INTRODUCTION

Cardiac arrest, also known as cardiopulmonary arrest or circulatory arrest, is the cessation of normal circulation of the blood due to failure of the heart to contract effectively, medical personnel may refer to an unexpected cardiac arrest as a sudden cardiac arrest (SCA).[1]

Arrested blood circulation prevents delivery of oxygen to the body, lack of oxygen to the brain causes loss of consciousness, which then results in abnormal or absent breathing, brain injury is likely to happen if cardiac arrest goes untreated for more than five minutes, for the best chance of survival and neurological recovery, immediate and decisive treatment is imperative.[2]

Cardiac arrest is a medical emergency that, in certain situations, is potentially reversible if treated early.The treatment for cardiac arrest is immediate defibrillation if a "shockable" rhythm is present, while cardiopulmonary resuscitation (CPR) is used to provide circulatory support and/or to induce a "shockable" rhythm.[3]

Classification

Clinicians classify cardiac arrest into "shockable" versus "non–shockable", as determined by the ECG rhythm. This refers to whether a particular class of cardiac dysrhythmia is treatable using defibrillation.[4] The two "shockable" rhythms are ventricular fibrillation and pulseless ventricular tachycardia while the two "non–shockable" rhythms are asystole and pulseless electrical activity.[5]

- **Ventricular fibrillation (VF)** is a condition in which there is uncoordinated contraction of the cardiac muscle of the ventricles in the heart, making them quiver rather than contract properly. Ventricular fibrillation is the most commonly identified arrhythmia in cardiac arrest patients. While there is some activity, the lay person is usually unable to detect it by palpating (feeling) the major pulse points of the carotid and femoral arteries. Such an arrhythmia is only confirmed by electrocardiography. Ventricular fibrillation is a medical emergency that requires prompt Advanced Life Support interventions. If this arrhythmia continues for more than a few seconds, it will likely degenerate further into asystole (flatline).[6]

- **Pulseless ventricular tachycardia**: type of tachycardia, or a rapid heart beat,that starts in the bottom chambers of the heart, called the ventricles, which are the main pumping chambers of the heart. This is a potentially life-threatening arrhythmia because it may lead to ventricular fibrillation, asystole, and sudden death.[7]

- **Asystole:** in medicine, asystole , is known as flatline, is a state of no cardiac electrical activity, hence no contractions of the myocardium and no cardiac output or blood flow. Asystole is one of the conditions that may be used for a medical practitioner to certify clinical or legal death.[8]

- **Pulseless electrical activity or PEA** : refers to a cardiac arrest situation in which a heart rhythm is observed on the electrocardiogram that should be producing a pulse, but is not. Under normal circumstances, electrical activation of muscle cells precedes mechanical contraction of the heart (known as electromechanical coupling). In PEA, there is electrical activity, but the heart either does not contract or there are other reasons why this results in an insufficient cardiac output to generate a pulse and supply blood to the organs.[9]

ETIOLOGY

SCA usually occurs in people with some form of underlying structural heart disease, most notably coronary heart diseases.[10]

Table (1): causes of sudden cardiac arrest:[10]

Ischemic heart diseases	Nonischemic heart diseases	Noncardiac diseases
1. Coronary artery disease with myocardial infarction or angina. 2. Coronary artery embolism. 3. Nonatherogenic coronary artery disease (arteritis, dissection, congenital coronary artery anomalies). 4. Coronary artery spasm.	1. Myocarditis 2. Acute pericardial tamponade 3. Acute myocardial rupture 4. Aortic dissection 5. Idiopathic ventricular fibrillation 6. Brugada syndrome 7. Long QT syndrome 8. Preexcitation syndrome 9. Complete heart block	1. Pulmonary embolism 2. Intracranial hemorrhage 3. Drowning 4. Pickwickian syndrome 5. Drug-induced 6. Central airway obstruction 7. Chest wall trauma

Coronary heart diseases

As much as 70 percent of SCAs have been attributed to coronary heart diseases (CHD). Among patients with CHD, SCA can occur both during an acute coronary syndrome (ACS) and in the setting of chronic, otherwise stable CHD (often such patients have had prior myocardial damage and scar that serves as a substrate for SCA).[11]

Potentially treatable conditions associated with cardiac arrest

1. **Acidosis:**Preexisting acidosis, diabetes, diarrhea, drugs and toxins, prolonged resuscitation, renal disease, and shock.[12]
2. **Hypovolemia:** Major burns, diabetes, gastrointestinal losses, hemorrhage, hemorrhagic diathesis, cancer, pregnancy, shock and trauma.[12]
3. **Hypoxia:** Consider in all patients with cardiac arrest.[12]

4. **Hypokalemia:** Alcohol abuse, diabetes, use of diuretics, drugs and toxins, profound gastroinstestinal losses, hypomagnesemia.(12)

5. **Hyperkalemia:** Metabolic acidosis, excessive administration of potassium, drugs and toxins, vigorous exercise, hemolysis, renal disease, rhabdomyolysis, tumorlysis syndrome, and clinically significant tissue injury.(12)

6. **Hypothermia:** Alcohol abuse, burns, central nervous system disease, debilitated or elderly patient, drowning, drugs and toxins, endocrine disease, history of exposure, homelessness, extensive skin disease, spinal cord disease, and trauma.(12)

7. **Thrombosis:**Myocardial infarction (Consider in all patients with cardiac arrest, especially those with a history of coronary artery disease or prearrest acute coronary syndrome), pulmonary embolism (Hospitalized patient, recent surgical procedure, peripartum, known risk factors for venous thromboembolism, history of venous thromboembolism, or prearrest presentation consistent with diagnosis of acute pulmonary embolism).(12)

8. **Tension pneumothorax:** Placement of central catheter, mechanical ventilation, pulmonary disease (including asthma, chronic obstructive pulmonary disease, and necrotizing pneumonia), thoracentesis, and trauma.(12)

9. **Toxins:** Alcohol abuse, bizarre or puzzling behavioral or metabolic presentation, classic toxicologic syndrome, occupational or industrial exposure, and psychiatric disease.(12)

10. **Cardiac tamponade:**Hemorrhagic diathesis, cancer, pericarditis, trauma, after cardiac surgery, and after myocardial infarction.(12)

RISK FACTORS

A number of clinical characteristics and other factors are associated with an increased risk of SCA among persons without prior clinically recognized heart disease . Most risk factors for CHD are also risk factors for SCA. These include dyslipidemia, hypertension, cigarette smoking, physical inactivity, obesity, diabetes mellitus, and a family history of premature CHD or myocardial infarction.(13)

1. **Smoking** : Current cigarette smoking and the number of cigarettes smoked per day among current smokers are strongly related to the risk of SCA in patients with CHD . Based upon the observations that the risk of SCA is particularly high among current smokers and declines rapidly after stopping smoking, smoking cessation should be viewed as a critical component of efforts to reduce the risk of SCA as well as a multitude of other complications.(14)

2. **Exercise :** The risk of SCA is transiently increased during and up to 30 minutes after strenuous exercise compared to other times. However, the actual risk during any one

episode of vigorous exercise is very low (1 per 1.51 million episodes of exercise). Furthermore, the magnitude of the transient increase in risk during acute exercise is lower among men who are regular exercisers compared with men for whom exercise is unusual.[15]

3. **Family history of SCA :**A family history of SCA, either alone or with myocardial infarction, is associated with a 1.5 to 1.8-fold increased risk of SCA. The increase in risk is not explained by traditional risk factors that tend to aggregate in families, such as hypercholesterolemia, hypertension, diabetes mellitus, and obesity.The magnitude of the increase in risk associated with the presence of a family history is modest compared to the two- to five-fold increase in risk associated with other modifiable risk factors such as physical inactivity and current cigarette smoking. Few studies have examined potential gene-environment interactions related to the risk of SCA. Nevertheless, it is likely that interactions of mutations or polymorphisms in specific genes and environmental factors influence this risk.[16]

4. **Excess alcohol intake :** Moderate alcohol intake (eg, one to two drinks per day, and avoidance of binge drinking) may decrease the risk of SCA. In comparison, heavy alcohol consumption (six or more drinks per day) or binge drinking increases the risk for SCA.[17]

5. **Excessive caffeine intake** has been investigated as a potential risk factor for SCA. In the limited data available, no significant association between caffeine intake and SCA have been found.[18]

Advanced cardiac life support (ACLS) in adults

The field of resuscitation has been evolving for more than two centuries. The Paris Academy of Science recommended mouth-to-mouth ventilation for drowning victims in 1740.[19] In 1891, Dr. Friedrich Maass performed the first documented chest compressions on humans. The American Heart Association (AHA) formally endorsed cardiopulmonary resuscitation (CPR) in 1963, and by 1966, they had adopted standardized CPR guidelines for instruction to lay-rescuers.[20]

Advanced cardiac life support (ACLS) guidelines have evolved over the past several decades based on a combination of scientific evidence of variable strength and expert consensus. The American Heart Association (AHA) developed the most recent ACLS guidelines in 2010 using the comprehensive review of resuscitation literature performed by the International Liaison Committee on Resuscitation.[21]

PRINCIPLES OF MANAGEMENT

1. **Basic life support and its importance :**

Excellent cardiopulmonary resuscitation (CPR) and early defibrillation for treatable arrhythmias remain the cornerstones of basic and advanced cardiac life support (ACLS).

Although the 2010 American Heart Association (AHA) Guidelines for ACLS (2010 ACLS Guidelines) suggest several revisions, including medications, electrical therapy, and monitoring, the emphasis on excellent CPR and its critical role in resuscitative efforts remains unchanged.(22)

In the past, clinicians frequently interrupted CPR to check for pulses, perform tracheal intubation, or obtain venous access. The 2010 ACLS Guidelines strongly recommend that every effort be made not to interrupt CPR; other less vital interventions (eg, tracheal intubation or administration of medications to treat arrhythmias) are made either while CPR is performed or during the briefest possible interruption. Interventions that cannot be performed while CPR is in progress (eg, defibrillation, pulse check) should be performed during brief interruptions at two minute intervals (after the completion of a full cycle of CPR). Studies in both the in-hospital and prehospital settings demonstrate that chest compressions are often performed incorrectly, inconsistently, and with excessive interruption.(23)

Chest compressions must be of sufficient depth (at least 5 cm, or 2 inches) and rate (at least 100 per minute), and allow for complete recoil of the chest between compressions, to be effective.(24) A single biphasic defibrillation remains the recommended treatment for ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT). CPR should be performed until the defibrillator is ready for immediate discharge and resumed immediately after the shock is given, without pausing to recheck a pulse at that moment. Interruptions in CPR (eg, for subsequent attempts at defibrillation or pulse checks) should occur no more frequently than every two minutes, and for the shortest possible duration.(25)

Patients are often over-ventilated during resuscitations, which can compromise venous return resulting in reduced cardiac output and inadequate cerebral and cardiac perfusion. A 30 to 2 compression to ventilation ratio (one cycle) is recommended in patients without advanced airways. According to the 2010 ACLS Guidelines, asynchronous ventilations at 8 to 10 per minute are administered if an endotracheal tube or extraglottic airway is in place, while continuous chest compressions are performed simultaneously.(26)

2. Resuscitation team management :

The resuscitation of a sudden cardiac arrest (SCA), by its nature a low frequency, high acuity event, is often chaotic. A growing body of literature demonstrates that by employing the principles of Crisis Resource Management, adapted from the aviation industry and introduced into medical care by anesthesiologists, disorganization during resuscitation decreases and patient care improves.(27) Training in these principles to improve the quality of ACLS performed by healthcare clinicians is feasible and recommended.(28)

Two principles provide the foundation for Crisis Resource Management: leadership and communication.(27) Resuscitations usually involve a number of healthcare providers from different disciplines, sometimes from different areas of an institution, who may not have worked together previously. Under these circumstances, role clarity can be difficult to establish. In CRM, it is imperative that one person assumes the role of team leader.(27) This person is responsible for the global management of the resuscitation, including: ensuring that

all required tasks are carried out competently; incorporating new information and coordinating communication among all team members; developing and implementing management strategies that will maximize patient outcome; and reassessing performance throughout the resuscitation.

The team leader should avoid performing technical procedures, as performance of a task inevitably shifts attention from the primary leadership responsibilities. In circumstances where staffing is limited (eg, small community hospital), the team leader may be required to perform certain critical procedures. In these situations, leadership may be temporarily transferred to another clinician or the team leader may be forced temporarily to perform both roles, although this compromises the ability to provide leadership.

In CRM, communication is organized to provide effective and efficient care. All pertinent communication goes through the team leader and the team leader shares important information with the team. When the team leader determines the need to perform a task, the request is directed to a specific team member, ideally by name. That team member verbally acknowledges the request and performs the task or, if unable to do so, informs the team leader that someone else should be assigned. Specific emphasis is placed on the assigned team member repeating back medication doses and defibrillator energy settings to the team leader. This "closed-loop" communication leads to a more orderly transfer of information and is the appropriate standard for all communication during resuscitations.

3. **Initial management and ECG interpretation**:

In the 2010 ACLS Guidelines, circulation has taken a more prominent role in the initial management of cardiac arrest. The new ‘mantra’ is: circulation, airway, breathing (C-A-B). Once unresponsiveness is recognized, resuscitation begins by addressing circulation (chest compressions), followed by airway opening, and then rescue breathing. The 2010 ACLS Guidelines emphasize the importance of excellently performed, uninterrupted chest compressions and early defibrillation. Rescue breathing is performed after the initiation of excellent chest compressions and definitive airway management may be delayed if there is adequate rescue breathing without an advanced airway in place. [(22)]The other initial interventions for ACLS include administering oxygen, establishing intravenous access, placing the patient on a cardiac and oxygen saturation monitor, and obtaining an electrocardiogram (ECG).[(22)]

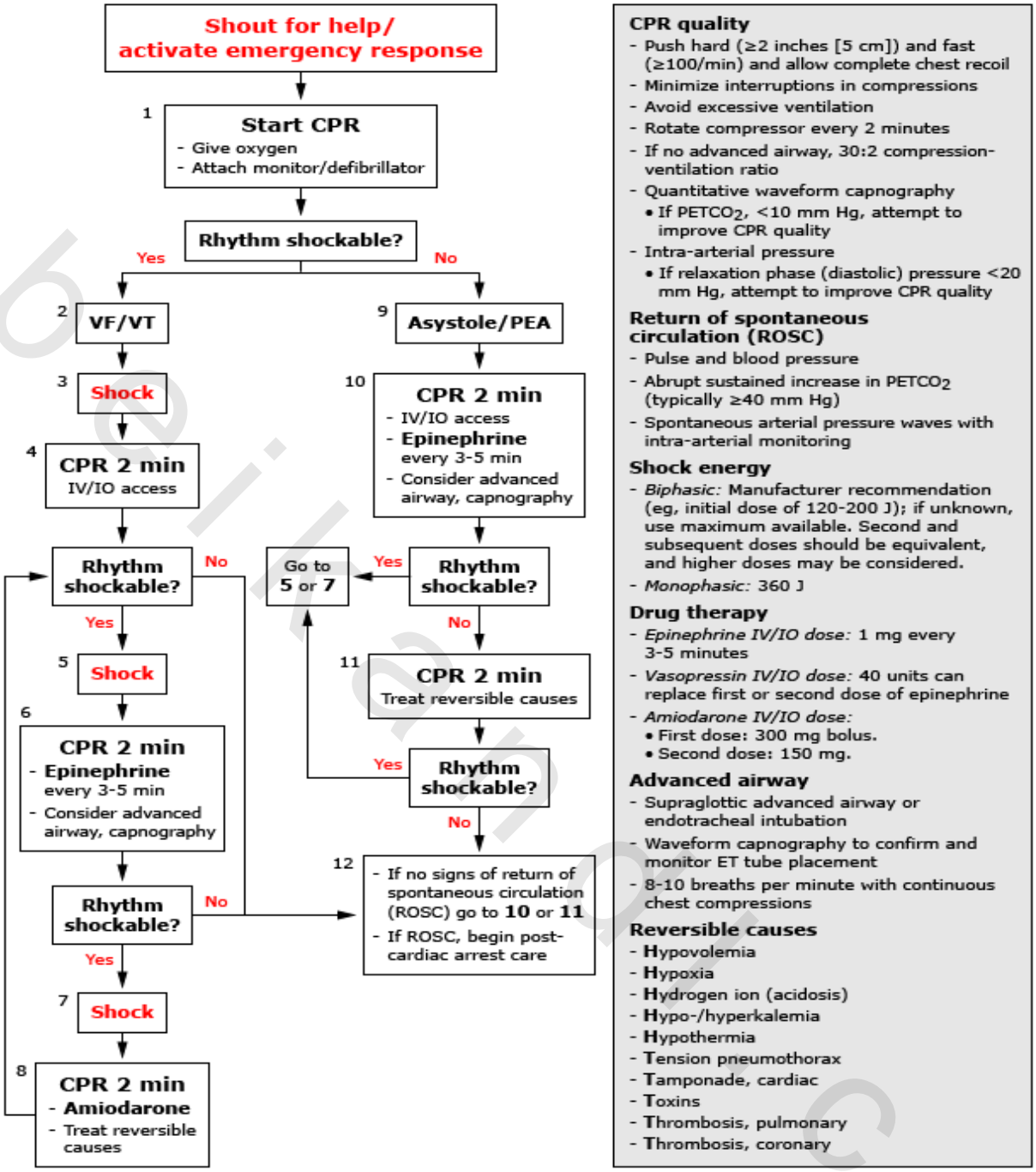

Figure (1): Adult cardiac arrest algorithm[29]

AIRWAY MANAGEMENT DURING ACLS

Ventilation is performed during CPR to maintain adequate oxygenation and eliminate carbon dioxide. Nevertheless, during the first few minutes following sudden cardiac arrest (SCA), oxygen delivery to the brain is limited primarily by reduced blood flow . Therefore, in adults, the performance of excellent chest compressions takes priority over ventilation during the initial period of basic life support. In settings with multiple rescuers or clinicians, ventilations and chest compressions are performed simultaneously. [29,30]

Although research has yet to identify the preferred parameters for ventilation (eg, respiratory rate, tidal volume, inspired oxygen concentration), it is widely believed that a lower minute ventilation is needed for patients in cardiac arrest. Therefore, lower respiratory rates are used (the 2010 ACLS Guidelines recommend 8 to 10 breaths per minute with an advanced airway in place). In addition, hyperventilation is harmful, as it leads to increased intrathoracic pressure, which decreases venous return and compromises cardiac output. Tidal volumes of approximately 600 mL delivered in a controlled fashion such that chest rise occurs over no more than one second is recommended in the 2010 ACLS Guidelines.[29]

Taking these principles into account, the 2010 ACLS Guidelines support the use of a bag-mask device or a blindly placed supraglottic airway for ventilation during the initial management of SCA, deferring placement of an endotracheal tube, unless intubation can be performed without interrupting chest compressions.[30]

A blindly inserted supraglottic airway (eg, laryngeal mask airway, Combitube, laryngeal tube) can be placed without interrupting chest compressions, provides adequate ventilation in most cases, and reduces the risk of aspiration compared to bag-mask ventilation. Therefore, clinicians may prefer to ventilate with a supraglottic device while CPR is ongoing, rather than performing tracheal intubation.[30]

If rescuers decide that tracheal intubation is necessary during CPR, an experienced intubator should perform the procedure, ideally intubation is performed while excellent chest compressions continue uninterrupted.However, if the operator is unable to intubate during the performance of chest compressions, further attempts should be deferred to the two minute interval (after a complete cycle of CPR) when defibrillation or patient reassessment is performed. This approach minimizes loss of perfusion. Attempts at intubation should last no longer than 10 seconds.[29]

The 2010 ACLS Guidelines include the following additional recommendations about airway management during the performance of ACLS: [29]

- Although evidence is lacking, it is reasonable to provide 100 percent oxygen during CPR.
- Routine use of cricoid pressure is NOT recommended.

- Oropharyngeal and nasopharyngeal airways can be useful adjuncts. We encourage their use when performing bag-mask ventilation.
- Continuous waveform capnography (performed in addition to clinical assessment) is recommended for confirming and monitoring correct endotracheal tube placement. If

waveform capnography is not available, a non-waveform CO2 detector or esophageal detector device, in addition to clinical assessment, may be used. Capnography also provides important feedback on the patient response to resuscitation, which is discussed separately.

MANAGEMENT OF SPECIFIC ARRHYTHMIAS

1. Ventricular fibrillation and pulseless ventricular tachycardia

Ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT) are nonperfusing rhythms emanating from the ventricles, for which early rhythm identification, defibrillation, and cardiopulmonary resuscitation (CPR) are the mainstays of treatment (algorithm 1). Early defibrillation is the most critical action in the resuscitation effort, followed by the performance of excellent CPR. Manage potentially treatable underlying causes as appropriate (TABLE 2).[29]

Begin performing excellent chest compressions as soon as sudden cardiac arrest (SCA) is recognized and continue while the defibrillator is being attached. If a defibrillator is not immediately available, continue CPR until one is obtained. As soon as a defibrillator is available, attach it to the patient, charge it, assess the rhythm, and treat appropriately (eg, defibrillate VF or pulseless VT; continue CPR if asystole or PEA). Resume CPR immediately after any shock is given. In the case of a witnessed cardiac arrest, perform defibrillation as quickly as possible. Decreased time to defibrillation improves the likelihood of successful conversion to a perfusing rhythm and of patient survival.[31]

Biphasic defibrillators are recommended because of their increased efficacy at lower energy levels. The 2010 ACLS Guidelines recommend that when employing a biphasic defibrillator clinicians use the initial dose of energy recommended by the manufacturer (120 to 200 J). If this dose is not known, the maximal dose may be used. IT is suggested a first defibrillation using 200 J with a biphasic defibrillator or 360 J with a monophasic defibrillator for VF or pulseless VT. It should be noted that many automated external defibrillators (AEDs) do not allow for adjustment of the shock output.The 2010 ACLS Guidelines recommend the resumption of CPR immediately after defibrillation without rechecking for a pulse. Interrupt CPR to assess the rhythm and administer additional shocks no more frequently than every two minutes. [32]

If VF or pulseless VT persists after at least one attempt at defibrillation and two minutes of CPR, give epinephrine (1 mg IV every 3 to 5 minutes) while CPR is performed continuously. Vasopressin (40 units IV) may replace the first or second dose of epinephrine.

Evidence suggests that antiarrhythmic drugs provide little survival benefit in refractory VF or pulseless VT. Nevertheless, the current ACLS Guidelines state that they may be used in certain situations. The timing of antiarrhythmic use is not specified. It is suggested that antiarrhythmic drugs be considered after a second unsuccessful defibrillation attempt in anticipation of a third shock: [30]

- Amiodarone (300 mg IV with a repeat dose of 150 mg IV as indicated) may be administered in VF or pulseless VT unresponsive to defibrillation, CPR, and epinephrine.
- Lidocaine (1 to 1.5 mg/kg IV, then 0.5 to 0.75 mg/kg every 5 to 10 minutes) may be used if amiodarone is unavailable.
- Magnesium sulfate (2 g IV, followed by a maintenance infusion) may be used to treat polymorphic ventricular tachycardia consistent with torsade de pointes.

Refractory VF or pulseless VT may be caused by an acute coronary syndrome (ACS), in which case percutaneous coronary intervention can be performed if the patient is successfully resuscitated and the procedure is feasible. Note that following cardiac arrest the ECG may be insensitive for ACS; cardiology consultation is needed for patients with return of spontaneous circulation (ROSC).[21]

In summary, the ROSC in VF and pulseless VT hinges on early defibrillation and excellent CPR. Although, the 2010 ACLS Guidelines advocate the appropriate use of advanced airway management and treatment with specific medications, these interventions have not been shown to improve survival in SCA. Therefore, such interventions must never be made at the expense of performing excellent CPR and early defibrillation.

2. Asystole and pulseless electrical activity

Asystole is defined as a complete absence of demonstrable electrical and mechanical cardiac activity. Pulseless electrical activity (PEA) is defined as any one of a heterogeneous group of organized electrocardiographic rhythms without sufficient mechanical contraction of the heart to produce a palpable pulse or measurable blood pressure. By definition, asystole and PEA are non-perfusing rhythms requiring the initiation of excellent CPR immediately when either is present.

In the 2010 ACLS Guidelines, asystole and PEA are addressed together because successful management for both depends on excellent CPR, vasopressors, and reversal of underlying causes, such as hypoxia, hyperkalemia, poisoning, and hemorrhage.After initiating CPR, treat reversible causes as appropriate and administer epinephrine (1 mg IV every three to five minutes). The 2010 ACLS Guidelines state that vasopressin may be given (40 units for the first 10 minutes of resuscitation) in place of the first or second epinephrine dose. Neither asystole nor PEA responds to defibrillation. Atropine is no longer recommended for the treatment of asystole or PEA. Cardiac pacing is ineffective for cardiac arrest and not recommended in the 2010 ACLS Guidelines.[29]

In summary, treatment for asystole and PEA consists of early identification and treatment of reversible causes and excellent CPR with vasopressor administration until either ROSC or a shockable rhythm occurs.

Table (2): Potentially treatable conditions associated with cardiac arrest:[29]

Condition	Common causes	Corrective actions
• **Acidosis**	• Acidosis,	• Reassess Adequacy Of

	• Diabetes, • Diarrhea, • Toxins, • Renal Disease • Shock	Cardiopulmonary Resuscitation, • Oxygenation, And Ventilation; • Consider Intravenous Bicarbonate If Ph<7.20 After Above Actions Have Been Taken
• **Cardiac tamponade**	• HemorrhagicDiathesis, Cancer, • Pericarditis, • Trauma, After Cardiac Surgery, • After Myocardial Infarction	• Administer fluids; • Obtain bedside echocardiogram, if available • Perform pericardiocentesis. • Immediate surgical intervention is appropriate if pericardiocentesis is unhelpful
• **Hypothermia**	• Alcohol Abuse, • Burns, • Central Nervous System Disease, Debilitated Or Elderly Patient, • Drowning, • Drugs And Toxins, • Endocrine Disease, • History Of Exposure, • Trauma	• Limit Initial Shocks For Ventricular Fibrillation Or Pulseless Ventricular Tachycardia To Three; • Initiate Active Internal Rewarming And Cardiopulmonary Support • If Hypothermia Is Moderate (Temperature 30-34°C), Passively Rewarm, And Actively Rewarm Truncal Body Areas.
• **Hypovolemia, haemorrhage**	• Major Burns, • Diabetes, Gastrointestinal Losses, • Hemorrhage, Hemorrhagic Diathesis, • Cancer, • Pregnancy, • Shock And Trauma	• Administer fluids • Transfuse packed red cells if hemorrhage or profound anemia is present • Thoracotomy is appropriate when a patient has cardiac arrest from penetrating trauma and a cardiac rhythm and the duration of cardiopulmonary resuscitation before thoracotomy is <10 min
• **Hypoxia**	• Consider in all patients with cardiac arrest	• Reassess Technical Quality Of Cardiopulmonary Resuscitation, • Oxygenation, And Ventilation; • Reconfirm Endotracheal-Tube Placement
• **Hypomagnesemia**	• Burns, • Diabetic Ketoacidosis, Severe Diarrhea, • Diuretics, And Drugs	• Administer 1-2 g magnesium sulfate intravenously over 2 min

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In summary, treatment for asystole and PEA consists of early identification and treatment of reversible causes and excellent CPR with vasopressor administration until either ROSC or a shockable rhythm occurs.

TERMINATION OF RESUSCITATIVE EFFORTS

Determining when to stop resuscitation efforts is difficult, and little data exist to guide decision-making.Physician survey data and clinical practice guidelines suggest that factors influencing the decision to stop resuscitative efforts include:[33]

- Duration of resuscitative effort >30 minutes without a sustained perfusing rhythm.
- Initial electrocardiographic rhythm of asystole.
- Prolonged interval between estimated time of arrest and initiation of resuscitation.
- Patient age and severity of comorbid disease.
- Absent brainstem reflexes.
- Normothermia.

More objective endpoints of resuscitation have been proposed. Of these, the best predictor of outcome may be the end tidal CO2 level following 20 minutes of resuscitation.[34] End tidal CO2 values are a function of CO2 production and venous return to the right heart and pulmonary circulation. A very low end tidal CO2 (<10 mmHg) following prolonged resuscitation (>20 minutes) is a sign of absent circulation and a strong predictor of acute mortality.[35]It is crucial to note that low end tidal CO2 levels may also be caused by a misplaced (esophageal) endotracheal tube, and this possibility needs to be excluded before the decision is made to terminate resuscitative efforts.[36]

Resuscitation in the emergency department does not appear to be superior to field resuscitation by emergency medical services personnel. Therefore, EMS personnel should not be required to transport all victims of sudden cardiac arrest to the hospital, if further resuscitation is deemed futile .[37]

Large, retrospective cohort studies have assessed criteria (BLS and ALS) for the prehospital termination of resuscitative efforts in cardiac arrest..[38]Both BLS and ALS criteria demonstrated high specificity for identifying out-of-hospital cardiac arrest patients with little or no chance of survival. Studies of another clinical decision rule suggest that it too accurately predicts survival and would reduce unnecessary transports substantially if implemented.[39]

Preliminary evidence suggests that bedside echocardiography may be useful during cardiac arrest to assess cardiac activity and to help determine prognosis.[40]

PROGNOSIS FOLLOWING SUDDEN CARDIAC ARREST

Despite advances in the treatment of heart disease, the outcome of patients experiencing SCA remains poor.[41] 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.[42]

The reasons for the continued poor survival of patients with SCA are not certain.[41] 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).[43]

With the brain's heightened susceptibility to global ischemia, the majority of cardiac arrest patients who are resuscitated successfully have impaired consciousness, and some remain in a vegetative state. The need for protracted high-intensity care of neurologically devastated survivors presents an immense burden to healthcare systems, patients' families, and society in general.[44]

To limit this burden, clinical factors and diagnostic tests are used to prognosticate functional outcome. With the limitation of care or withdrawal of life-sustaining therapies as a likely outcome of prognostication, studies have focused on poor long-term prognosis (vegetative state or death) based on clinical or test findings that indicate irreversible brain injury. A recent study showed that prognostication based on neurological examination and diagnostic modalities influenced the decision of physicians and families on the timing of withdrawal of life-sustaining therapies.[45]

Recently, several systematic reviews evaluated predictors of poor outcome, including clinical circumstances of cardiac arrest and resuscitation, patient characteristics, neurological examination, electrophysiological studies, biochemical markers, and neuroimaging.[46]Despite

a large body of research in this area, the timing and optimal approach to prognosticationof futility are controversial. Most importantly, the impact of therapeutic hypothermia on the overall accuracy of clinical prognostication has undergone only limited prospective evaluation.

Prognostication in Patients Not Treated With Hypothermia

1. Pre–Cardiac Arrest Factors

Many studies have identified factors associated with poor functional outcome after resuscitation, but no studies have shown a reliable predictor of outcome.

- **Age:** Advanced age is associated with decreased survival after resuscitation,[47]but at least 1 study suggested that advanced age did notpredict poor neurological outcome in survivors.[48]
- **Pre cardiac arrest health:** including conditions such as diabetes mellitus,[49]sepsis,[50] metastatic cancer,[51]renal failure,[52] were associated with outcome, although not enough to be reliable predictors of function.

2. Intra–Cardiac Arrest Factors

Many factors during the resuscitation process have been associated with functional outcome, but no single factor has been identified as a reliable predictor.

- **Time between arrest and CPR:** some association with poor functional outcome has been found between a long interval between collapse and the start of CPR and increased duration of CPR to ROSC,[53]but high false-positive rates (FPRs) make this unreliable for predicting poor outcome.[54]
- **Quality Of CPR:**Lack of adherence to established CPR guidelines,including failure to deliver a shock or achieve ROSC before transport, and long preshock pauses with extended interruption to assess rhythms and provide ventilation have been associated with poor outcome.[55]
- **end tidal carbon dioxide:**A maximum end-tidal carbon dioxide (ETCO2) of 10 mm Hg (as a marker of cardiac output during CPR) is associated with worse outcomes.[56]

3. Post–Cardiac Arrest Factors

The bedside neurological examination remains one of the most reliable and widely validated predictors of functional outcome after cardiac arrest.[57]With sudden interruption of blood flow to the brain, higher cortical functions, such as consciousness, are lost first, whereas lower brain-stemfunctions, such s spontaneous breathing activity, are lost last.[58]

Not surprisingly, retention of any neurological function during or immediately after CPR portends a good neurological outcome. The absence of neurological function immediately after ROSC, however, is not a reliable predictor of poor neurological outcome.

The reliability and validity of neurological examination as a predictor of poor outcome depends on the presence of neurological deficits at specific time points after ROSC.[59]

- **Brain stem reflexes:**Findings of prognostic value include the absence of pupillary light reflex, corneal reflex,facial movements, eye movements, gag, cough, and motor response to painful stimuli. Of these, the absence of pupillary light response, corneal reflex, or motor response to painful stimuli at day 3 provides the most reliable predictor of poor outcome (vegetative state or death).[60]On the basis of a systematic review of the literature, it was reported that absent brain-stem reflexes or a Glasgow Coma Scale motor score of 2 at 72 hours had an FPR of 0% (95% CI 0% to 3%) for predicting poor outcome.[54] In a recent prospective trial, it was reported that absent pupillary or corneal reflexes at 72 hours had a 0% FPR (95% CI 0% to 9%), whereas absent motor response at 72 hours had a 5% FPR (95% CI 2% to 9%) for poor outcome.[60]Poor neurological outcome is expected with these findings because of the extensive brain injury involving the upper brain stem (midbrain), which is the location of the ascending reticular formation (responsible for arousal) and where the pupillary light response and motor response to pain are facilitated.[61]When the neurological examination is used as the basis for prognostication, it is important to consider that physiological and pathological factors (hypotension, shock, and severe metabolic abnormalities) and interventions (paralytics, sedatives, and hypothermia) may influence the findings and lead to errors in interpretation.[54] Therefore, adequate efforts must be undertaken to stabilize the patient medically before prognosis is determined. Use of the bedside neurological examination can also be compromised by complications such as seizures and myoclonus, which, if prolonged and repetitive, may carrytheir own grave prognosis.[62]

- **Myoclonus status epilepticus:**Although status myoclonus has been regarded as a reliable predictor of poor outcome (FPR 0% [95% CI 0% to 8.8%]),[54]it may be misdiagnosed by nonneurologists.

- **Glasgow coma scale (GCS):**Combinations of neurological findings have been studied in an attempt to find a simple summary scale such as the Glasgow Coma Scale,[63]which is based on the patient's best verbal, eye, and motor responses. The Glasgow Coma Scale score especially a low motor component score is associated with poor outcome.[64]

4. Neurophysiological Tests

- **Somatosensory-evoked potentials:**The recording of somatosensory-evoked potentials (SSEPs) is neurophysiological test of the integrity of the neuronal pathways from a peripheral nerve, spinal cord, or brain stem to the cerebral cortex.[65]The SSEP is probably the best and most reliable prognostic test, because it is influenced less by common drugs and metabolic derangements. The N20 component (which represents the primary cortical response) of the SSEP with median nerve stimulation is the best studied evoked-potential waveform in prognostication.[66] In an unresponsive cardiac

arrest survivor, the absence of the bilateral N20 component of the SSEP with median nerve stimulation from 24 hours to 1 week after ROSC very reliably predicts poor outcome (FPR for poor outcome_0.7%, 95% CI 0.1% to 3.7%).[54]The presence of the N20 waveform in comatose survivors, however, did not reliably predict a good outcome.[67]It also has been suggested that the absence of the N20 waveform is better than the bedside neurological examination as a predictor of poor outcome.[60]Widespread implementation of the SSEP in postresuscitation care requires advanced neurological training; this investigation can be completed and interpreted only in specialized centers. Other evoked potentials, such as brain-stem auditory and visual and long-latency evoked-potential tests, have not been thoroughly tested or widely replicated for their prognostic value in brain injury after cardiac arrest.[68]

- **Electroencephalography:**electoencephalography (EEG) has been studied extensively as a tool for evaluating the depth of coma and extent of damage after cardiac arrest. Many malignant EEG patterns have been associated with poor functional outcome, the most reliable of which appear to be generalized suppression to 20 microvolts, burst-suppression pattern with generalized epileptiform activity, and generalized periodic complexes on a flat background.[54] However, the predictive value of individual patterns is poorly understood, because most studies categorize a panel of patterns as malignant. A meta-analysis of studies reporting malignant EEG patterns within the first 3 days after ROSC calculated an FPR of 3% (95% CI 0.9% to 11%), The authors concluded that the EEG alone was insufficient to prognosticate futility.[54]Electroencephalography is noninvasive and easy to record even in unstable patients, but its widespread application is hampered by the lack of a unified classification system, lack of consistent study design, the need for EEG expertise, and its susceptibility to numerous drugs and metabolic disorders.[69]Recent advances in the analysis of electroencephalography and continuous bedside recording have addressed many of these limitations. Quantitative EEG (QEEG) analysis will enable nonneurologists to use this technology at the bedside.[70] Given the capability of the EEG to monitor brain activity continuously, future research can focus on developing better methods to prognosticate early, track the brain's real-time response to therapies, help understand the impact of neurological injury caused by seizures, and develop novel treatment strategies.[71]

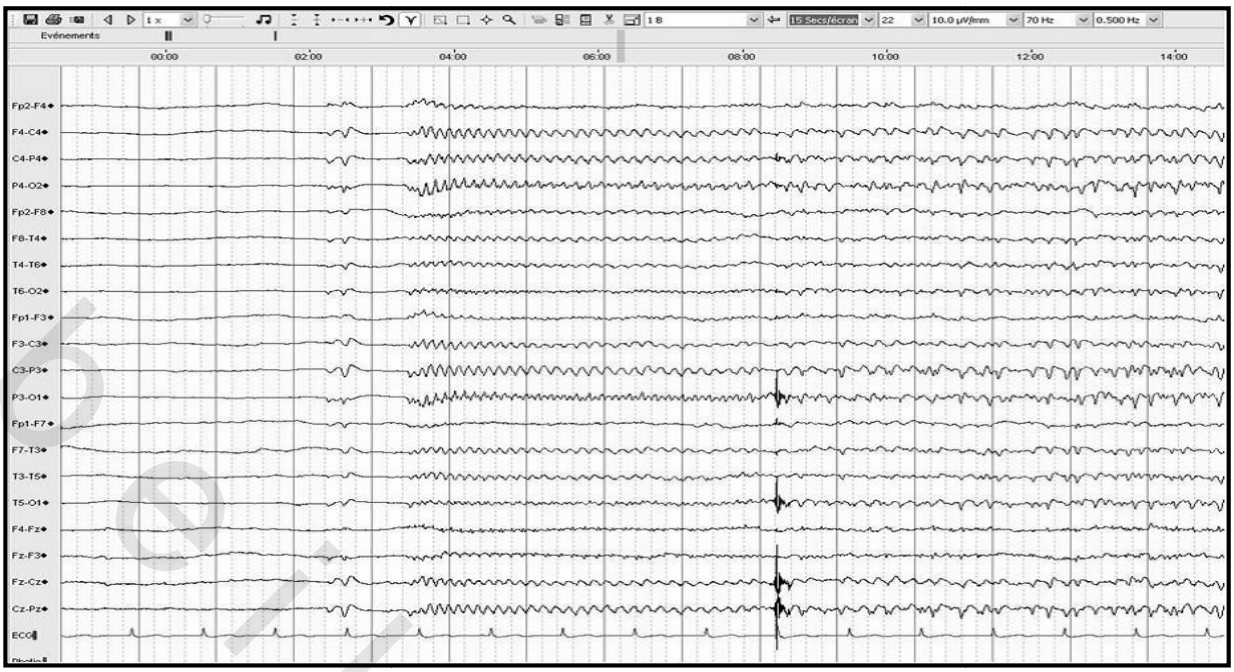

Figure 2: EEG shows discontinuous EEG background activity ("burst-suppression pattern").

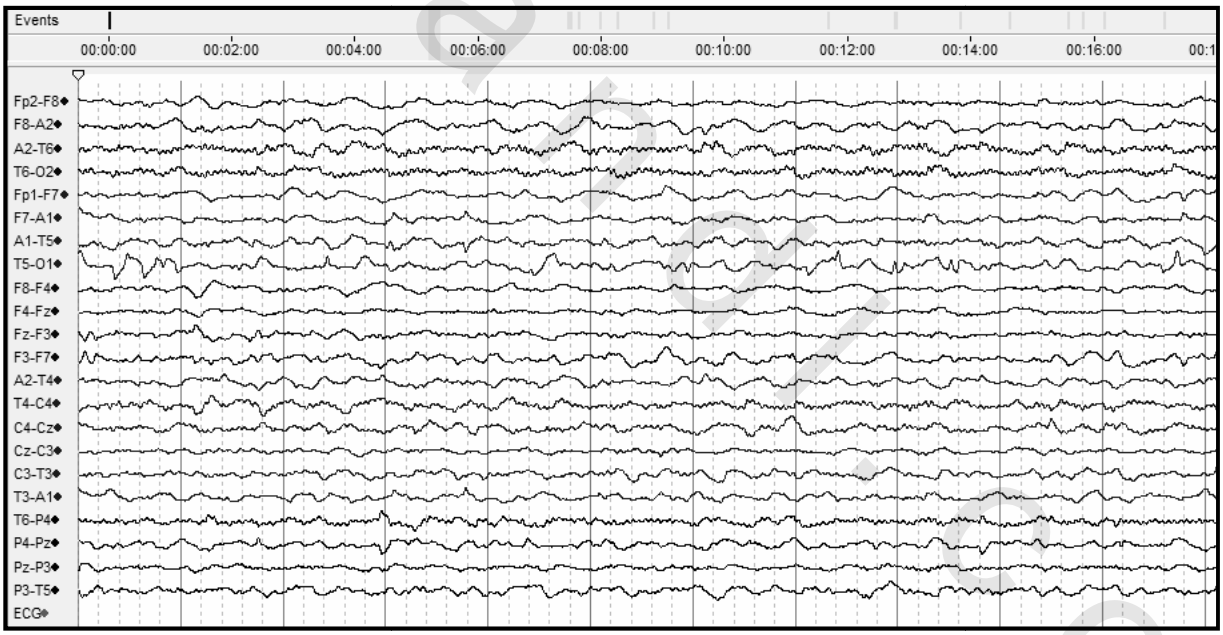

Figure 3:EEG of post-cardiac arrest male patient, classified as low voltage background, showing diffuse cerebral slowing with suppression of the background, calibration of 10uv/cm.

5. Neuroimaging and Monitoring Modalities

Neuroimaging is performed to define structural brain injury related to cardiac arrest. The absence of a well-designed study has limited the use of neuroimaging in the prediction of

outcome after cardiac arrest. The most common type of neuroimaging studied has been cranial CT.

- **Cranial CT studies** can show widespread injury to the brain with changes in edema characteristics.[72]The acquisition of magnetic resonance imaging studies is challenging in critically ill patients because of restrictions on the type of equipment that can be placed in the room; however, this is becoming less problematic, and magnetic resonance imaging studies in the critically ill are increasingly being undertaken. Some limited studies have shown that diffuse cortical abnormalities in diffusion-weighted imaging or fluid-attenuated inversion recovery are associated with poor outcome.[73]

- **Metabolic abnormalities**ie, (increasing lactate) detected in the brain using functional neuroimaging with magnetic resonance spectroscopy[74] and positron emission tomography have also been associated with poor outcome.[75]

6. Biochemical Markers

Biochemical markers derived initially from cerebrospinal fluid (creatine phosphokinase–BB)[76] or peripheral blood (neuron-specific enolase[NSE] and S100_) have been used to prognosticate functional outcome after cardiac arrest. The ease of obtaining samples has favored blood-based biochemical markers over those in cerebrospinal fluid.

- **Neuron specific enolase:** neuron specific enolse (NSE) is a cytoplasmic glycolytic enzyme found in neurons, cells, and tumors of neuroendocrine origin; concentrations increase in serum a few hours after injury.

One study showed that an NSE cutoff of 71.0 g/L drawn between 24 and 48 hours after ROSC was required to achieve an FPR of 0% (95% CI 0% to 43%) for predicting poor outcome with a sensitivity of 14%.[77]

Another study showed that serum NSE concentrations 33 g/L drawn between 24 and 72 hours after ROSC predicted poor outcome after 1 month, with an FPR of 0% (95% CI 0% to 3%).[78] Numerous other studies show various thresholds from 30 to 65 _g/L for poor outcome and mortality.[79]

- **S100 marker:** The biochemical marker S100_ is a calcium-binding protein from astroglial and Schwann cells. In cardiac arrest survivors, 1 study showed that an S100_ cutoff of _1.2 _g/L drawn between 24 and 48 hours after ROSC was required to achieve an FPR of 0% (95% CI 0% to 14%), with a sensitivity of 45%.315 Other less robust studies show similar high specificity with low sensitivity.[80] Although a recommendation has been made on the use of biochemical markers, specifically NSE _33 _g/L, as a predictor of poor outcome,[54] care must be taken. This caution is based on problems such as lack of standardization in study design and patient treatment, the wide variability of threshold values to predict poor outcome.