

Obviously they deserve identification and correction of additional cardiac ischemia and the administration of the currently advised pharmacological regimen of beta-blockade, statins and ACE or ARB's, in combination with a healthy life style.

As shown in tables 2 and 3 many different tests alone or in combination have been suggested for SCA risk stratification in these patients. Again, the positive predictive accuracy of those tests is too low to apply other measures than the ones mentioned above.

Patients from group 3, characterized by poor left ventricular function, with or without serious ventricular arrhythmias can profit from a defibrillator implant as indicated by studies such as MADIT-I, MUSTT, MADIT-2, and SCD-HeFT (6-9). However, we do know that we are not very good in properly selecting those needing a defibrillator for survival.

About 2% of the victims dying suddenly (group 4) have a monogenic disease, either primary electric, usually a cardiac channel disorder, such as long or short QT, or a structural abnormality like hypertrophic cardiomyopathy or arrhythmogenic right ventricular dysplasia. Ability to identify them before the event is hampered by the absence or variable expression of a diagnostic phenotype, inability to find the responsible mutation in a number of cases and the problem that the link between genotype and phenotype is subject to broad variability with limited predictability.

Unfortunately, when we look at table 1 we have to conclude that only in a minority of victims we can accurately identify the sudden cardiac arrest candidate before the event with sufficiently high positive predictive accuracy.

Residual ischemia

- Exercise testing (ECG + nuclear)
- Holter
- Stress echo
- Coronary angio

Pump function

- ECG
  - sinus rate
  - atrial dilatation
  - scar (size and location)
  - QRS width
  - LV hypertrophy
  - QRS/T angle
- NYHA class
- LVEF

Neurohumoral

- Heart rate in rest
- Heart rate variability
- Baroreflex sensitivity
- Heart rate turbulence
- Deceleration
  - capacity
  - runs
- MIBG

Psychosocial factors

Genetic background

No information about significance of age of the patient and time interval after an acute event!

Table 2: Tests currently used for risk stratification for sudden death after myocardial infarction (part 1)

Electrical instability

- 12 lead ECG
  - scar size
  - LV hypertrophy
  - QRS width
  - QT interval
    - duration
    - disparity
    - T wave alternans
    - dynamicity
  - Non sust. VT
- Holter
- Signal averaged ECG
- Arrhythmia substrate (MRI)
- EPS
- Biochemical parameters
- Lipid profile
- CRP
- BNP
- Diabetes

No information about significance of age of the patient and time interval after an acute event!

Table 3: Tests currently used for risk stratification for sudden death after myocardial infarction (part 2)

How to improve results of the resuscitation attempt

Only 10 % of people dying suddenly have suffered from serious cardiac damage before the event. That means that 90 % of the victims have no or minimal to moderate cardiac damage before the event and a successful resuscitation followed by correction of the offending abnormality opens the door for many years of satisfactory living. That knowledge has been the basis for continuing efforts (unfortunately without much success!) to educate the public on seeking immediate help when symptoms suggestive of acute myocardial ischemia occur, and also how to perform correctly and rapidly the different steps required for survival in case of cardiac arrest. Unfortunately, in spite of all these efforts it remains exceptional to save more than 5% of cardiac arrest victims (10).

The weak links in the chain of survival and how to correct them

In order to survive sudden cardiac arrest several conditions have to be fulfilled like the presence of a witness, rapid recognition of the cause of syncope of the victim, a bystander trained in cardiac massage, immediate transmission of the location of the victim with rapid arrival of advanced life support (ALS), with a defibrillator. Ideally, the time interval between cardiac collapse by ventricular fibrillation and defibrillation should not exceed 5 to 6 minutes. The first step is to make the time interval between collapse and call for ALS as short as possible. This requires a bystander who quickly overcomes the paralysis that occurs when one witnesses cardiac arrest. Even with a bystander trained in CPR, it easily takes at least one minute to confirm circulatory arrest and to start cardiac massage and at least one more minute to call emergency medical services. Before they leave an average of 2-3 minutes will pass and than it will take several minutes before they reach the victim.

The dispatch time can be shortened by having a special telephone number other than 911 in the United States and 112 in Europe that is exclusively used for a cardiac emergency (11). The time interval between collapse and defibrillation can also be shortened by having a sufficient number of automated external defibrillators (AED's) and a dense network of "cardiac arrest watchers" in the community who can be alarmed, for example by SMS, when cardiac arrest occurs.

Placing the AED in public settings and training laymen in their correct use has resulted in improved outcome of cardiac resuscitation (12,13) However, the challenge to shorten the time interval between collapse and start of resuscitation is especially difficult when circulatory arrest takes place at home which happens in 80 % of cases with frequently no witness present (2). Not surprising therefore having an AED at home did not result in an appreciable improvement of the resuscitation attempt (14).

What could be of great help?

An important breakthrough to improve the results of cardiac resuscitation could come from developing a device specifically geared toward diminishing the time interval between collapse and the start of the resuscitation effort and notification of advanced life support of the location of the victim. This device should continuously register vital signs (like cardiac rhythm, arterial pulsations or heart sounds) allowing prompt recognition of circulatory arrest. This should be followed by an audible alarm to attract bystanders and immediate transmission of the location of the victim to the nearest site of an AED in the community and to the emergency medical services (15).

As shown in fig 1 such an approach would result in a marked reduction in time required for diagnosis and dispatch. Also, wearing the device would indicate that the person wants to be resuscitated, a question one cannot answer in case of anonymous victim.

In order to be informed about the time intervals between collapse and subsequent steps in the chain of survival the device should also have a clock to help in decision making as to the best treatment in the individual patient (16). As indicated in table 4 it will be a real challenge to develop a reliable device able to continuously register artifact-free vital signs. This probably requires intracutaneous or subcutaneous sensors (17), although, recently Rickard et al (18) published a watch-based pulse detection system to diagnose pulselessness at the time of cardiac arrest.

Our current inability to identify most cardiac arrest victims before the event calls for a better strategy to improve results of the resuscitation attempt. The availability of devices as described above could markedly shorten the time intervals of the different steps in the

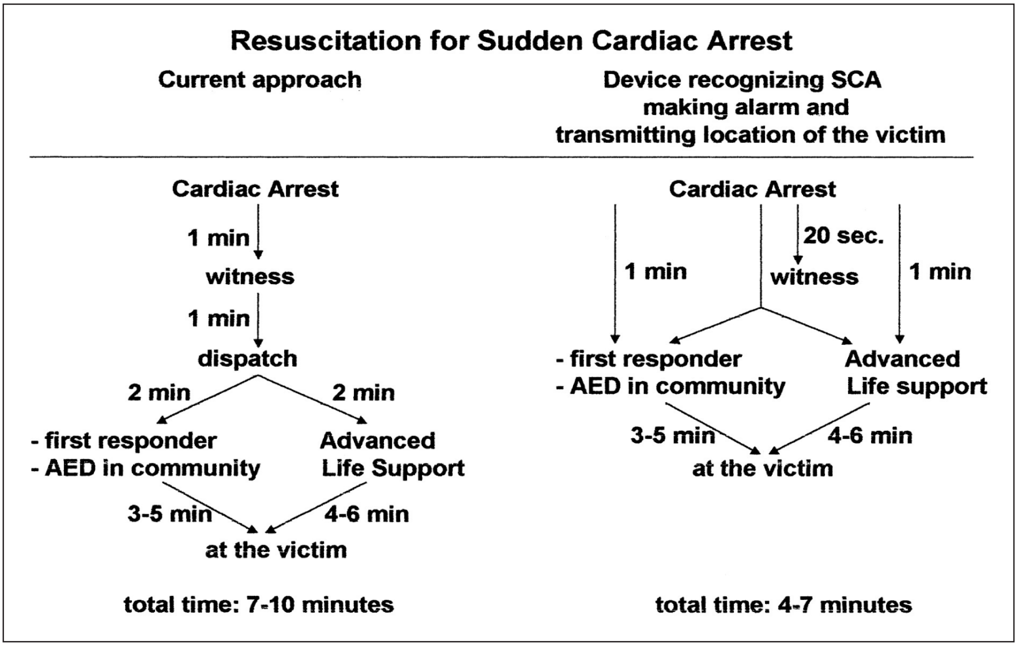

Figure 1: Time intervals during our current approach to resuscitation compared to those when a monitoring device is available that recognizes sudden cardiac arrest (SCA), sounds an alarm, and transmits the location of the victim to the first responder, the nearest AED in the community and advanced life support.

Table 4: Technical challenges in the development of a cardiac arrest device

1, Continuous monitoring of cardiac activity.
2. Selection of the best sensors (ECG?, Pulsations?).
3. Artifact free recording (Cutaneous?, Subcutaneous?).
4. Wireless transmission of the signals.
5. Reliable circulatory arrest detection.
6. Miniaturization.
7. Low power consumption.
8. Exact localization of the victim.
9. Clock to register time interval between arrest to start of resuscitation and to defibrillation.

chain of survival and could also allow more phase-specific therapies according to the time elapsed after cardiac arrest. Such an approach could bring the overall success rate of a resuscitation attempt from 5% to 30% or more, meaning thousands of additional lives saved!

Conclusion

Our current inability to identify risk for dying suddenly before the event in most of the victims requires new developments to shorten the time interval between circulatory arrest and the start of the resuscitation attempt including more rapid availability of appropriately trained rescuers and material at the scene. As indicated an important step to reach that goal is the availability of a wearable personal warning system.

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Correspondence address:
Hein J. Wellens, M.D.
Cardiovascular Research Institute Maastricht
21 Henric van Veldekeplein
6211 TG Maastricht
The Netherlands
hwellens@xs4all.nl