MANAGEMENT OF CARDIOPULMONARY RESUSCITATION

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The American population is aging and the incidence of cardiac arrests will increase because the prevalence of heart disease and arrhythmias increases with advancing age. Twenty-five million people are now over the age of 65, and 2.7 million are over the age of 85. Projected estimates by the US Census Bureau for the year 2030 indicate that one in five persons in the US (approximately 35 million people) will be older than age 65, and one in four of the elderly will be older than age 85.1

In 1990, there were approximately 2 million deaths in the United States, of which cardiovascular disease accounted for approximately 50% or 1 million deaths.3 Sudden cardiac death represents 30% of all traumatic and 50% of all coronary artery disease-related deaths,36 or approximately 300,000 to 400,000 deaths annually in the United States.31 Sudden cardiac arrest from coronary artery disease may be treatable with rapid resuscitation and defibrillation. Delayed or ineffective intervention may result in avoidable deaths in these patients. Owing to the large numbers of affected people, the American Heart Association has strived to present to health care workers, paramedics, and lay people the latest research on cardiopulmonary resuscitation (CPR). The most recent national conference in 1992 resulted in new guidelines for CPR, but no separate recommendations were given for the elderly.

Early in the development of resuscitation guidelines, it became apparent that neonates and children have very different causes of arrest and different physiologic responses to various interventions as compared with adults. Separate guidelines have been developed for resuscitation in the pediatric population. In the future, it may become apparent that the elderly will also need separate guidelines from the other adults, but few data exist currently regarding the responses of geriatric patients to various interventions. This article discusses
CPR in the elderly by examining the available outcome data, the known physiologic changes with aging that may affect decisions made during resuscitation, and the possible altered responses to resuscitation drugs owing to aging.

OUTCOME OF RESUSCITATION

Because modern CPR was first described by Kouwenhoven et al, it has achieved wide application as a standardized medical intervention both in and out of the hospital. When they first presented closed-chest CPR from Johns Hopkins, they reported a 70% survival-to-discharge rate in patients ranging in age from 2 months to 80 years. Unfortunately, this has never been duplicated. Most recent studies of CPR of hospitalized patients report rates of survival to discharge that are much lower (0%-30%).

The questions of whether resuscitative efforts are effective in the elderly have been extensively studied and reviewed. Despite numerous studies, the results remain conflicting. Results of CPR outcome in hospitalized patients following cardiac arrest have been variable. Table 1 summarizes the literature reporting the effect of age on survival-to-hospital discharge after CPR for adult in-hospital cardiac arrest from 1980 to the present. Studies involving only intensive care units (ICUs) or cardiac care units (CCUs) were not included. Most of the information available on CPR comes from studies of patients of all ages. Three studies examined the results of CPR in geriatric departments or specifically set a certain age as study inclusion criteria. The survival-to-discharge rate varied from 0% to 29%, and age was or was not a factor depending on the study.

A major problem in comparing the various studies and drawing firm conclusions regarding the appropriateness of CPR in the elderly lies in the difficulty of comparing varied patient populations. Even among in-hospital arrests, there still remains variability in underlying disease, time to onset of resuscitation efforts, and different initial rhythms. Many of the studies did not give specific numbers regarding whether the arrest occurred in the emergency department, on the ward, in the ICU, or whether the patient was on telemetry. This is important because it has been shown that resuscitations on the ward and in the ICU have a lower success rate than in specialized areas such as the CCU, operating room, or emergency room. The low rate of successful resuscitation in ICUs probably reflects the severity of illness in that patient population, while the low success rate on the ward probably reflects delayed detection.

It is supported by several of these studies that the response to CPR is not equivalent in the elderly with debilitating diseases versus the fit, vigorous, and active elderly. Comparisons between studies are again difficult owing to the evaluation of different diseases felt to be possible confounding variables. Pre-arrest factors believed to be most predictive of a poor CPR outcome are not consistently identified in the literature. For instance, Bedell et al described homebound patients as those who had not pursued activities outside the home before their acute illness. This definition proved to be an important marker for the outcome of CPR in that study because only 4% of homebound patients survived as compared with 27% of non-homebound patients. Using different definitions, Murphy et al and Urberg and Ways found a similar trend toward increased survival with higher patient functioning prior to the arrest.

In an effort to identify patients who have little chance of surviving CPR, George et al proposed a pre-arrest morbidity (PAM) index. Three points were assigned to five variables (hypotension, uremia, malignancy, pneumonia, and homebound lifestyle). One point was assigned to 10 other variables (angina
Table 1. SUMMARY OF OUTCOME DATA REGARDING IN-HOSPITAL ARREST AND SURVIVAL-TO-HOSPITAL DISCHARGE

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>N</th>
<th>Year</th>
<th>Survival</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedell⁷</td>
<td>Prospective</td>
<td>294</td>
<td>1981–1982</td>
<td>41/294 = 14%</td>
<td>Age not predictive</td>
</tr>
<tr>
<td>Burns¹¹</td>
<td>Retrospective</td>
<td>122</td>
<td>1985</td>
<td>9/122 = 7%</td>
<td>Age not predictive</td>
</tr>
<tr>
<td>George²⁴</td>
<td>Prospective</td>
<td>140</td>
<td>1985</td>
<td>34/140 = 24.3%</td>
<td>Age ≥ 65 is a risk factor, but no association with age partitioned at 60, 63, 67, 70, 80</td>
</tr>
<tr>
<td>Gulati²⁸</td>
<td>Prospective</td>
<td>52</td>
<td>1982</td>
<td>9/52 = 17%</td>
<td>Age not significant</td>
</tr>
<tr>
<td>Kvale³⁷</td>
<td>Retrospective</td>
<td>86</td>
<td></td>
<td>10/86 = 12%</td>
<td>All patients &gt; age 75</td>
</tr>
<tr>
<td>Lawrence⁹⁹</td>
<td>Retrospective</td>
<td>340</td>
<td>1987–1989</td>
<td>88/340 = 25.9%</td>
<td>VT or VF improved survival</td>
</tr>
<tr>
<td>Murphy⁴⁶</td>
<td>Retrospective</td>
<td>259</td>
<td>1978–1987</td>
<td>17/259 = 6.5%</td>
<td>All patients ≥ age 70</td>
</tr>
<tr>
<td>O’Keeffe⁴⁸</td>
<td>Retrospective</td>
<td>274</td>
<td></td>
<td>25/274 = 9.1%</td>
<td>19.2% survival (&lt;70) vs. 3.4% survival (≥ 70) P = 0.001</td>
</tr>
<tr>
<td>Roberts⁵⁸</td>
<td>Retrospective</td>
<td>310</td>
<td>1985–1986</td>
<td>30/310 = 9.7%</td>
<td>Age not predictive</td>
</tr>
<tr>
<td>Robinson⁹⁹</td>
<td>Retrospective</td>
<td>83</td>
<td>1989</td>
<td>24/83 = 29%</td>
<td>EMD/asystole increased mortality</td>
</tr>
<tr>
<td>Rosenberg⁶¹</td>
<td>Retrospective</td>
<td>300</td>
<td>1988–1989</td>
<td>82/300 = 23.3%</td>
<td>VT or VF improved survival</td>
</tr>
<tr>
<td>Rozenbaum⁶²</td>
<td>Retrospective</td>
<td>71</td>
<td>1986</td>
<td>13/71 = 18%</td>
<td>Age not significant</td>
</tr>
<tr>
<td>Schneider⁶⁴</td>
<td>Meta analysis</td>
<td>19,955</td>
<td>1966–1990</td>
<td>2994/19,955 = 15%</td>
<td>16.2% survival (&lt;70) vs. 12.4% survival (≥ 70) P &lt;0.001</td>
</tr>
<tr>
<td>Taffet⁷⁴</td>
<td>Retrospective</td>
<td>329</td>
<td>1984–1985</td>
<td>22/329 = 16%</td>
<td>All survivors &lt;70 years old</td>
</tr>
<tr>
<td>Tortolani⁷⁷</td>
<td>Retrospective</td>
<td>470</td>
<td></td>
<td>69/470 = 15%</td>
<td>From Veterans hospital</td>
</tr>
<tr>
<td>Tresch⁷⁸</td>
<td>Retrospective</td>
<td>151</td>
<td>1989–1990</td>
<td>39/151 = 26%</td>
<td>Age predictive</td>
</tr>
<tr>
<td>Urberg⁶⁴</td>
<td>Retrospective</td>
<td>121</td>
<td>1983–1984</td>
<td>13/121 = 11%</td>
<td>Age not predictive</td>
</tr>
</tbody>
</table>
pectoris; S3 gallop; oliguria; sepsis; and New York Heart Association class III, IV heart failure, acute myocardial infarction, coma, cirrhosis, recent cerebrovascular event, and mechanical ventilation). They found that the score was correlated linearly with CPR success. No patient with a PAM score greater than 8 survived to discharge in their study. Again, other studies have only partly supported the criteria listed in the PAM index, and several have proposed modifications to the index with variable results.\textsuperscript{18, 49}

The time to the start of resuscitation and defibrillation has been examined as an independent variable. Rapid correction of ventricular fibrillation (VF) or ventricular tachycardia (VT) by defibrillation is the definitive treatment.\textsuperscript{73} Defibrillation is probably the most important intervention in terms of survival. Many clinical studies have shown that the likelihood of survival is inversely related to the time from arrest to the first defibrillation attempt.\textsuperscript{29} These results have led the American Heart Association to state that all personnel whose jobs require performance of CPR must be trained to use defibrillators, especially automated external defibrillators (AED).\textsuperscript{2}

Aside from time to onset of resuscitation, it also has been recognized that the duration of the arrest was an important factor in determining outcome. Prolonged CPR leads to increased defibrillation thresholds and decreased cardiac output, and usually rarely leads to successful resuscitation.\textsuperscript{85} Patients who did not respond in the field have very little chance of responding after arrival in the emergency room.\textsuperscript{13} In the study, no patient lived to be discharged from the hospital. This grim prognostic factor has also been reported in the pediatric population and, therefore, does not appear to be age related.\textsuperscript{50}

The initial rhythm at the time of onset of CPR has been shown to be an independent variable in determining outcome in numerous studies. According to reviews by several authors, survival is improved if the initial rhythm is VF or VT.\textsuperscript{46, 59} The elderly may tend to have different rhythms during cardiac arrest. Tresch et al studied 381 patients who experienced out-of-hospital cardiac arrests and whose arrests were witnessed by the paramedics.\textsuperscript{79} Patients were divided into elderly patients (>70 years old) and younger patients (\(\leq 70\) years old). Interestingly, 42\% of younger patients demonstrated VF as the initial out-of-hospital rhythm compared with only 22\% of elderly patients \((P < 0.001)\). Elderly patients were more likely to demonstrate pulseless electrical activity (PEA) or asystole on arrest. This study led investigators to propose that there may be a difference in the mechanism of cardiac arrest between elderly and younger patients. Tresch et al\textsuperscript{79} hypothesized that cardiac arrest in many elderly patients may be related to abnormal left ventricular function with underlying heart failure because many had such prior histories and were receiving digoxin and diuretics. Other investigators speculate that the presence of PEA may represent a noncardiac cause of arrest such as massive pulmonary embolus.\textsuperscript{14} It is generally accepted that outcomes are poorer with rhythms not involving VF or VT for the elderly as well as the rest of the adult population. When analyzed separately, elderly who do present with VT or VF appear to have the expected resuscitation success rates of younger adults.

There is one last reason why the studies have been inconclusive regarding age. The analysis of age as a continuous or dichotomous variable may be the reason why age has not consistently been shown to influence the success of CPR.\textsuperscript{11} Treating age as a dichotomous rather than a continuous variable may influence age-associated likelihood of resuscitation.\textsuperscript{18} For instance, Burns et al\textsuperscript{11} reported an odds ratio of 2.7 in their logistic regression model for CPR success in patients aged 40 to 70. When the data were analyzed with age as a continuous variable, age was not associated with the outcome of CPR. Tortolani et al
reported a significant difference in survival-to-discharge rate of 10.3% for patients 68 years or older versus 19.4% for patients younger than 68 years old. They did not explain their rationale for this age grouping, and the age limits may have been determined during the data analysis rather than prospectively.

A large number of studies have tried to evaluate the outcome of CPR in the elderly, but there are many variables to consider. Studies are difficult to compare owing to patient variances, differences in start and duration of resuscitation, presenting rhythm, and the place of arrest. It is clear that not all elderly people can be considered equal. The severely debilitated of any age may have a significantly reduced chance of survival when compared with a vigorous healthy elderly person with arrest secondary to myocardial infarction. It is not possible or reasonable based on current data to consider drafting guidelines concerning initiation or withholding resuscitative efforts based on age alone. Proper patient selection is critical.

**PHYSIOLOGIC CHANGES WITH AGING AND EFFECTS ON CARDIOPULMONARY RESUSCITATION**

The elderly may have changes that can negatively impact on the efficacy of various interventions during all stages of CPR. More studies are now available regarding the physiologic changes in the elderly; but currently, there are no studies involving the impact of age on CPR interventions. Table 2 lists some of the physiologic changes known to occur with aging. The following sections will address some of the possible ramifications these physiologic differences can have during CPR.

<table>
<thead>
<tr>
<th>Pulmonary</th>
</tr>
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<tbody>
<tr>
<td>Lung volumes: FRC, VC, RV</td>
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<tr>
<td>PaO₂, Physiologic dead space</td>
</tr>
<tr>
<td>Ventilatory drive with hypercapnia</td>
</tr>
<tr>
<td>Ventilatory drive with hypoxemia</td>
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<tr>
<td>Lung compliance</td>
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<tr>
<th>Cardiovascular</th>
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<tbody>
<tr>
<td>Basal heart rate</td>
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<tr>
<td>Maximal heart rate</td>
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<tr>
<td>Stroke volume</td>
</tr>
<tr>
<td>Circulating norepinephrine levels</td>
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<tr>
<td>Circulating epinephrine levels</td>
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<tr>
<td>Response to adrenergic stimulation</td>
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<tr>
<td>Receptor density</td>
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<tr>
<th>Renal</th>
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<tr>
<td>Renal blood flow</td>
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<td>Glomerular filtration rate</td>
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<tr>
<th>Gastrointestinal</th>
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<tr>
<td>Hepatic blood flow</td>
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<td>Hepatic mass</td>
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<tr>
<th>Musculoskeletal</th>
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<tr>
<td>Muscle mass</td>
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<tr>
<td>Total body water</td>
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<tr>
<td>Bone density</td>
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<th>Neurologic</th>
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<tr>
<td>Cortical neurons</td>
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<tr>
<td>Cerebral blood flow</td>
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Airway: Evaluation

The initial steps in the basic life support (BLS) protocols are aimed at establishing an airway and providing adequate oxygenation and ventilation. The elderly have a decrease in upper airway reflex sensitivity, possibly owing to a reduction in the nerve ending of the irritant receptors. This should be considered during decisions regarding whether or not patients need endotracheal intubation in order to minimize complications and prevent life-threatening aspiration.

Anatomically, the geriatric airway differs from the younger adult in several ways. Mouth opening may be limited by temporomandibular joint disease. Teeth, when present, may be in poor condition and be easily dislodged and lost down the oropharynx. Special care must be used during direct laryngoscopy. Dentures and bridges need to be removed; however, ventilation can be more difficult in an edentulous patient owing to difficulty establishing a seal with either mouth-to-mouth or mouth-to-mask procedures.

Establishment of an airway may be more difficult owing to inability to position the head because of decreased range of motion in the cervical spine. Immobility at the atlanto-occipital joint may make visualization of the glottis challenging or impossible owing to inability to extend the neck. Forced extension of the neck can result in atlanto-occipital subluxation and spinal cord injury.

Airway: Management

There has been recent interest in several new techniques for providing oxygenation and ventilation during CPR, which might be applicable to resuscitation of the elderly. One of these is transtracheal ventilation, where a catheter is placed through the cricothyroid membrane. Oxygen can then be delivered through the catheter with a jet mechanism or by continuous flow. One major disadvantage is that dislodgement of the transtracheal catheter may lead to life-threatening pneumomediastinum, pneumothorax, or subcutaneous emphysema. Once these complications occur, laryngoscopy, cricothyroidotomy, or tracheostomy may be impossible to perform successfully.

Other alternative methods to establish an airway other than intubation involve using the esophageal obturator airway (EOA), pharyngo-tracheal lumen airway (PTLA), or the laryngeal mask airway (LMA). All function by allowing the provider to establish ventilation without direct visualization of the vocal cords, but all require prior training in order to place the airway.

The EOA is a large bore tube with a distal cuff that when inflated in the esophagus prevents regurgitation. Multiple openings at the pharynx allow air to be delivered into the trachea. Although this appears to be an excellent solution for the patient in whom direct laryngoscopy cannot be accomplished, several cases of esophageal rupture and unrecognized tracheal intubation leading to hypoxia and death have been reported.

Similar to the EOA, the PTLA consists of a double balloon system. The distal balloon can occlude either the esophagus or the trachea depending on the blind placement. It can function as an endotracheal tube if the trachea is entered, or as an EOA if the esophagus is entered. This may be easier to use in the elderly because a face-to-mask seal is not required to deliver adequate tidal volume ventilation when properly positioned. Excellent ventilation and oxygenation can be achieved in canine models, but more human studies are required to evaluate the efficacy of this device, and no studies specific to the elderly exist.

Another method for airway establishment is the laryngeal mask airway.
This device consists of an inflatable diaphragm with an opening, which fits over the larynx. A recent study demonstrated that 94% of paramedic and medical students could successfully place the LMA on the first attempt after adequate training. The major disadvantages of the LMA are lack of ability to ventilate with high airway pressures and lack of ability to prevent aspiration. Older patients ventilated with the LMA may present a problem owing to their decreased airway reflexes, increased risk for aspiration, and higher incidences of restrictive or obstructive pulmonary processes requiring high airway pressures for oxygenation and ventilation.

Training is required for insertion of any of the above mentioned devices, and serious complications have been reported for all of them. If possible, the endotracheal tube remains the optimal method for airway protection and ventilation during CPR.

**Circulation: Evaluation**

After ventilation, the next step in BLS/advanced cardiac life support (ACLS) algorithms is assessment of the circulation. The usual recommendation is to assess for a carotid pulse. Unfortunately, the elderly have an increase in the number of carotid artery lesions and more severe vascular narrowing. Patients older than 74 years have an average of two carotid plaques per patient, 20.5% of whom have more than three plaques. The mean percentage of narrowing was 9.1% in those aged 45 to 64 years, 17.3% in subjects aged 65 to 74 years, and 27.1% in those 74 years or older. Palpation at the carotid artery may increase risk for either occluding carotid flow or disrupting a plaque with distal embolization and a lack of pulsation in the carotid may not indicate lack of circulation. A possible alternative would be to use the femoral pulse as a measure of circulation.

Measurement of carbon dioxide in the exhaled air has been proposed as one method for evaluating cardiac output during CPR. If the minute ventilation and carbon dioxide production are constant, and cardiac output equals pulmonary blood flow, then the excretion of carbon dioxide will be dependent on lung perfusion, which reflects systemic perfusion. End tidal carbon dioxide values over 15 mm Hg have been associated with additional successful resuscitation. Elderly patients who may have a higher incidence of lung disease and reasons for larger dead space have not been studied separately.

**Circulation: Management**

Chest compressions are to be instituted when the patient does not have evidence of adequate circulation. Chest compressions generate limited blood flow. Cardiac output is reported to be between 25% to 30% of normal, at best, and rapidly decreases with delays in initiation of CPR.

Two theories have been proposed to explain how CPR creates blood flow. The cardiac pump theory suggests that the heart is compressed between the sternum and the spine and that this results in blood being squeezed into the systemic and pulmonary circulation. A more recent theory, the thoracic pump model, suggests that pressure changes in the thorax are responsible for forward flow and the heart is merely a conduit. No model completely explains all the physiologic observations during CPR, and blood flow is probably owing to a combination of the two models. The elderly, who have a high incidence of underlying valvular dysfunction, may be at risk for even lower cardiac outputs owing to inefficient blood movement with external chest compressions.
External cardiac massage also carries significant risk. It can produce extensive injuries, especially in the elderly, whose ribs and sternum may be weakened by osteoporosis or other metabolic conditions. Internal injuries of the heart, lungs, great vessels, liver, and upper gastrointestinal tract are also at risk in older patients who have decreased resilience in their thoracic wall. In patients with osteopenia and dorsal kyphosis, there have been case reports of chest compression induced thoracolumbar transvertebral fractures as well.5

Several studies have addressed manual and mechanical compression devices. Mechanical devices appear to improve cardiac output as judged by the end tidal carbon dioxide concentration.86 The force and depth of compression with the mechanical devices should be more standardized and less susceptible to human error and fatigue. Theoretically, they should increase cardiac output while decreasing the risk of patient injury.

One device currently being investigated is the active compression-decompression device (ACD). This mechanical adjunct was developed from a case report where a patient was successfully resuscitated by his son who used a toilet plunger to perform CPR.43 Studies in humans have been performed with a handheld device that includes a handle, force gauge, and a suction cup. The device allows standard compression of the chest according to ACLS guidelines, and active decompression of the chest by lifting upward on the handle. The force gauge allows the user to gauge the force and depth of compressions.

In two studies of hospitalized patients, the use of ACD CPR led to increased 24-hour survival, but survival-to-hospital discharge did not achieve significance.83 ACD and manual CPR were similar in terms of incidence of rib fractures, hepatic trauma, and other visceral damage on autopsy. Further studies are needed to better define the best patient population that may benefit from this new intervention. No data are available on long-term survival or differential survival of elderly populations using this device.

Drug Therapy

It has been well established that changes in body composition occur with aging, including decreases in total body water and lean body weight and an increase in body fat content.90 This results in an increase in volume of distribution for lipophilic drugs, and a decrease in volume of distribution for hydrophilic drugs. The degree of drug binding to plasma proteins might also be decreased in old age because of a decrease in albumin, the major binding protein in the human body. There is evidence to show that there is decreased beta-adrenergic responsiveness in the elderly.38 This change may be responsible for changes in resting heart rate and cardiac output as well as changes in the sensitivity to pharmacologic interventions.81 During a cardiac arrest, establishment of intravenous access should be accomplished rapidly. If adequate peripheral access is available, then that access should be used until time is available and circumstances determine the need for central access.

Epinephrine

The use of adrenergic agonists during resuscitation has been a subject of much research and controversy. The most recently published ACLS guidelines state that standard-dose epinephrine (1 mg IV push) be given as the first drug following three unsuccessful attempts at defibrillation. Successive doses have been changed from every 5 minutes to a range of 3 to 5 minutes. Alternative epinephrine dosing guidelines are considered class IIb (possibly effective) recommendations. Other options include escalating dosing with 1 mg followed by 3
mg, followed by 5 mg every 3 minutes; intermediate dosing with 2 to 5 mg per dose, or high dosing with 0.1 mg/kg every 5 minutes. The data on both the efficacy and safety of the use of high-dose epinephrine continue to be conflicting. Several studies on both human and animal models have suggested that the coronary perfusion pressure, cerebral blood flow, and return of spontaneous circulation are improved with high-dose epinephrine. However, the cardiac index, oxygen consumption, and systemic oxygen delivery are decreased, and systemic vascular resistance and 6-hour lactic acid levels were higher. No significant difference was found in survival-to-hospital discharge (5% of the patients in the high-dose group versus 4% in the standard group). Increasing cumulative dose of epinephrine administered during resuscitation is independently associated with poor neurologic outcome, but in randomized trials of high-dose versus standard-dose epinephrine, there were no statistically significant differences in neurologic outcomes between the two groups. The conflicting results can probably be explained by differences in the time of resuscitation as opposed to the actual dose of epinephrine given.

Some investigators have questioned whether epinephrine in any dose is the most effective adrenergic agonist in improvement of cerebral blood flow and coronary perfusion pressure. It may be that the improved hemodynamics seen with high-dose epinephrine are actually related to alpha effects. This has led investigators to study whether use of pure alpha agonists can increase hemodynamics and vital organ perfusion. So far, no outcome advantages have been found for norepinephrine, phenylephrine, or methoxamine in the general adult population.

Vasopressin

Vasopressin, a nine amino acid peptide that is a potent vasoconstrictor and nonadrenergic agent, has been found to improve myocardial blood flow and cerebral perfusion in the porcine model of cardiac arrest. In 1996, eight adult cases of in-hospital cardiac arrest resuscitated with vasopressin after unsuccessful defibrillation and epinephrine were reported. Three patients lived to hospital discharge with no neurologic deficits. Lindner et al then designed a randomized, double-blind trial using 40 units of vasopressin or epinephrine in 40 out-of-hospital patients with VF resistant to defibrillation or epinephrine. There was a statistically significant difference in restoration of spontaneous circulation and 24-hour survival in the vasopressin group, but only a trend toward improved hospital-to-discharge survival. Although these preliminary results appear promising, no large trials have been completed, and standard guidelines using epinephrine are still preferred for all adults, including the elderly.

Determining the optimal use of adrenergic agonists in elderly patients has special problems. Aging leads to increased beta-adrenergic receptor density but a reduced cardiovascular response to sympathtic stimulation when compared with younger adults. Baseline levels of norepinephrine, but not epinephrine are increased. Changes in left ventricular compliance, cardiac output, heart rate, and baroreceptor responses may increase the elderly patient’s response to numerous drugs. These altered responses need to be considered during resuscitation efforts. Higher risk for coronary artery stenosis and carotid artery stenosis may further alter the fine balance between oxygen supply and demand. The critically ill elderly may pose a challenge when trying to find an effective adrenergic agonist therapy owing to competing physiologic needs.

Magnesium

Magnesium therapy is recommended in the ACLS guidelines as the treatment for torsades de pointes as well as for patients after myocardial infarction.
Magnesium deficiency is associated with cardiac arrhythmias, cardiac insufficiency, and sudden cardiac death. Hypomagnesemia also increases coronary and systemic vasoconstriction and increases afterload. The elderly are prone to both hypomagnesemia and hypermagnesemia. Hypomagnesemia is mostly owing to decreased intake, but has also been reported in patients taking diuretic therapy, or in patients with malabsorption or diabetes mellitus. Hypermagnesemia has been associated with impaired renal function or with increased abnormal absorption.

No separate reports exist regarding the use of magnesium or incidence of torsades de pointes in the elderly. Studies have shown decreased in-hospital mortality in patients 70 years or older who received magnesium versus placebo after an acute myocardial infarction. Rapid infusions of magnesium have been reported to lead to hypotension or asystole, but the elderly in the trial tolerated 6 grams of magnesium sulfate during the first 3 hours, 10 grams during the next 21 hours, and 6 grams during the last 24 hours.

**Adenosine**

Adenosine is now recommended as the drug of choice for narrow complex tachycardias and as a second agent for use in indeterminate wide-complex tachycardias. The mechanism of action of adenosine includes inhibition of atrioventricular (AV) and sinoatrial (SA) node activity, attenuation of ventricular automaticity, and inhibition of some ventricular arrhythmias. A comparison of responses in young and elderly patients showed no difference, suggesting that the sensitivity to adenosine does not change with age. These data suggest that the elderly may have tachyarrhythmias that are as responsive to adenosine as in a younger adult population.

Adenosine may lead to transient periods of sinus bradycardia, heart block, or ventricular ectopy, but given its short half-life, it produces few adverse hemodynamic effects. Recent studies have used adenosine safely for wide-complex tachycardia and prehospital treatment of supraventricular tachycardias. It has also been found to be safe in postoperative and critically ill patients. No evidence exists to contraindicate using adenosine in the elderly. However, there are several drug interactions that are important and may be encountered in the elderly patient. Theophylline is an adenosine receptor antagonist and patients taking the drug may be refractory to adenosine. Patients taking carbamazepine and dipyridamole may experience a prolonged effect of adenosine owing to drug interactions, which prolong its half-life.

**Antiarrhythmics**

In animals, both lidocaine and bretylium increase the amount of energy required to induce VF and decrease the defibrillation threshold, although this is somewhat more controversial. In two randomized, controlled trials comparing lidocaine and bretylium in cardiac arrest patients, it appears that both agents were comparable in efficacy. This has led the American Heart Association to recommend using lidocaine first in the algorithm because physicians are more familiar with this drug. Some investigators believe that there may be additive effect between bretylium and lidocaine and recommend alternating the doses. No separate studies comparing the two drugs exist for the elderly. With prolonged infusions, there is data that the half-life of lidocaine can increase. The recommendations are to reduce the infusion in patients older than 70 years of age and in patients with hepatic dysfunction and decreased cardiac output.
There has been some enthusiasm for the use of amiodarone during CPR. It may be beneficial for patients who intermittently develop rhythms capable of adequate perfusion but the arrhythmia cannot be permanently suppressed with other antiarrhythmics. The clinical efficacy of amiodarone use in CPR is not well established, but the use of bretylium and amiodarone appear comparable for the treatment of ventricular arrhythmias in a randomized study. In long-term use of amiodarone in the elderly, dose-dependent bradycardia is more common, especially in combination with either beta blockers or digoxin.

**Sodium Bicarbonate**

In the new guidelines from the American Heart Association (AHA), sodium bicarbonate is now only recommended for the treatment of hyperkalemia. Pre-existing metabolic acidosis and overdose with a tricyclic antidepressant are class IIa (probably efficacious) indications and prolonged arrest time is a class IIIb indication. Data on treatment of metabolic acidosis with differing buffers have found no survival benefit.

Bicarbonate may shift the oxyhemoglobin curve, produce hypernatremia, cause a paradoxic acidosis in the heart and brain, and inactivate simultaneously administered catecholamines. Adequate ventilation and restoration of cardiac output should be the main goals used to treat acidemia during cardiac arrest. It is unknown whether or not aging changes any of the above effects. It is important to remember that older patients with underlying lung disease may have difficulty eliminating the carbon dioxide that is generated from the sodium bicarbonate and, therefore, may be at risk for worsening acidosis.

**Cerebral Protection**

The ultimate goal of CPR is to restore cardiac, pulmonary, and neurologic function. Standard resuscitative efforts provide only about 20% of normal cerebral perfusion. The global cerebral ischemia of cardiac arrest is different from that associated with atherosclerotic cerebrovascular disease. Many studies involving mechanisms of neurologic injury resulting from ischemia, as well as the secondary injuries that result from reperfusion, are in progress. Much of the research on cerebral protection has been directed at therapy which could possibly prevent the reperfusion injury. Studies have included the use of calcium channel blockers, free radical scavengers, mediators of inflammation, antagonists to excitatory neurotransmitter receptors, and hypothermia. Some have shown marginal success, but no clearly useful interventions are currently available.

Better understanding of vascular tone and control of regional blood flow will be necessary in order to maximize neurologic protection. In rats, intermediate age brain may be more tolerant to hypoxic ischemic brain injury than either the very young or the very old brain. In humans, some studies have suggested that no age-related changes occur in cerebral blood flow or autoregulation in the resting, awake state. However, other studies have reported changes in cerebral perfusion in the elderly with dementia, hyperlipidemia, and inactivity. It may be that alterations in regional blood flow and autoregulation may occur with aging and make neurologic recovery following resuscitation more difficult, but no studies have addressed this issue with thorough neuropsychiatric testing post-resuscitation.
PATIENTS' EXPECTATIONS

The goals of health care are to preserve life and relieve suffering. Unfortunately, CPR often does not achieve these goals. For some patients, CPR ends up returning a rhythm capable of generating cardiac output, but only after multiple organ systems have suffered ischemia. These patients are now left with several days of invasive procedures in the ICU unit until care is eventually withdrawn or multi-organ system failure develops. Many health care providers agree that the process of making a decision regarding whether or not to perform CPR should include the patient’s quality of life, medical condition, and his or her expressed wishes (see also article by P. Hoehner elsewhere in this issue). In order to become active participants, patients must be well informed. Unfortunately, studies have shown that few patients were knowledgeable about CPR and that most overestimated their chances of survival. In a study involving patients 65 years of age or older, in either an acute care hospital or long-term care facility, 45% of study participants felt that the average person would have a better than 50% chance of surviving CPR. Only 15% believed that for the older adult, the success rate would be 11% to 25% (the actual success rate as reported in the literature). Forty percent believed that their own chances of surviving CPR were greater than 50%. Given their current health status and quality of life, 65% of the study population wanted CPR and 15% were not sure. From these results, it appears that more effort must be placed on providing accurate information about CPR to the elderly population.

Patients believe it is the physician’s responsibility to discuss the issue, but are often hesitant to interrupt their physician’s busy schedule to insist on a discussion. On the other hand, caregivers often are reluctant to raise the issue. They are concerned that the patient might interpret the discussion as subtle hints that his or her condition is poor or that the physician is unwilling to provide maximal therapy. Unfortunately, it is these pre-arrest discussions that may be the most important in the overall management of CPR.

Discussions of CPR prior to the patient becoming ill would allow him/her a chance to discuss wishes with family members, and avoid having to make decisions in a crisis situation. It should also be stressed to the patients that a do-not-resuscitate order does not mean that other treatments will be limited or that they will be abandoned. In the best scenario, the decision of whether to perform CPR should involve physicians, nurses, patients, and their families, and the decision should be determined well in advance of the crisis. This management actually should apply to all patients and not just the elderly.

CONCLUSION

Many physiologic changes occur with aging, and there are many elderly adults at risk for cardiac arrest in this country. Few data exist to explain how these changes may alter the response to resuscitation or whether this subpopulation should be treated differently with respect to airway management, chest compression, drug therapy, or cerebral protection.

Numerous attempts have been made to define whether or not resuscitation efforts should be based on age alone. The present data do not support withholding or terminating efforts based on age, but do suggest that the circumstances surrounding the arrest, the underlying condition of the patient, and prior wishes of the patient must be taken into consideration. More research on these questions, as well as cost benefit analyses, must be done before guidelines can be established for this unique but growing population.
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