Prognosis and outcomes following sudden cardiac arrest in adults

AUTHOR: Philip J Podrid, MD, FACC
SECTION EDITORS: Brian Olshansky, MD, Scott Manaker, MD, PhD
DEPUTY EDITOR: Todd F Dardas, MD, MS

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Literature review current through: **Jan 2024.**
This topic last updated: **Sep 18, 2023.**

INTRODUCTION

Sudden cardiac arrest (SCA) and sudden cardiac death (SCD) refer to the sudden cessation of cardiac mechanical activity with hemodynamic collapse, often due to sustained ventricular tachycardia/ventricular fibrillation. These events mostly occur in patients with evidence for ischemia due to coronary artery disease, disease of the myocardium (due to hypertrophy, fibrosis, scar replacement, or other myocardial abnormality that may or may not have been previously diagnosed), valvular abnormalities, or congenital heart disease or congenital or genetic electrical abnormalities or channelopathies. (See "Pathophysiology and etiology of sudden cardiac arrest".)

The event is referred to as SCA (or aborted SCD) if an intervention (eg, defibrillation) or spontaneous reversion of the heart rhythm restores circulation. The event is called SCD if the patient dies. However, the use of SCD to describe both fatal and nonfatal cardiac arrest persists by convention. (See "Overview of sudden cardiac arrest and sudden cardiac death", section on 'Definitions'.)

The prognosis of patients who have SCA will be reviewed here. The issues related to acute therapy for SCA, including guidelines for advanced cardiovascular life support (ACLS), and issues related to prevention of recurrent sudden cardiac death, are discussed separately. (See "Supportive data for advanced cardiac life support in adults with sudden cardiac arrest" and

"Advanced cardiac life support (ACLS) in adults" and "Pharmacologic therapy in survivors of sudden cardiac arrest".)

PROGNOSIS FOLLOWING SUDDEN CARDIAC ARREST

Despite advances in the treatment of heart disease, the outcome of patients experiencing SCA remains poor [1-5]. As examples:

- A report analyzed outcomes for over 12,000 patients treated by emergency medical services (EMS) personnel in Seattle over 24 years [1]. Survival to hospital discharge for those treated between 1998 and 2001 was not significantly better than for those treated between 1977 and 1981 (15.7 versus 17.5 percent). In contrast, the long-term outcome among patients who survive until hospital discharge following SCA appears to be improving [2].

- Among a nationwide cohort of 547,153 patients in Japan with out-of-hospital SCA between 2005 and 2009, survival to hospital discharge with favorable neurologic status improved approximately twofold in several groups over the five-year period (from 1.6 to 2.8 percent among all patients with out-of-hospital SCA, from 2.1 to 4.3 percent among bystander-witnessed SCA, and from 9.8 to 20.6 percent among bystander-witnessed SCA with ventricular fibrillation as the initial rhythm) [3]. However, in spite of this doubling of neurologically favorable survival, overall survival following SCA remains poor.

- Among 70,027 United States patients prospectively enrolled in the CARES registry following out-of-hospital SCA between 2005 and 2012, survival to hospital discharge improved significantly from 5.7 percent in 2005 to 8.3 percent in 2012 [4]. Improvements were also noted in pre-hospital survival and neurologic function at hospital discharge.

- In a Canadian study of 34,291 patients who arrived at the hospital alive following out-of-hospital cardiac arrest between 2002 and 2011, survival at both 30-day and one-year increased significantly between 2002 and 2011 (from 7.7 to 11.8 percent for one-year survival) [5]. Similarly, among a cohort of 6999 Australian patients with out-of-hospital SCA resuscitated by EMS between 2010 and 2012, 851 patients (12.2 percent) survived for at least one year, with more than half of patients reporting good neurologic recovery and functional status at one year [6].

The reasons for the continued poor survival of patients with SCA are not certain [1]. Although some aspects of acute resuscitation have improved over time (increased bystander cardiopulmonary resuscitation [CPR] and shortened time to defibrillation), these positive trends have been off-set by adverse trends in clinical features of patients presenting with SCA (such as increasing age and decreasing proportion presenting with ventricular fibrillation) [1,7]. In addition, the response times of both basic life support (BLS) and advanced life support (ALS) services have increased, possibly as a result of population growth and urbanization [8].

Marked regional differences in the incidence and outcome of SCA have been observed. In a prospective observational study of 10 North American regions, the adjusted incidence of EMS-treated out-of-hospital SCA ranged from 40.3 to 86.7 (median 52.1) per 100,000 census population; known survival to discharge ranged from 3.0 to 16.3 percent (median 8.4 percent) [9]. The adjusted incidence of ventricular fibrillation ranged from 9.3 to 19.0 (median 12.6) per 100,000 census population; known survival to discharge ranged from 7.7 to 39.9 (median 22) percent. These regional differences highlight the importance of local health care and EMS systems to SCA outcomes. A pilot study comparing the feasibility of EMS transport to a regional cardiac arrest center (with increased transit time) versus transport to the closest hospital suggested no difference in 30-day mortality or major adverse cardiac events, results which should be considered hypothesis-generating for larger scale studies [10].

Neurologic prognosis following sudden cardiac arrest — Survivors of SCA have variable susceptibility to hypoxic-ischemic brain injury, depending on the duration of circulatory arrest, extent of resuscitation efforts, and underlying comorbidities. The prognosis following hypoxic-ischemic brain injury is discussed in detail separately. (See "Hypoxic-ischemic brain injury in adults: Evaluation and prognosis".)

OUTCOME ACCORDING TO ETIOLOGY

There is an association between the mechanism of SCA and the outcome of initial resuscitation.

Asystole — When the initial observed rhythm is asystole (even if preceded by ventricular tachycardia or ventricular fibrillation), the likelihood of successful resuscitation is low. The longer ventricular fibrillation is present, the finer are the fibrillatory waves, and ultimately asystole occurs. The duration of ventricular fibrillation impacts the success of defibrillation (see below). Only 10 percent of patients with out-of-hospital arrests and initial asystole survive until hospital admission [11,12] and less than 5 percent survive until hospital discharge with good neurologic function [12-14]. The poor outcome in patients with asystole or bradycardia due to a very slow idioventricular rhythm probably reflects the prolonged duration of the cardiac arrest (usually more than four minutes) and the presence of severe, irreversible myocardial, brain and other end-organ damage. (See "Hypoxic-ischemic brain injury in adults: Evaluation and prognosis".)

Factors associated with successful resuscitation of patients presenting with asystole include spontaneous conversion to a shockable rhythm, witnessed arrest, younger patient age, shorter time to arrival of emergency medical services (EMS) personnel, and no further need for treatment with atropine for a bradyarrhythmia after initial resuscitation [12,15,16]. In a systematic review of 1,108,281 patients (from 12 studies) with SCA and initial nonshockable rhythms, approximately 4.6 percent of patients had spontaneous conversion to a shockable rhythm, which was associated with a greater chance of return of spontaneous circulation (odds ratio 1.47, 95% CI 1.40-1.55) as well as greater odds of survival and favorable neurologic status at 30 days [16].

Pulseless electrical activity — Patients who have SCA due to pulseless electrical activity (also called electrical-mechanical dissociation) also have a poor outcome due to absence of cardiac output and organ perfusion. In one study of 150 such patients, 23 percent were resuscitated and survived to hospital admission; only 11 percent survived until hospital discharge [17].

Ventricular tachyarrhythmia — The outcome is much better when the initial rhythm is a sustained ventricular tachyarrhythmia, especially ventricular tachycardia as there is some cardiac output and organ perfusion. The most frequent etiology is ventricular fibrillation (VF). Approximately 25 to 40 percent of patients with SCA caused by VF survive until hospital discharge [1,18,19]. Survival is dependent upon the duration of VF and time to defibrillation. In the Seattle series cited above of over 12,000 EMS-treated patients with SCA, 38 percent had witnessed VF [1]. Patients with witnessed VF (in whom time to defibrillation is shorter) had a significantly greater likelihood of surviving to hospital discharge than those with other rhythms (34 versus 6 percent).

Acute myocardial infarction (MI) or myocardial ischemia is the underlying cause of VF for many of the patients who survive to hospital discharge. In a series of 79 such patients from the Mayo Clinic, 47 percent had an acute MI, while in a series of 47 such patients from the Netherlands, 51 percent had an acute MI [18,19].

Survival is approximately 65 to 70 percent in patients who present with hemodynamically unstable ventricular tachycardia (VT) [20]. The prognosis may be better in patients found in monomorphic VT because of the potential for some systemic perfusion during this more organized arrhythmia. In addition, patients with VT tend to have a lower incidence of a previous infarction and may have a higher ejection fraction when compared with those with VF [21].

SCA due to noncardiac causes — As many as one-third of cases of SCA are due to noncardiac causes [1,22]. Trauma, nontraumatic bleeding, intoxication, near drowning, and pulmonary embolism are the most common noncardiac etiologies. In one series, 40 percent of such patients were successfully resuscitated and hospitalized; however, only 11 percent were discharged from the hospital and only 6 percent were neurologically intact or had mild disability.

FACTORS AFFECTING OUT-OF-HOSPITAL SCA OUTCOME

Despite the efforts of emergency personnel, resuscitation from out-of-hospital SCA is successful in only one-third of patients, and only about 10 percent of all patients are ultimately discharged from the hospital, many of whom are neurologically impaired [4,5,7,23-27]. (See "Hypoxic-ischemic brain injury in adults: Evaluation and prognosis".)

The cause of death in-hospital is most often noncardiac, usually anoxic encephalopathy from poor or absent cerebral perfusion or respiratory complications from long-term ventilator dependence [28]. Only about 10 percent of patients die primarily from recurrent arrhythmia, while approximately 30 percent die primarily from a low cardiac output or cardiogenic shock as the consequence of mechanical failure. Recurrence of severe arrhythmia in the hospital is associated with a worse outcome [29].

Race-ethnic differences in out-of-hospital CPR — Across all neighborhood income strata, the frequency of bystander CPR at home and in public locations was lower among Black and Hispanic persons with out-of-hospital cardiac arrest than among White persons [30]. Within a large United States registry, out of 35,469 witnessed out-of-hospital cardiac arrests from 2013 to 2019, 32.2 percent occurred in Black or Hispanic persons. Black and Hispanic persons were less likely to receive bystander CPR at home than White persons (38.5 versus 47.4 percent; odds ratio [OR] 0.74; 95% CI 0.72-0.76) and less likely to receive bystander CPR in public locations than White persons (45.6 versus 60 percent; OR 0.63; 95% CI 0.60-0.66).

The incidence of bystander CPR among Black and Hispanic persons was less than that among White persons in the following settings:

- In predominantly White neighborhoods at home (43.8 versus 49.1 percent; OR 0.82; 95% CI 0.74-0.90) and in public locations (50.7 versus 61.8 percent; OR 0.68; 95% CI 0.60-0.75).

- In majority Black or Hispanic neighborhoods at home (37.3 versus 43.4; OR 0.79; 95% CI 0.75-0.83) and in public locations (41.7 versus 55.7 percent; OR 0.63; 95% CI 0.59-0.68).

- In integrated neighborhoods at home (40.9 versus 47.1 percent; OR 0.78; 95% CI 0.74-0.81) and in public locations (50.4 versus 60.3 percent; OR 0.73; 95% CI 0.68-0.77).

The investigators suggested that public health interventions that go beyond CPR training in Black and Hispanic communities, including use of linguistically and culturally appropriate CPR training, funding for dispatcher-assisted CPR in majority Black and Hispanic neighborhoods, and engagement of community leaders, may be indicated to reduce racial and ethnic differences in bystander CPR.

Similar findings were reported in a large registry of 64,007 people in the post-COVID-19 era [31]. Black/Hispanic people with witnessed out-of-hospital SCA had decreased odds of receiving bystander CPR compared with White individuals (60 versus 67 percent). Differences in CPR existed for OHSCA in the home (OR 0.77; 95% CI 0.74-0.81) as well as in public (OR 0.69; 95% CI 0.64-0.76). Differences also persisted among neighborhoods of different socioeconomic status and across the rural-urban spectrum.

Risk scores to assess likelihood of survival — In addition to later initiation of CPR and the presence of asystole or pulseless electrical activity (electromechanical dissociation) [11-13,17], there are a number of other factors that are associated with a decreased likelihood of survival with neurologic function intact following out-of-hospital SCA [19,32-36]:

- Absence of any vital signs
- Sepsis
- Cerebrovascular accident with severe neurologic deficit
- Cancer or Alzheimer disease
- History of more than two chronic diseases
- A history of cardiac disease
- Prolonged CPR more than five minutes

There are also several poor prognostic features in patients with SCA who survive until admission:

- Persistent coma after CPR (see "Hypoxic-ischemic brain injury in adults: Evaluation and prognosis")
- Hypotension, pneumonia, and/or renal failure after CPR
- Need for intubation or pressors
- History of class III or IV heart failure
- Older age

Clinical risk scores incorporating a variety of patient characteristics have been developed in an effort to predict survival post-SCA [37-40]. Risk scores, when used, should be interpreted in conjunction with the overall clinical assessment. As examples:

- The NULL-PLEASE score (from 0 to 10), retrospectively validated in a single-center cohort of 547 patients with out-of-hospital SCA between 2013 and 2016, stratifies risk of mortality [37].

  - Nonshockable rhythm
  - Unwitnessed arrest
  - Long no-flow period (no bystander CPR)
  - Long low-flow period (>30 minutes before return of spontaneous circulation [ROSC])
  - pH (arterial) <7.2
  - Lactate >7 mmol/L
  - End-stage kidney disease on dialysis
  - Age ≥85 years
  - Still (ongoing) CPR on arrival to hospital
  - Extracardiac cause

  Patients with ≥5 features on the NULL-PLEASE score had a greater than threefold risk of mortality compared with patients with a score from 0 to 4 (odds ratio [OR] 3.3, 95% CI 2.3-4.9).

- The CREST score (from 0 to 5), derived from 638 patients and validated in 318 patients who experienced out-of-hospital cardiac arrest and were enrolled in the International Cardiac Arrest Registry (INTCAR), stratifies patients on risk of circulatory death following ROSC [38].

  - Coronary artery disease (preexisting)
  - Rhythm nonshockable
  - Ejection fraction <30 percent
  - Shock at presentation
  - Time (ischemic time prior to ROSC) >25 minutes

  Risk of circulatory death increased with every additional point, from 10 percent mortality with CREST = 0 up to 50 percent mortality with CREST = 5.

VF duration — Ventricular fibrillation (VF) in the human heart rarely, if ever terminates spontaneously or reverts with an antiarrhythmic drug, and survival is therefore dependent upon the prompt delivery of effective CPR. Electrical defibrillation is the **only** way to reestablish organized electrical activity and myocardial contraction. (See "Cardioversion for specific arrhythmias".)

Increasing duration of VF has two major adverse effects: it reduces the ability to terminate the arrhythmia and, as with prolonged VF, the fibrillatory waves become finer and ultimately become absent, reflecting less electrical activity and thus less responsiveness to defibrillation, and, if VF continues for more than four minutes, there is the beginning of irreversible damage to the central nervous system and other organs [41-43]. As a result, the longer the duration of the cardiac arrest, the lower the likelihood of resuscitation or survival with or without neurologic impairment even if CPR is successful. It has been suggested that without CPR, survival from a cardiac arrest caused by VF declines by approximately 10 percent for each minute without defibrillation, and after more than 12 minutes without CPR, the survival rate is only 2 to 5 percent [44-46].

Time to resuscitation — These observations constitute the rationale for attempts to provide more rapid resuscitation in patients with out-of-hospital SCA, especially more prompt defibrillation. One approach is optimizing the EMS system within a community to reduce the response interval to less than eight minutes [47].

However, in some areas, the response times of both BLS and ALS services have actually increased, possibly as a result of population growth and urbanization. In the Seattle series of over 12,000 EMS-treated patients, the BLS response interval increased from 3.8 to 5.1 minutes between 1977 and 2001, and the ALS response interval increased from 8.4 to 9.0 minutes [1].

Thus, bystander CPR and even defibrillation (using an automatic external defibrillator or AED) have been recommended and have been implemented in some settings. Such interventions permit more rapid responses than those provided by ALS or BLS personnel, with better survival as a result. In the Seattle series, the OR for survival to discharge for patients who received bystander CPR to those who did not was 1.85 [1].

Bystander CPR — The administration of CPR by a layperson bystander (bystander CPR or bystander-initiated CPR) and prompt defibrillation with an AED are important factors in determining patient outcome after out-of-hospital SCA. Survival after SCA is greater among those who have bystander CPR when compared with those who initially receive more delayed CPR from EMS personnel [48]. In addition to improved survival, early restoration or improvement in circulation is associated with better neurologic function among survivors [49-51].

For adults with sudden out-of-hospital SCA, compression-only bystander CPR (without rescue breathing) appears to have equal or possibly greater efficacy compared with standard bystander CPR (compressions plus rescue breathing). With prompt chest compression, there is some cardiac output and systemic blood flow to organs. The 2010 American Heart Association (AHA) Guidelines for CPR, along with subsequent professional society guidelines, recommended that *bystanders* perform compression-only CPR to provide high-quality chest compressions prior to the arrival of emergency personnel [52-56]. (See 'Chest compression-only CPR' below.)

The importance of bystander CPR and support for compression-only bystander CPR comes from a combination of retrospective and prospective studies. An initial report from the Seattle Heart Watch program in the late 1970s evaluated 109 consecutive patients resuscitated at the scene by a bystander trained in CPR and compared their outcomes with those of 207 patients who initially received CPR from EMS personnel [57]. There was no difference between the two groups in the percentage of patients resuscitated at the scene and admitted alive to the hospital (67 versus 61 percent), but the percentage discharged alive was significantly higher among those with bystander CPR (43 versus 22 percent). The most important reason for the improvement in survival in this study was that earlier CPR and prompt defibrillation were associated with less damage to the central nervous system and other organs, including the heart. More patients with bystander CPR were conscious at the time of hospital admission (50 versus 9 percent), and more regained consciousness by the end of hospitalization (81 versus 52 percent).

These observations were subsequently confirmed in larger studies [50,51,58-64].

- In a nationwide study of out-of-hospital cardiac arrest in Japan between 2005 and 2012, during which time the number of out-of-hospital cardiac arrests grew by 33 percent (n = 17,882 in 2005 compared with n = 23,797 in 2012), rates of bystander CPR increased (from 39 to 51 percent), and recipients of bystander CPR had a significantly greater chance of neurologically intact survival (8.4 versus 4.1 percent without bystander CPR; OR 1.52, 95% CI 1.45-1.60) [50]. Early defibrillation by bystanders was also associated with a significantly greater odds of neurologically intact survival.

- In a cohort of 25,505 persons with out-of-hospital cardiac arrest in Denmark between 2001 and 2010 which was not witnessed by EMS personnel (from the nationwide Danish Cardiac Arrest Registry), the frequency of bystander CPR increased significantly from 2001 to 2014 in both public locations (from 36 to 83 percent) and private residences (from 16 to 61 percent), with a corresponding significant increase in survival at 30 days (from 6.4 to 25.2 percent in public locations and from 2.9 to 10 percent in private residences) [63].

- In a nationwide cohort of 30,445 bystander-witnessed cardiac arrests in Sweden between 2000 and 2017, the frequency of bystander CPR prior to EMS arrival improved significantly over time, from 40.8 percent between 2000 and 2005 to 68.2 percent between 2011 and 2017 [48]. While the number of patients receiving standard CPR improved by 3 percent over the same time period (from 35.4 to 38.1 percent), administration of compression-only CPR increased from 5.4 to 30.1 percent. Both standard CPR and compression only CPR administered by bystanders were associated with more than twofold increased likelihood of survival compared with no CPR prior to EMS arrival.

Despite the benefits of bystander CPR, it is not always performed. Reasons for this include the bystander's lack of CPR training and concerns about possible transmission of disease while performing rescue breathing [65]. Neighborhood demographics (eg, income level) also appear to be a factor in the rates of bystander CPR performance. In an analysis of 14,225 patients with cardiac arrest in 29 United States sites participating in Cardiac Arrest Registry to Enhance Survival (CARES), bystander CPR was significantly more likely to be performed in higher-income (above 40,000 USD per year) than in lower-income (less than 40,000 USD per year) neighborhoods [66].

Interventions that appear to improve the rate of bystander CPR include verbal encouragement and instruction in CPR by EMS dispatchers, and public campaigns to promote the delivery of bystander CPR [65]:

- In a series of over 12,000 EMS-treated patients from Seattle, bystanders not trained in CPR were given instructions by telephone from the EMS dispatcher [1]. The proportion of patients receiving bystander CPR increased from 27 to 50 percent, almost entirely as a result of the implementation of dispatcher-assisted CPR in that interval.

- A prospective observational study of 4400 adults with out-of-hospital sudden cardiac death noted a rise in the delivery of bystander CPR from 28 to 40 percent over the course of a five-year public campaign to encourage bystander compression-only CPR [67].

Chest compression-only CPR — Bystander CPR with chest compressions alone results in improved survival to hospital discharge, compared with chest compressions with interruptions for rescue breathing, with an absolute improvement in mortality of 2.4 percent (NNT = 42 to save one additional life) [68]. With continuous chest compressions, there is better systemic circulation.

Initial observational studies that evaluated the delivery of compression-only CPR versus standard CPR including rescue breathing found no significant differences in survival or long-term neurologic function between the two groups, suggesting that compression-only CPR could be safely delivered [67,69-71]. Three randomized trials of compression-only CPR versus standard CPR all showed a trend toward improved outcomes in the compression-only CPR group [72-74]. The trends toward improved survival to discharge with compression-only CPR became statistically significant when the results of the three trials (thereby increasing the number of patients) were combined in a meta-analysis (14 versus 12 percent in the standard CPR group; risk ratio 1.22, 95% CI 1.01-1.46) [75,76].

Nationwide cohort studies of out-of-hospital cardiac arrest victims in both Japan and Sweden have demonstrated improvements in the number of SCA victims receiving bystander CPR, as well as the number of patients surviving with chest compression-only CPR [48,77]. These findings hold promise for improving the delivery of bystander CPR. Further data are required to determine if bystander-delivered compression-only CPR (rather than standard CPR) will translate into better neurologic outcomes for patients with out-of-hospital cardiac arrest. (See "Adult basic life support (BLS) for health care providers".)

Automated mechanical CPR devices — Several automated devices that deliver chest compressions have been developed in an attempt to improve upon chest compressions delivered by humans as well as to allow rescuers to perform other interventions simultaneously. While a 2013 meta-analysis of 12 studies (only 3 of which were randomized clinical trials) suggested higher rates of the ROSC when an automated device was used, subsequent randomized trials showed no significant differences in survival between the mechanical CPR and manual CPR groups. Additional discussion of automated mechanical CPR devices is presented separately. (See "Therapies of uncertain benefit in basic and advanced cardiac life support", section on 'Mechanical compression devices'.)

Timing of defibrillation — The standard of care for resuscitation from ventricular fibrillation has been defibrillation as soon as possible. In the Seattle series of over 12,000 EMS-treated patients, 4546 had witnessed VF. For these patients, the defibrillation response interval was significantly correlated with survival to hospital discharge (OR 0.88 for every one-minute increase in response time) [1]. Subsequent studies have shown similar benefits, with earlier defibrillation being associated with improved survival and neurologic outcomes [50,58,78,79].

Despite these findings, it has been suggested that outcomes may be improved by performing CPR **before** defibrillation, at least in patients in whom defibrillation is delayed for more than four to five minutes [80,81]. An initial report from Seattle compared outcomes in two time periods: when an initial shock was given as soon as possible; and, subsequently, when the initial shock was delayed until 90 seconds of CPR had been performed [80]. Survival to hospital discharge was significantly increased with routine CPR before defibrillation, primarily in patients in whom the initial response interval was four minutes or longer (27 versus 17 percent without prior CPR).

However, in the largest study to date comparing shorter versus longer periods of initial CPR prior to defibrillation in 9933 patients with SCA, patients were randomly assigned to receive 30 to 60 seconds versus 180 seconds of CPR prior to cardiac rhythm analysis and defibrillation (if indicated) [82]. There was no significant difference in the primary endpoint of survival to hospital discharge with satisfactory functional status (5.9 percent in both groups).

For patients with SCA and ventricular tachyarrhythmia, we perform early defibrillation and CPR as recommended in the 2010 advanced cardiovascular life support (ACLS) guidelines (algorithm 1). (See "Advanced cardiac life support (ACLS) in adults".)

Automated external defibrillators — The use of automated external defibrillators (AEDs) by early responders is another approach to more rapid resuscitation. In most but not all studies, AEDs have been found to improve survival after out-of-hospital cardiac arrest. The development, use, allocation, and efficacy of AEDs are discussed elsewhere. (See "Automated external defibrillators".)

One example of the efficacy of AEDs when used by bystanders prior to the arrival of emergency responders comes from a study of 49,555 out-of-hospital cardiac arrests at nine regional centers from 2011 to 2015, of which 4115 (8.3 percent) were observed in public by bystanders. Among the observed public arrests, 60 percent had an initially shockable rhythm, and 19 percent were shocked with an AED. Patients shocked by bystanders using the AED were significantly more likely to survive to hospital discharge (67 versus 43 percent) and to have favorable neurologic function (defined as modified Rankin score ≤2) at discharge (57 versus 33 percent) [83].

Predictive value of BLS and ALS rules — The OPALS study group has proposed two termination of resuscitation rules for use by EMS personnel. The rule for BLS providers equipped with AEDs includes the following three criteria: event not witnessed by emergency medical services personnel; no AED used or manual shock applied in out-of-hospital setting; and no ROSC in out-of-hospital setting [84]. The advanced life support (ALS) rule includes the BLS criteria as well as two additional criteria: arrest not witnessed by bystander and no bystander-administered CPR [85].

Validation of the predictive value of the BLS and ALS termination rules was performed with data from a retrospective cohort study that included 5505 adults with out-of-hospital SCA [86]. The overall rate of survival to hospital discharge was 7 percent. Of 2592 patients (47 percent) who met BLS criteria for termination of resuscitation efforts, only 5 survived to hospital discharge. Of 1192 patients (22 percent) who met ALS criteria, none survived to hospital discharge.

However, the validity of these termination rules may be reduced with improvements in EMS and postresuscitation care. One potential target for understanding and ameliorating current limitations to postarrest care is the observed marked regional variation in prognosis following SCA. (See 'Prognosis following sudden cardiac arrest' above.)

Adequacy of CPR — The adequacy of CPR delivered to a victim of cardiac arrest and outcomes related to resuscitation efforts may depend on a variety of factors (eg, rate and depth of chest compressions, amount of time without performing chest compressions while performing other tasks such as defibrillation, etc). The American Heart Association (AHA) 2010 Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care emphasized early defibrillation (when available) and high-quality chest compressions (rate at least 100 per minute, depth of two inches or more) with minimal interruptions [53]. The effect of CPR quality has been evaluated in several studies [87-89]:

- In a 2013 systematic review and meta-analysis which included 10 studies (4722 patients total, 4516 of whom experienced out-of-hospital cardiac arrest), persons surviving cardiac arrest were significantly more likely than nonsurvivors to have received deeper chest compressions and have had compression rates between 85 and 100 compressions per minute (compared with shallower and slower compression rates) [87].

- In a study of 3098 patients with out-of-hospital cardiac arrest, ROSC was highest at a rate of 125 compressions per minute [88]. However, higher chest compression rates were not significantly associated with survival to hospital discharge, which is consistent with the finding in the systematic review and meta-analysis above. (See "Adult basic life support (BLS) for health care providers", section on 'Performance of excellent chest compressions'.)

End-tidal carbon dioxide levels have an excellent correlation with very low cardiac outputs when measured after at least 10 minutes of CPR and may provide prognostic information, suggesting that the cardiac output maintained during CPR is a determinant of outcome. This concept is discussed in greater detail elsewhere. (See "Carbon dioxide monitoring (capnography)", section on 'Effectiveness of CPR'.)

Body temperature — An increase in body temperature is associated with unfavorable functional neurologic recovery after successful CPR. The increase in temperature may be neurally-mediated and can exacerbate the degree of neural injury associated with brain ischemia. For the highest temperature within 48 hours, each degree Celsius higher than 37°C increases the risk of an unfavorable neurologic recovery (OR of 2.26 in one report) [90].

On the other hand, the induction of mild to moderate hypothermia (target temperature 32 to 34°C for 24 hours) may be beneficial in patients successfully resuscitated after a cardiac arrest, although studies have shown variable outcomes. This issue is discussed in greater detail elsewhere. (See "Initial assessment and management of the adult post-cardiac arrest patient", section on 'Temperature management'.)

Prehospital ACLS — The incremental benefit of deploying EMS personnel trained in ACLS interventions (intubation, insertion of intravenous lines, and intravenous medication administration) on survival after cardiac arrest probably depends upon the quality of other prehospital services.

- In the OPALS study, ACLS interventions were added to an optimized emergency medical services program of rapid defibrillation [58]. No improvement in the rate of survival for out-of-hospital cardiac arrest was observed with addition of an ACLS program.
- In a retrospective report from Queensland with an emergency services program not optimized for early defibrillation, the presence of ACLS-skilled EMS personnel was associated with improved survival for out-of-hospital cardiac arrest [91].

Effect of older age — The risk of SCA increases with age, and older age has been associated with a poorer survival in some, but not all studies of out-of-hospital cardiac arrests [1,92-96]:

- In one study of 5882 patients who experienced an out-of-hospital cardiac arrest, 22 percent were >80 years of age [97]. Compared with patients <80 years of age, octogenarians and nonagenarians had a lower rate of hospital discharge (9.4 and 4.4 versus 19 percent for those <80). The discharge rate was higher in those with VF or pulseless ventricular tachycardia (VT) as the initial rhythm. Very old patients still had a poorer survival (24 and 17 versus 36 percent), but age was a weaker predictor than the initial rhythm.
- In the Seattle series of over 12,000 EMS-treated patients, every one-year increase in age was associated with a lower likelihood of survival to hospital discharge for all patients (OR 0.97 per year) and for those with witnessed VF (OR 0.98 per year) [1].
- In a study of 36,605 patients ages 70 years or older enrolled in a Swedish registry between 1990 and 2013 following SCA, 30-day survival was significantly higher in patients ages 70 to 79 years (6.7 percent) compared with patients ages 80 to 89 years (4.4 percent) and those over 90 years of age (2.4 percent) [96].

Effect of sex — The incidence of SCA is greater in males than females [1,98]. The effect of sex on outcome has been examined in multiple cohorts, with the following findings [98-100]:

- Males are more likely than females to have VF or VT as an initial rhythm.
- Males are more likely than females to have a witnessed arrest.
- Males have a higher one-month survival than females following SCA, due to the higher likelihood of VF/VT as their presenting rhythm. However, when considering only patients

with VF/VT as the initial rhythm, females have a greater survival with favorable neurologic outcome.

Effect of comorbidities — The impact of preexisting chronic conditions on the outcome of out-of-hospital SCA was evaluated in a series of 1043 SCA victims in King County, Washington, in the United States [101]. There was a statistically significant reduction in the probability of survival to hospital discharge with increasing numbers of chronic conditions, such as congestive heart failure, prior MI, hypertension, and diabetes (OR 0.84 for each additional chronic condition). The impact of comorbidities was more prominent with longer EMS response intervals.

Association of depression and anxiety with long-term outcomes — In a study of 2373 patients from South Korea with out-of-hospital cardiac arrest followed for a median of 5.1 years for the outcome of mortality, 16.7 percent were diagnosed with depression or anxiety [102]. Patients with depression or anxiety had a higher rate of long-term mortality versus those without these conditions (35.5 versus 27 percent; adjusted hazard ratio 1.41; 95% CI 1.17-1.70).

FACTORS AFFECTING IN-HOSPITAL SCA OUTCOME

The outcome of patients who experience SCA in the hospital is poor, with reported survival to hospital discharge rates of 6 to 19 percent [103-108]. However, outcomes appear to be improving over time [107,109].

- In a cohort of 64,339 patients at 435 hospitals who had in-hospital SCA between 2000 and 2008 and underwent standard resuscitation procedures, 49 percent had return of spontaneous circulation (ROSC), with 15 percent overall survival to hospital discharge [106].

- In a cohort of 151,071 adults at 470 United States hospitals who had in-hospital SCA between 2000 and 2014, 62 percent had ROSC, with 19 percent overall survival to hospital discharge [107]. In this study, patients with SCA during "on hours" (Monday through Friday from 7 AM through 11 PM) had significantly greater survival compared with SCA occurring during "off hours" (Monday through Friday from 11:00 PM through 7:00 AM and all day Saturday and Sunday); this difference did not significantly change between 2000 (16 versus 11.9 percent, respectively) and 2014 (25.2 versus 21.9 percent, respectively).

Specific factors — Several clinical factors have been identified that predict a greater likelihood of survival to hospital discharge [103,106,107,110]:

- Witnessed arrest.

- Ventricular tachycardia (VT) or ventricular fibrillation (VF) as initial rhythm.
- Pulse regained during first 10 minutes of CPR.
- Arrest during "on hours" (Monday through Friday from 7:00 AM through 11:00 PM).
- Identification of early warning signs.
- The presence of a dedicated resuscitation team with diverse team composition, clearly defined roles and communication, and ongoing training [111].

Other factors have been identified that predict a lower likelihood of survival to hospital discharge [110,112]:

- Longer duration of overall resuscitation efforts.
- Multiple resuscitation efforts.

Delays in providing initial defibrillation have been associated with worse outcomes. This was illustrated in a report of 6789 patients with in-hospital SCA due to VT or VF from 369 hospitals participating in the National Registry of Cardiopulmonary Resuscitation [112]. Delayed defibrillation (more than two minutes after SCA) occurred in 30 percent of patients and was associated with a significantly lower probability of surviving to hospital discharge (22.2 versus 39.3 percent). Delayed defibrillation was more common with noncardiac admitting diagnosis, cardiac arrest at a hospital with fewer than 250 beds, an unmonitored hospital unit, and arrest during after-hours periods.

A national early warning score (NEWS) was developed in the United Kingdom in 2012 and updated in 2017 in an effort to standardize early detection of patients at risk for in-hospital SCA [113]. The score incorporates seven vital signs (respiratory rate, oxygen saturation, supplemental oxygen, heart rate, systolic blood pressure, temperature, and level of consciousness), with a maximal score of 20 points (0 to 4, 5 to 6, and 7 or more considered low, medium, and high scores, respectively). In a single-center study of all in-hospital SCA in 2014 and 2015, patients had markedly high risk of dying from SCA if they had a medium (odds ratio [OR] 4.4, 95% CI 1.8-10.8) or high (OR 9.9, 95% CI 2.8-35.3) NEWS score compared with patients with a low NEWS score [114].

Multiple resuscitations involving CPR have also been associated with worse outcomes. Among 166,519 hospitalized patients (from the Nationwide Inpatient Sample, an all-payer United States hospital database) who underwent CPR while hospitalized between 2000 and 2009, 3.4 percent survived the initial CPR and ultimately had multiple rounds of CPR during their hospitalization

[110]. Patients who had multiple rounds of CPR had a significantly lower likelihood of survival to discharge (OR 0.41, 95% CI 0.37-0.44), and those who survived multiple rounds of CPR had high hospitalization costs and were more likely to be discharged to hospice care.

Survival following in-hospital SCA treated with an automated external defibrillator (AED) has also been evaluated using data derived from the National Registry of Cardiopulmonary Resuscitation [115]. When compared with usual resuscitative care, the use of an AED did not improve survival among patients with a shockable rhythm and was associated with a lower survival to hospital discharge among patients with a nonshockable rhythm. (See "Automated external defibrillators", section on 'In-hospital AED allocation'.)

In 2013 the American Heart Association issued consensus recommendations regarding strategies for improving outcomes following in-hospital SCA [116]. While the consensus recommendations focused on many of the same factors as out-of-hospital cardiac arrest (ie, early identification of SCA, provision of high-quality CPR, early defibrillation [when indicated]), the authors commented on a lack of evidence specifically focused on in-hospital SCA, with many of the current guideline recommendations based on extrapolations of data from out-of-hospital SCA. Further data specifically focusing on in-hospital SCA are required prior to making any additional recommendations.

GO-FAR score to predict neurologically intact survival — The ability to predict neurologically favorable survival following in-hospital SCA has not been well-defined, with most estimates based on clinical judgment of the treating clinician(s). However, it seems most likely that no single factor can effectively predict outcomes but rather a combination of factors.

Using data obtained from 366 United States hospitals participating in the Get With The Guidelines-Resuscitation registry, 51,240 patients were identified who experienced in-hospital SCA during the period from 2007 to 2009 [117]. The data were used to derive (44.4 percent), test (22.2 percent) and validate (33.4 percent) the GO-FAR score predicting the likelihood of survival with good neurologic function following SCA based on 13 clinical variables. Patients were divided into the following groups based on likelihood of survival to discharge:

- Very low likelihood of survival (<1 percent chance) – Score of 24 or greater
- Low likelihood of survival (1 to 3 percent chance) – Score 14 to 23
- Average likelihood of survival (>3 to 15 percent chance) – Score -5 to 13
- Higher than average likelihood of survival (>15 percent chance) – Score -15 to -6

In general, younger patients with normal baseline neurologic function and fewer medical comorbidities had a greater likelihood of survival following in-hospital SCA [118]. A subsequent prospective registry study of 62,131 patients with in-hospital SCA between 2010 and 2016 validated the ability of the GO-FAR score to predict the chance of survival; survival rates were slightly higher, likely related to ongoing improvements in postresuscitation care [119]. The GO-FAR score appears to be an effective aid for patients and/or caregivers to better understand the likely goals and outcomes of care. (See "Communication in the ICU: Holding a meeting with families and caregivers", section on 'Sharing clinical information'.)

IMPACT OF ARTERIAL OXYGEN LEVEL

Oxygenation goals should be individualized and hyperoxia should be avoided. Arterial hyperoxia early after SCA may have deleterious effects, perhaps due to oxidative injury. The 2008 International Liaison Committee on Resuscitation cited preclinical evidence of harm from hyperoxia and suggested a goal arterial oxygenation of 94 to 96 percent post SCA [120]. A more detailed discussion of oxygenation with mechanical ventilation is presented separately. (See "Overview of initiating invasive mechanical ventilation in adults in the intensive care unit", section on 'Fraction of inspired oxygen'.)

A study to examine this issue was performed using a multicenter database including 6326 patients with arterial blood gas analysis within 24 hours after ICU arrival following cardiac arrest [121]. The study included patients with in-hospital and out-of-hospital SCA (57 percent were hospital inpatients and 43 percent were from the emergency department). Oxygenation status was categorized according to the first ICU arterial blood gas value, with hyperoxia defined as PaO_2 ≥300 mmHg, hypoxia as PaO_2 <60 mmHg, and the remaining as normoxia. The majority of patients had hypoxia (63 percent) with similar numbers having hyperoxia (18 percent) and normoxia (19 percent). The hyperoxia group had higher in-hospital mortality compared with the normoxia and the hypoxia groups (63 percent versus 45 percent and 57 percent). In a multivariable model, hyperoxia was an independent risk factor for death (odds ratio [OR] 1.8, 95% CI 1.5-2.2). Hypoxia was also an independent risk factor (OR 1.3, 95% CI 1.1-1.5). Further data are needed to determine the impact of oxygen titration during and after resuscitation. In a subsequent, smaller, prospective cohort study of 280 patients with cardiac arrest, among whom 105 patients (38 percent) were exposed to hyperoxia (defined as PaO_2 >300 mmHg) during the first six hours of care after return of spontaneous circulation, death or poor neurologic function at discharge (defined as modified Rankin score >3) was significantly more likely in patients exposed to hyperoxia (77 versus 65 percent) [122].

LONG-TERM OUTCOME

The reported long-term survival of resuscitated SCD is variable and may depend upon multiple factors:

- In patients with out-of-hospital ventricular fibrillation, was early defibrillation achieved?
- Do the data come from randomized trials, in which many, often sicker, patients are excluded, or from community-based observations?
- Was the patient treated with early revascularization, antiarrhythmic drugs, or an implantable cardioverter-defibrillator (ICD)?
- Does the patient have other risk factors, particularly a reduced left ventricular ejection fraction?
- Do patients with seemingly transient or reversible causes of SCA have a better prognosis?
- Did the episode of SCA begin as ventricular fibrillation (VF) or ventricular tachycardia (VT)?

The potential effect of successful early defibrillation on long-term outcome following out-of-hospital cardiac arrest due to VF was assessed in a population-based study of 200 patients [123]. Over 70 percent of these patients survived until hospital admission, and 40 percent of these patients were discharged with mild or absent neurologic impairment. Among these 79 patients, 43 underwent coronary revascularization and 35 received an ICD, 13 of whom had subsequent shocks for VT or VF. The expected five-year survival of the study population (79 percent) was the same as that of age-, sex-, and disease-matched controls who did not have out-of-hospital cardiac arrest, but significantly lower than age- and sex-matched controls in the general population.

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5^{th} to 6^{th} grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10^{th} to 12^{th} grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topics (see "Patient education: Sudden cardiac arrest (The Basics)")

SUMMARY AND RECOMMENDATIONS

- **Prognosis following cardiac arrest** – Despite advances in the treatment of heart disease, the outcome of patients experiencing sudden cardiac arrest (SCA) remains poor. The reasons for the continued poor outcomes are likely multifactorial (eg, delayed bystander cardiopulmonary resuscitation [CPR], delayed defibrillation, advanced age, decreased proportion presenting with ventricular fibrillation [VF]). (See 'Prognosis following sudden cardiac arrest' above.)

- **Outcome** – When SCA is due to a ventricular tachyarrhythmia, the outcome of resuscitation is better compared with those with asystole or pulseless electrical activity. (See 'Outcome according to etiology' above.)

- **Factors affecting outcome** – Among the many factors that appear to have an influence on the outcome of SCA, the elapsed time prior to effective resuscitation (ie, establishment of an effective pulse) appears to be the most critical element. There are several ways to decrease the time to the onset of resuscitative efforts:

  - Rapid emergency medical services (EMS) response – Optimizing the EMS system within a community to reduce the response interval to eight minutes or less has been proposed as a way to improve the outcomes of SCA. However, due to a variety of factors, EMS response time of eight minutes or less cannot always be achieved. (See 'Time to resuscitation' above.)

  - Bystander CPR – The administration of CPR by a layperson bystander (bystander CPR) is an important factor in determining patient outcome after out-of-hospital SCA, as early restoration or improvement in circulation has been shown to result in greater survival and better neurologic function among survivors. Bystander CPR, however, is not always performed, primarily due to the bystander’s lack of CPR training and/or concerns about possible transmission of disease while performing rescue breathing. (See 'Bystander CPR' above.)

- Early defibrillation – The standard of care for resuscitation of SCA has been defibrillation as soon as possible when indicated. Shorter defibrillation response intervals correlate with greater survival to hospital discharge. (See 'Timing of defibrillation' above and "Advanced cardiac life support (ACLS) in adults".)

- Automated external defibrillators – The use of automated external defibrillators (AEDs) by early responders is another approach to more rapid resuscitation. In most, but not all studies, AEDs have been found to improve survival after out-of-hospital cardiac arrest. (See "Automated external defibrillators".)

- **Cardiopulmonary resuscitation** – Several observational studies evaluating compression-only CPR versus standard CPR including rescue breathing reported no significant differences in survival or long-term neurologic function between the two groups, suggesting that compression-only CPR could be safely delivered (as long as the arrest is not a respiratory arrest). Three randomized trials of compression-only CPR versus standard CPR have all shown a trend toward improved outcomes in the compression-only CPR group, and a 2010 meta-analysis of the three randomized trials reported an increased survival to hospital discharge among patients who received compression-only CPR. As such, if a sole bystander is present or multiple bystanders are reluctant to perform mouth-to-mouth ventilation, we encourage the performance of CPR using chest compressions only. (See 'Bystander CPR' above and "Adult basic life support (BLS) for health care providers", section on 'Chest compressions'.)

- **Temperature management** – The induction of mild to moderate hypothermia (target temperature 32 to 34°C for 24 hours) may be beneficial in patients successfully resuscitated after a cardiac arrest. Improved neurologic outcome and reduced mortality has been demonstrated in series of patients with VF arrest in whom spontaneous circulation was restored, even when the patient remains comatose after resuscitation. (See "Initial assessment and management of the adult post-cardiac arrest patient", section on 'Temperature management'.)

ACKNOWLEDGMENT

The UpToDate editorial staff acknowledges Jie Cheng, MD, who contributed to an earlier version of this topic review.

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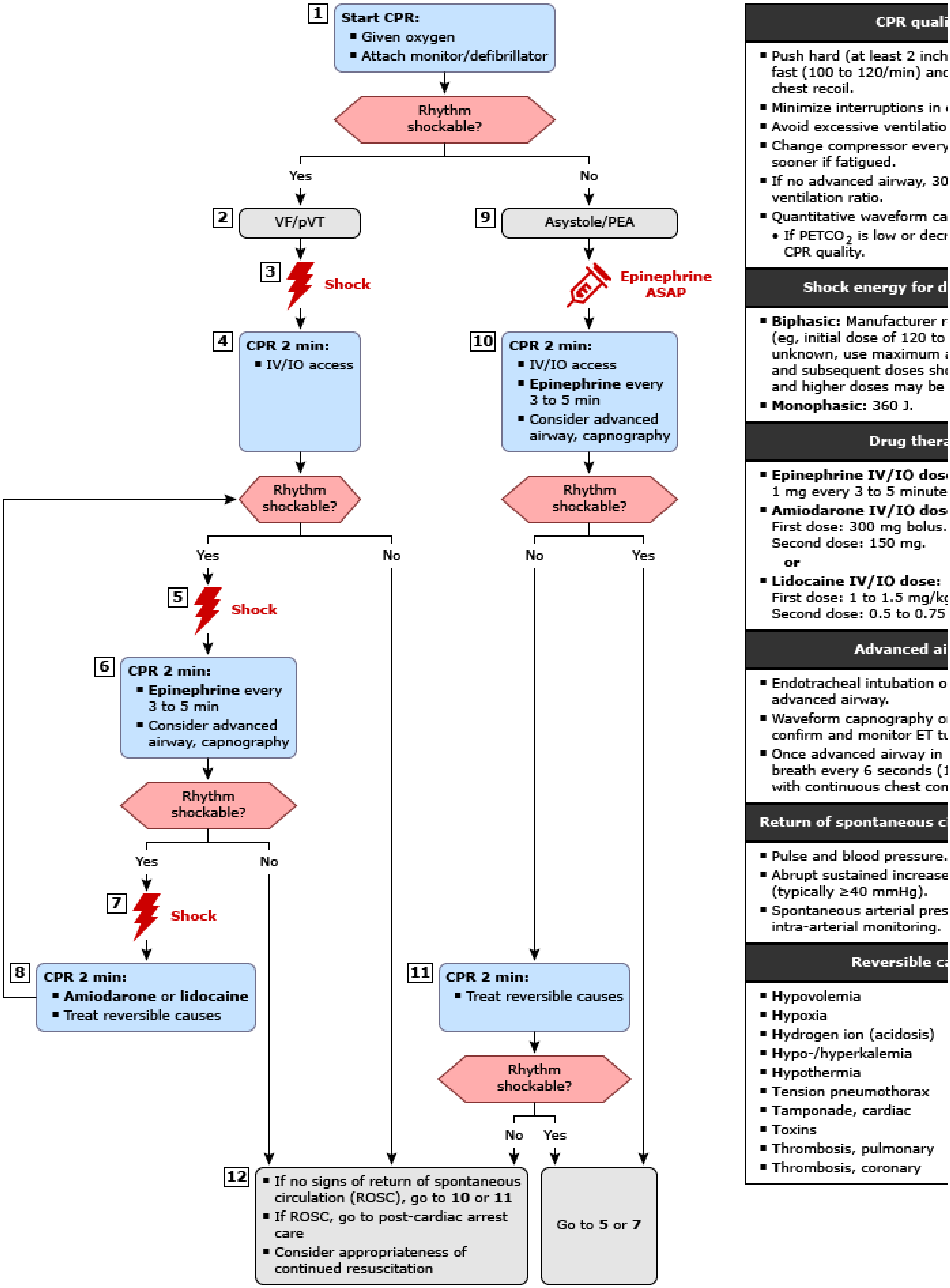
GRAPHICS

Adult cardiac arrest algorithm


1
Start CPR:
Given oxygen
Attach monitor/defibrillator
Rhythm shockable?
Yes
No
2
VF/pVT
9
Asystole/PEA
3
Shock
Epinephrine ASAP
4
CPR 2 min:
IV/IO access
10
CPR 2 min:
IV/IO access
Epinephrine every 3 to 5 min
Consider advanced airway, capnography
Rhythm shockable?
Yes
No
Rhythm shockable?
No
Yes
5
Shock
6
CPR 2 min:
Epinephrine every 3 to 5 min
Consider advanced airway, capnography
Rhythm shockable?
Yes
No
7
Shock
8
CPR 2 min:
Amiodarone or lidocaine
Treat reversible causes
11
CPR 2 min:
Treat reversible causes
Rhythm shockable?
No
Yes
12
If no signs of return of spontaneous circulation (ROSC), go to 10 or 11
If ROSC, go to post-cardiac arrest care
Consider appropriateness of continued resuscitation
Go to 5 or 7
CPR quali
Push hard (at least 2 inch
fast (100 to 120/min) anc
chest recoil.
Minimize interruptions in
Avoid excessive ventilatio
Change compressor every
sooner if fatigued.
If no advanced airway, 30
ventilation ratio.
Quantitative waveform ca
If PETCO2 is low or decr
CPR quality.
Shock energy for d
Biphasic: Manufacturer r
(eg, initial dose of 120 to
unknown, use maximum
and subsequent doses sh
and higher doses may be
Monophasic: 360 J.
Drug thera
Epinephrine IV/IO dos
1 mg every 3 to 5 minute
Amiodarone IV/IO dos
First dose: 300 mg bolus.
Second dose: 150 mg.
or
Lidocaine IV/IO dose:
First dose: 1 to 1.5 mg/kg
Second dose: 0.5 to 0.75
Advanced ai
Endotracheal intubation o
advanced airway.
Waveform capnography o
confirm and monitor ET tu
Once advanced airway in
breath every 6 seconds (1
with continuous chest con
Return of spontaneous c
Pulse and blood pressure.
Abrupt sustained increase
(typically ≥40 mmHg).
Spontaneous arterial pres
intra-arterial monitoring.
Reversible ca
Hypovolemia
Hypoxia
Hydrogen ion (acidosis)
Hypo-/hyperkalemia
Hypothermia
Tension pneumothorax
Tamponade, cardiac
Toxins
Thrombosis, pulmonary
Thrombosis, coronary

Graphic 129983 Version 10.0

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