Cardio-pulmonary Resuscitation : an overview of Recent Advances in Concepts and Practices

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Introduction

During the 40 years since the introduction of modern cardio-pulmonary resuscitation (CPR), there have been many advances in the field of emergency cardiovascular care (ECC). For the first time an international consensus on the art and science of CPR has been achieved. There have been significant changes in the practice of CPR based on new evidences and the survival rates following arrest are on the rise. The range of activities and skills to be learnt during Basic Life Support (BLS) have been expanded to include defibrillation with Automated External Defibrillators (AED), prompt recognition and action for myocardial infarction and stroke, and recognition and relief of foreign body airway obstruction (FBAO) in addition to initial airway assessment, rescue breathing by expired air ventilation and chest compressions.

While performing expired air ventilation, small volumes of air are recommended, whereas a uniform compression-ventilation ratio of 15:2 has been adopted for a single rescuer as well as two rescuers. AED have been made available in an ongoing effort to reduce time lapse in defibrillation and since their introduction, survival rate after cardiac arrest has been reported to go up from 30% to 49%. Defibrillators with biphasic current are also being used with several advantages.

None of the alternative techniques of chest compression have been shown to be universally superior to standard manual CPR. Vasopressin has been recommended in case of fibrillatory arrest and is claimed to have several advantages over adrenaline, the age old vasopressor in CPR. Contribution of lignocaine during arrest to aid resuscitation from refractory ventricular fibrillation remains contentious, whereas amiodarone has been found useful in treatment of both atrial and ventricular arrhythmias and is now recommended

during Advanced Cardiac Life Support (ACLS) after defibrillation and adrenaline.

Cardiac arrest is defined as cessation of cardiac mechanical activity. It is a clinical diagnosis, confirmed by unresponsiveness, absence of detectable pulse and apnea or agonal respirations. CPR is an attempt to restore spontaneous circulation through any of the broad range of manoeuvres and techniques. It is essential to act immediately as irreversible damage can occur in a short time. Within 15 seconds of cardiac arrest, the patient loses consciousness, electro-encephalogram (EEG) becomes flat after 30 sec, pupils dilate fully after 60 seconds and cerebral damage takes place within 90-300 seconds.

In the last four decades, there have been significant changes in the practice of CPR leading to improvement in the survival rates. Over the past few years, an attempt has been made to reach a consensus regarding various concepts and practices with a view to bring uniformity in all the aspects of CPR. Towards achieving this aim, an International Guidelines 2000 Conference on CPR and ECC was organized, which was the first international conference of the world, assembled specifically to produce international guidelines [1]. At the same time, the International Liaison Committee on Resuscitation (ILCOR) which was formed earlier in 1992, was entrusted with responsibility for co-ordinating the international science review and developing advisory statements in the field of resuscitation. CPR now includes training in first aid, recognition of warning signs of myocardial infarction and stroke and management of foreign body airway obstruction. However, the present account will limit itself to summarising the newer trends in the practice of BLS and ACLS.

Emergency cardio-vascular care

It consists of all the responses that are necessary to

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deal with sudden and often life-threatening events affecting the cardiovascular, cerebrovascular and pulmonary systems in order to promote the highest chance of survival. These responses include recognition of early warning signs of heart attack and stroke, provision of BLS at the scene, provision of ACLS and defibrillation at the scene, and lastly stabilization before transport and transfer to hospital. However, this is possible only if following sequence of events occur in quick succession :

Early Access → Early BLS → Early Defibrillation → Early ACLS

These events are like links of a chain and if any link is weak the outcome is likely to be poor. The first link is to gain early access to the Emergency Medical System (EMS). Since, ischaemic heart disease (IHD) remains the commonest cause of cardiac arrest and ventricular fibrillation is the commonest presenting rhythm, the current recommendation in adults is to phone the EMS first since the aim is to defibrillate as early as possible [2]. On the contrary, in children where the primary event is respiratory or in victims of trauma and drowning, one should provide BLS first and then activate the EMS (phone fast). In both the situations, particularly in the first instance, early bystander CPR can be of immense value.

Basic Life Support

The action taken during the first few minutes of an emergency are critical to victim's survival. BLS covers 3 links in the chain of survival. This refers to maintaining airway, supporting breathing and circulation at the site of arrest till further help becomes available (Fig 1). It also implies that no equipment is used initially and if any equipment is used it is then called BLS with airway adjuncts. Conventionally BLS comprises initial airway assessment, rescue breathing by expired air ventilation and chest compressions. However, the range of activities and skills to be learnt during BLS have been expanded to include defibrillation with AED, prompt recognition and action for myocardial infarction and stroke, and recognition and relief of foreign body airway obstruction [3].

Sequence of action during BLS: the new changes

Maintaining Airway

The first aim is to ensure safety of the rescuer and victim followed by assessment of responsiveness by shaking the victim and shouting. If the victim is unresponsive, his head should be positioned and airway should be opened by performing the Triple Airway Manoeuvre (Head tilt-Chin lift-Jaw thrust) (Fig 2). If there is suspicion regarding cervical spine injury in trauma victims, head tilt should be avoided so as to eliminate

any movement at the neck.

Supporting Breathing

Breathing is assessed by looking at the chest for any respiratory movements, listening or feeling for breath sounds. If there are no breathing efforts, initially 2 rescue breaths are provided. In absence of any equipment, mouth to mouth or nose resuscitation remains the best method [4]. However, barrier devices are more acceptable from hygiene point of view. While performing expired air ventilation, the aim should be to deliver small volume (400-600 ml) over 1-2 seconds with cricoid pressure if possible. The earlier practice of delivering large volume of air (800-1200 ml) and step on step breathing is no longer recommended [5] because of the risk of regurgitation. Besides, it was thought that large volume also helps in CO₂ elimination. However, it is now recognized that during arrest, CO₂ delivery to the lungs is very low. It is hypoxia, which needs to be prevented and small volumes are equally effective in achieving same level of oxygenation as achieved by larger volumes.

Supporting Circulation

No longer than 10 seconds should be spent in assessing circulation. Pulse check for lay rescuer has now been de-emphasized since it takes too much time and the accuracy is only 65% [6]. Therefore, one should look for other signs of life such as movements or respiratory efforts. Only trained persons should check for carotid pulse (Fig 3) and if it is absent, one should get ready for performing chest compressions.

Chest compressions mimic the state of circulation and provide coronary and cerebral blood flow. Properly performed external chest compressions can produce peak systolic pressure of 60-80 mm of Hg. In adults, a ratio of 15:2 (15 chest compressions followed by 2 artificial breaths) has been adopted for a single rescuer (Fig - 4) as well as two rescuers. The ratio has been found to provide more number of chest compressions as compared to erstwhile 5:1 which was recommended for two rescuers. There is evidence to suggest that victims of arrests are more likely to survive if a higher number of compressions are delivered during CPR even if the victims receive fewer ventilations [7]. In children however, the rate of compression should be maintained close to 100/min or roughly 2 per second. Optimal sternal compression is generally gauged by identifying the compression force that generates a palpable carotid or femoral pulse. Effective cerebral and coronary blood flow has been shown to occur when for each compression, 50% of duty cycle is devoted to the chest compression phase and 50% to the chest relaxation phase [8].

Defibrillation

This step is the key link in survival. Early detection is central to the chances of successful outcome, which decreases rapidly. The survival rate is 90% if the patient is defibrillated within 1 minute and only 10% if it is delayed till 10 minutes after arrest [9]. Therefore the aim should be to defibrillate within 5 minutes before ventricular fibrillation (VF) degenerates into asystole. The conventional defibrillators use monophasic sinusoidal wave pattern current whereas the newer ones are automated and use biphasic current with several advantages such as low energy, less myocardial damage as indicated by less ST changes in post resuscitation electrocardiogram [10]. In many developed countries with advanced EMS, AEDs have been made available (Figs. 5, 6). These are positioned at various places and paramedical, police or fire brigade personnel are trained to handle it as early as possible in case of any arrest. AEDs are simple devices which have only two leads which, when applied on the chest, diagnose the rhythm and deliver electric shock in case of fibrillation. Since the introduction of AEDs, survival rate after cardiac arrest has been reported to go up from 30% to 49% [11] and hence, these are claimed to be the single greatest advance in the field of CPR.

Correct defibrillation technique is important so that trans-thoracic impedance is minimized and amount of electrical energy delivered to heart is maximized [12]. Common faults are inadequate contact with paddles, excessive jelly and improper positioning. In an adult, one should start with 200 J and increase the energy to 360 J after two shocks. In case of biphasic defibrillators, non-escalating energy of 200 J is considered optimal. In children, the energy requirement is calculated @2-4 J/kg. The optimal paddle sizes are 13 cm (adults), 8-10 cm (children) and 4.5-5 cm (infants). The standard paddle position is where one electrode is placed over the right side of upper part of sternum just below clavicle and the other one is placed over apex.

Advanced Cardiac Life Support

Even though BLS, if performed properly, can effectively maintain circulation for 10 to 15 minutes, further help must be sought. The best BLS efforts can achieve a cardiac output which is only 30% of normal [13]. Oxygenation also is less than ideal as the expired air contains only 16% oxygen. ACLS is best done in a hospital or at the scene by expert paramedical personnel if significant delay is anticipated in transfer of the victim to the hospital. The tasks performed during this phase, include continuation of BLS, use of equipment for ventilation and circulation, 12 lead electrocardiography (ECG) and arrhythmia recognition, establishment of

intravascular access and drug therapy and lastly prehospital fibrinolytic therapy for acute coronary syndromes (ACS) and stroke in certain advanced health care setups.

Adjuncts for Oxygenation

The victims of arrest are likely to have significant amount of ventilation perfusion mismatch, intrapulmonary shunting and acidosis, all contributing to hypoxia. 100% inspired oxygen will tend to maximize arterial blood oxygen saturation and, in turn, systemic oxygen delivery. Various devices which can improve oxygenation, are bag and mask devices (Fig-7), airway adjuncts, such as oral airways, laryngeal mask airway (LMA) and Combitube (Figs. 8,9). In certain situations such as complete airway obstruction with foreign body, surgical airway may have to be obtained by using minitracheostomy sets (Fig. 10) or Trans-Tracheal Jet Ventilation (TTJV). However, the best method and the "Gold standard" of oxygen delivery is, without doubt, tracheal intubation [14] and should be done at the first available opportunity.

Alternative Techniques of Chest Compression

The classical form of chest compression is the one that has been described above. However, several other methods have been evaluated in the quest of a technique which can achieve better cardiac output and thus improve survival. There are certain methods which are as efficacious and are therefore recommended; such as Interposed Abdominal Compression CPR (IAC-CPR) (Fig. 11). Active compression and decompression CPR (ACD-CPR) and Pneumatic Vest CPR. However these methods need extra personnel, equipment and training which may not be available. These methods have been shown to increase forward blood flow but to levels which are still significantly less than normal cardiac output. Maximum benefits are obtained when these adjuncts are begun early in the treatment of cardiac arrest [15]. However, to date no adjunct has been shown to be universally superior to standard manual CPR. Invasive CPR or internal cardiac compressions can be undertaken in specific situations such as thoracic trauma, suspected cardiac tamponade, open heart surgery or in cases of fracture ribs where external compressions are likely to be ineffective.

Venous access in CPR

Drugs are used with an aim to improve organ perfusion and to protect brain and heart from hypoxia, to facilitate defibrillation and to prevent recurrence of arrhythmias and to normalize metabolic derangements. An important issue during CPR is the best route of drug administration. Even though a central venous line is

Fig. 1 : Algorithmic approach to cardiac arrest

Fig. 2 : Head tilt and chin lift

Fig. 3 : Feeling the carotid pulse

ideal, its placement takes time, expertise and it has the potential to interrupt the process of CPR. Therefore, the next best option is a peripheral line. It has been shown that circulation time can be significantly reduced if 20 ml of saline is pushed after a drug bolus in a

Fig. 4 : External cardiac compression : the correct position

Fig. 5 : Automated external defibrillator

peripheral line [16]. The other routes of drug delivery are tracheal, intra-osseous and even intra-cardiac/nasal/femoral. The tracheal route deserves special mention as it has been found to be very effective for lignocaine, epinephrine, atropine and naloxone (LEAN) and can be used if there are no venous lines [17]. The drug (2-3 times the intravenous dose) is diluted in 10 ml of saline and instilled in the tube, followed by 5 ventilations. Intra-osseous route may be tried in children in the same dosages as those for the tracheal route. Intra-cardiac, nasal or femoral routes are no longer recommended.

Pharmacotherapy in CPR

(i) Vasopressors

Adrenaline or epinephrine enhances cerebral and myocardial blood flow by preventing arterial collapse and by augmenting aortic diastolic pressure through alpha 1 and 2 receptors. The optimal dose is 1 mg every 3-5 minutes. In children, it can be given in the dosages of 10 µg/kg or 0.1 ml/kg of 1 in 10000 solution. Dose

Fig. 6 : Automated external defibrillator on patient

Fig. 7 : Holding bag and mask on the patient

Fig. 8 : The laryngeal mask airway

dependent improvement in regional myocardial and cerebral blood flow has been recorded in various studies but no improvement in hospital discharge and survival has been seen. Therefore, high doses are not recommended at present but can be considered [18].

Fig. 9 : The combitube (with tracheal and oesophageal cuffs)

Fig. 10 : Minitracheostomy set

Fig. 11 : Interposed abdominal compression CPR

Vasopressin acts on non-adrenergic V_1 receptors and has been recommended in case of fibrillatory arrest (40 IU, single dose). The studies have recorded several advantages over adrenaline such as lack of beta effect, no impact of acidosis on its efficacy and even lower incidence of post resuscitation myocardial dysfunction [19]. However, its role in asystole, in children and

whether a second dose is required or not, is not established.

(ii) Antiarrhythmic agents [20] :

Lignocaine is of undoubted value in treatment of ventricular tachycardia (VT) and its ability to prevent VF has also been demonstrated. However, contribution of lignocaine during arrest, to aid resuscitation from refractory VF remains contentious. Other problems associated with it are increase in defibrillation threshold, higher incidence of asystole after its use and a very delicate toxic to therapeutic ratio. However, on the basis of available evidence, lignocaine is acceptable in pulseless VT after defibrillation, haemodynamically unstable ventricular premature contractions and haemodynamically stable VT but is a second choice behind amiodarone and procainamide. Dose of lignocaine is 1-1.5 mg/kg bolus. It is repeated in the dose of 0.5-0.75 mg/kg not exceeding 3mg/kg in one hour. Infusion @ 1-4 mg/min is started only if spontaneous circulation returns during CPR.

There are now reports of efficacy of antiarrhythmic agents such as amiodarone, procainamide, sotalol and flecainide. Amiodarone is a complex drug with effect on sodium, potassium and calcium channels as well as alpha and beta blocking properties. It is useful in treatment of both atrial and ventricular arrhythmias. It is now recommended during ACLS after defibrillation and adrenaline. It is effective in haemodynamically stable VT, polymorphic VT and wide complex tachycardia of uncertain origin. It is also an effective adjunct to cardioversion in paroxysmal supra ventricular tachycardia (PSVT) and atrial fibrillation (AF). It is useful in patients with poor left ventricular function and has low incidence of pro-arrhythmogenicity compared to other drugs. The dose is 150 mg diluted in 20 ml of 5% dextrose given over 10 min, followed by infusion @ 1 mg/min for 6 hours and then @ 0.5 mg/min. Bretylium is now not recommended as a second line drug in VF since the drug is not freely available and is also associated with troublesome side effects such as hypotension.

(iii) Others

Sodium-bicarbonate (NaHCO_3) : There is no definite recommendation regarding its use in cardiac arrest. There are no studies demonstrating its effect on outcome in cardiac arrest. For brief resuscitation procedures sodium-bicarbonate is probably irrelevant but in prolonged arrest exceeding 10 minutes, one may consider giving sodium-bicarbonate in the dose of 1 meq/kg. However, bicarbonate therapy should be considered only after the confirmed interventions such as defibrillation, cardiac compression, intubation, ventilation and vasopressor

therapy have been ineffective. Whenever possible, bicarbonate therapy should be guided by the bicarbonate concentration or calculated base deficit obtained from blood gas analysis. Sodium-bicarbonate is definitely indicated if there is hyperkalemia and tricyclic anti-depressant toxicity and pre-existing metabolic acidosis.

Calcium (Ca^{++}) usually has no role unless patient presents with calcium channel blocker toxicity or if there is evidence of hypocalcemia or hyperkalemia. The dose of calcium gluconate is 0.5 ml/kg (maximum - 20 ml) of 10% solution whereas 10% solution of calcium chloride can be given in a dose of 0.2 ml/kg upto a maximum of 10 ml.

Magnesium (Mg^{++}) mirrors the action of extracellular potassium in stabilizing myocardial cell membrane and it is indicated only if hypokalemia or hypomagnesemia is known to be present or the patient is diagnosed to be having a rhythm called "Torsade de Pointers". The dose (as magnesium sulphate) is 1-2 gm diluted in 100 ml of 5% dextrose given over 30-60 min followed by an infusion of 0.5-1.0 gm/hour.

Atropine enhances automaticity and conduction of both sinoatrial and atrio-ventricular node and is most effective in haemodynamically significant bradycardia because of vagal stimulation. It also has a role in slow pulseless electrical activity (PEA). The recommended dose in PEA and asystole is 1.0 mg IV and repeated 3-5 minutes if required. For bradycardia, the dose is 10 µg/kg repeated every 3-5 minutes up to a total dose of 40 µg/kg.

Assessment of CPR and when to stop?

While continuing CPR, one must check for proper placement of tube which may get dislodged during chest compressions and attention should be paid to reversible causes such as hypoxia, hypovolemia, hypothermia, hyper / hypokalaemia (4Hs) and cardiac tamponade, tension pneumothorax, toxin or tablets (poisoning) and thromboembolism (4Ts). Unfortunately, there is no certain method of knowing about the efficacy of CPR. Amongst various parameters which have been studied, end tidal carbon-di-oxide measurements show promise as a measurement of CPR effectiveness. Clinical studies have shown that patients, who were successfully resuscitated from cardiac arrests, had significantly higher end-tidal CO_2 levels than the patients who could not be resuscitated [21].

Termination of CPR efforts can be a difficult decision to make. It is apparent from the literature that prolonged resuscitative efforts are unlikely to be successful if there is no return of spontaneous circulation within 30 minutes of commencement of CPR [22]. It is appropriate to extend the duration of CPR accordingly, if spontaneous

circulation returns at any time. Before discontinuation however, one must ensure that hypothermia and other reversible causes have been ruled out, appropriate drugs have been given, adequate defibrillation has been done, ventilation has been adequate and the rhythm of asystole has been present for more than 5-10 minutes. It is equally important to know when not to start CPR. While 'Do Not Attempt Resuscitation' directives are still not legally tenable in our country, there is definitely a case for not starting CPR for neonates with known anencephaly or congenital anomaly incompatible with survival

Conclusion

Survival from cardiac arrest depends on a series of critical interventions. There are additional variables which modify the outcome, the most important being the interval between collapse to initiation of CPR and collapse to defibrillation. All the EMSs in developed world are trying to build up a system, which would be able to extend BLS activity within as short a time as possible. In our context where community training as well as pre-hospital emergency services are non-existent, the aim should be to strengthen all the links within the hospital so that victims of cardiac arrest receive adequate and timely CPR and therefore have higher chances of survival. Regular training of doctors and paramedical personnel is equally important as CPR skills are easily forgotten and hence need to be reinforced periodically. At the same time an effort should be made to begin a programme to train wider groups of population with CPR skills so that bystander CPR can become a possibility.

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