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In Patients With Cardiac Arrest, Does Early Defibrillation Reduce Mortality?

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In Patients With Cardiac Arrest, Does Early Defibrillation Reduce Mortality?

A Literature Review

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Abstract

Background: Cardiac arrest is a devastating disorder that affects millions of people each year. Often having a sudden onset, cardiac arrest is almost certainly lethal if prompt treatment is not started. In hopes to both better understand how treatment of cardiac arrest has evolved and to quantitatively measure the outcome of defibrillation, multiple pieces of literature have been reviewed.

Methods: Articles were found that were pertinent by using PubMed and Google Scholar. Literature was obtained that researched a wide spectrum of topics relating to defibrillation and cardiac arrest that did not focus on traumatic cardiac arrests as it is beyond the scope of this paper.

Conclusion: The use of defibrillation has been thoroughly researched for decades, showing a reduction in mortality. Evidence-based research has continuously concluded the benefits of early defibrillation far outweighs any potential adverse outcome. Although algorithms used during treatment in cardiac arrest have varied significantly over the past 100 years, defibrillation remains a staple in the treatment. Governing agencies like the American Heart Association have consistently advocated for early defibrillation over the last few decades as more data has become available, specifically the data on the reduction of mortality. With the rapid adaptation of using Automated External Defibrillators in public locations, we can safely conclude that mortality rates will continue to decline. Further research is needed to determine the ideal order of interventions during cardiac arrest, as there is much debate on the correct ratio of compressions to ventilations and the use of medications to help 'jump start' the heart.

Introduction

The heart is one of the most amazing organs in the human body. Constantly contracting and providing vital blood flow to every inch of the body, it rarely fatigues in a healthy person. The cells that make up the heart are unique as they have automaticity, excitability, and contractility.[1] Arguably more important than the brain, the heart begins beating only a few weeks after conception to the very end of our life. Most of us live our life unaware that the heart is beating almost every second, awake or asleep. Involuntary control and the ability of our body to maintain homeostasis allows us to dedicate our consciousness to other tasks, such as executing motor functions and interpreting sensations. Our heart will fluidly increase or decrease its cardiac output depending on what we demand it to do, without hesitation. This mighty workhorse of the human body has perhaps the most important function of all organs, so it rightfully deserves its own unique blood supply. No tissue can be expected to complete complex tasks without fuel, so thankfully the heart has its own blood supply coming primarily from the left coronary artery and the right coronary artery. These vessels primarily fill during diastole of the cardiac cycle, defined as the resting phase of the heart where the intracardiac pressures are the lowest. With patent lumens that maintain elasticity in the vessel walls, the blood vessels can effectively perfuse the cardiac muscle.[2]

Ensuring blood vessels are patent is only half of the physiology for obtaining adequate perfusion to the heart, as the heart must contract in an organized rhythm to pump the blood. There are many heart rhythms that exist, but the most common rhythm in healthy individuals is a sinus rhythm, where the impulse is initiated from the sinoatrial node located in the right atrium of the heart. This rhythm has the most efficient cardiac output, as all chambers of the heart are working at precise timing to create the largest stroke volume. When hypoperfusion occurs, there

are a variety of arrhythmias that may be present. Resulting from countless things such as a ruptured plaque causing blockage in a coronary artery, electrolyte imbalances, or hypothermia, these arrhythmias are often lethal if the pathology is not reversed quickly. The arrhythmias often lead to a cessation of organized contractility, resulting in cardiac arrest. Some of the common types of lethal arrhythmias to be present during a cardiac arrest include pulseless ventricular tachycardia (V-tach) and ventricular fibrillation (V-fib).[3] Without treatment, these are lethal rhythms.

As described above, cardiac arrest is when the heart stops beating. Causes of this can be broken down into two categories, medical and trauma. In traumatic cardiac arrests, cardiac arrest may be due to trauma directly to the chest wall, internal or external hemorrhage, electrical disturbances such as lightning strikes, and much more. When caused by trauma, patient survival rates heavily depend on the timing and level of definitive care that is available to them. There are advanced procedures that can only be done by critical care providers, which may worsen outcomes if the traumatic arrest happens in a rural area with limited access to the providers. Medical cardiac arrest is often due to a ruptured plaque that becomes trapped in the lumen of a coronary artery, impeding blood flow. The plaque is caused by hyperlipidemia, which is cholesterol build-up within the blood vessels. With the lack of blood flow, the cardiac tissue begins to infarct, resulting in loss of contractility and ability to conduct electrical impulses. The percentage of obstruction, location within the vessel, and time blood flow is halted determines the severity of damage done to the cardiac tissue.[4] Often described as a lethal event, cardiac arrest due to either medical causes or trauma have poor outcomes. According to the American Heart Association (AHA), there are more than 356,000 out-of-hospital cardiac arrests annually in the U.S. each year with almost 90% of them fatal. Combining in-patient and out-patient, the

Center for Disease Control and Prevention reports that there are roughly 800,000 Americans that have a heart attack each year. With a mortality rate of almost 90%, far too many lives are lost. Myocardial infarctions affect millions worldwide, further showing the need to investigate every aspect of the treatment plan. Our treatment has constantly been evolving over the past 100 years, but statistically it is very poor. Having worked in emergency medical services (EMS), I have seen many lives be cut short after both the family and EMS failed to resuscitate their loved one. It is for this reason that my thesis is investigating the effectiveness of one of the main treatments for those in cardiac arrest, defibrillation. I would like to do an analysis of the other interventions done during the treatment of cardiac arrest, but the discussion and research in this paper will primarily focus on defibrillation.

Current guidelines for the treatment of nontraumatic cardiac arrest is cardiopulmonary resuscitation (CPR). CPR has multiple components, with the primary ones being external chest compressions to mechanically pump the heart, and positive pressure ventilation to deliver oxygen to the cells. If a cardiac monitor or Automated External Defibrillator is available, a patient in cardiac arrest may be shocked with electricity if they are in certain arrythmias. The arrythmias that are coined ‘shockable’ are V-tach and V-fib, while the act of shocking is called defibrillation. Defibrillation delivers a set number of joules to the heart in an instant, causing all cells of the heart to contract at the same time. The hope is that by causing all cells to contract simultaneously, any abnormal rhythm that was causing the heart to contract irregularly will be ceased, therefore allowing a perfusing rhythm to be established. Administration of various medications such as epinephrine and 0.9% sodium chlorine are also indicated on current AHA guidelines.

Treatment for cardiac arrest has been documented as early as the 16th century when Mr. Vesallus began resuscitating animals.[5] Initially, isolated artificial respirations were the first to be used. This progressed to the mouth-to-mouth resuscitation, then positive ventilation methods of the 18th and 19th centuries. It was not until 1874 that cardiac massage began with the open chest method. This continued until the 1960s when closed chest compressions replaced internal cardiac massage. Shortly after, in 1956 external electrical defibrillation slowly became incorporated in the guidelines for management of cardiac arrest.[5] Seven years later, the AHA incorporated defibrillation into the guidelines for CPR at the same time it formally endorsed CPR in 1963. Defibrillation remains in the current 2020 AHA guidelines and is promoted that "Early defibrillation…. can be targeted by resuscitation training programs to improve patient outcomes".[6]

With the endless advances in CPR that have occurred in the past 200 years, defibrillation has stayed consistent for the past 50 plus years. With survival rates hovering around 10%, I question the effectiveness of it. There are numerous interventions in medicine that are performed for the sole reason that it has always been that way in history, yet these interventions lack any scientific support. My objective for this paper is to analyze the statistical evidence of the effect of defibrillation on patients with cardiac arrest, specifically when it is performed early in cardiac arrest. The patient population will be of any age group that enters nontraumatic cardiac arrest. Analysis of the effectiveness of defibrillation will be measured by patient mortality and the absence of sustained return of spontaneous circulation (ROSC) during the cardiac arrest date. Both inpatient and outpatient populations will be included. Based off my own personal experiences with defibrillation, as well as my education as a physician assistant student, my hypothesis is that early defibrillation will reduce mortality in patients who have cardiac arrest.

Background

Action Potentials of Cardiac Cells

To understand the theory behind how defibrillation works, it is first necessary to be competent on how cells generate their own electrical charge. Cardiac cells can produce their own action potential, a term that means a change in voltage across the membrane. Cations and anions move across the cells through various channels, generating a flow of electricity which can then be passed down to a nearby adjacent cell. The propagation of these action potentials through gap junctions allows cells to communicate with one another via intercalated discs, a unique feature of cardiomyocytes.[7] The ability to pass on a stimulus from one cell to another allows the heart to contract in an organized manor if the electrical pathways within the cells are functioning properly, and if the pacemaker of the heart is originating from what is known as the sinoatrial node. The generation of an action potential is a complex movement of ions that occur in a set sequence to allow depolarization and repolarization of the cell membrane. Appendix attachment #1 outlines the action of the ions within each cell. Phase 0 is when the cation sodium rapidly enters the cell, causing a substantial increase in positive charge of the membrane. This is known as depolarization. At phase 1, the sodium channels close. Phase 2 is known as the plateau phase and is highlighted by the slow influx of the cation calcium followed by the cation potassium leaving the cell. As potassium increases its rate of leaving the cell, we then enter phase 3 which is where repolarization of the cell membrane occurs. Phase 4 is known as the resting potential, where the cell membrane regains its baseline homeostasis between the concentration of sodium and potassium concentrations through the sodium potassium pump. The cell is then ready to begin phase 0 again.

With the understanding of how a cell depolarizes and repolarizes, we can now correlate that with the physical contraction of the cardiomyocytes. When the cardiomyocytes receive a stimulus to depolarize, this contractility cell - primarily found in the myocardium of the heart - responds to the sudden release of calcium by shortening the myosin and actin filaments. Leading to a shortening of the cell, this results in a cellular contraction. A cell by itself is only micrometers in diameter but combined with millions of other cells in the same organ, this contraction can produce a visible movement that can generate immense pressure within the heart. The events above define a 'normal' cardiac cycle within the heart. With the initial pacemaker of the heart being in the sinoatrial node, the cells within the atria of the heart depolarize simultaneously resulting in an organized contraction. The impulse is then transmitted to the atrioventricular node where there is a momentary pause, followed by propagation into both ventricles. The depolarization of the ventricles within the same time results in blood being ejected from the heart, measured as stroke volume.

When cells are failing to depolarize and repolarize in an organized pattern, arrythmias develop. When the irregular action of the cardiomyocytes fails to produce a sufficient stroke volume, this leads to an absence of pulse and is defined as cardiac arrest. If cells are depolarizing and repolarizing independently from one another in the ventricles, the rhythm is called V-fib. If there is an absence of all electrical activity, this is called asystole. If the rhythm is defined as a wide QRS complex that is regular, tachycardiac (heart rate greater than 100 beats per minute), and failing to produce a palpable pulse, the rhythm is defined as pulseless V-tach. Both pulseless V-tach and V-fib are coined the shockable rhythms as there is electrical activity in the heart, but it is scattered in its organization. The theory of defibrillation is that a large dose of electricity is delivered simultaneously to the cardiomyocytes, resulting in widespread depolarization. Ending

the arrhythmia, the sinoatrial node can hopefully re-establish an organized rhythm. The movement of cations and anions across the cell membrane to their baseline concentration will set the ideal setting for depolarization to occur.

Methods and Timing of Defibrillation

The delivery of a shock during V-fib or V-tach can be performed either externally by placing defibrillating pads on the patient's chest, or internally by shocking directly against the cardiac tissue. When internally shocked, this is accomplished by either the placement of a pacemaker/defibrillator that connects directly to the heart tissue or is performed using paddles by a surgeon during open heart surgery. The number of joules that is delivered does vary on the method that is used, with internal defibrillating being a fraction of the 2020 AHA guidelines of 120-200J for a biphasic defibrillator.[8] Most current external cardiac monitors are able to detect the amount of resistance the chest wall has, being able to adjust the voltage accordingly. For example, a larger number of joules will be needed to penetrate a morbidly obese patient since the shock must travel a further distance to the heart. This calculation allows a consistent shock to be delivered that is current with the provider's ordered dose. AEDs are programmed to automatically deliver a set number of joules after accounting for resistance, which is programmed by the manufacturer. AEDs are becoming more prevalent in public places after several studies - that I will discuss below - have demonstrated their effectiveness in reducing mortality.

The timing of defibrillation is believed to play a substantial role in the mortality rate of those who present in cardiac arrest with a shockable rhythm. As I will soon investigate, we will see the outcomes from patients with cardiac arrest who were not defibrillated compared to those

who were defibrillated. For those who were defibrillated, they will further be broken down into early vs late defibrillation.

Asystole and Pulseless Electrical Activity

In cardiac arrest, current practice is to defibrillate pulseless V-tach and V-fib. Any other arrhythmia in cardiac arrest is treated with medications and/or CPR. The two arrhythmias that are not shockable in cardiac arrest are pulseless electrical activity and asystole. Recall that asystole is the complete absence of all electrical activity; it is the rhythm that patients are in when they are pronounced dead. Since there is no electrical activity, the theory is that the cells will not respond to the defibrillation. In 1992, the AHA stated that delivering shocks in asystole was considered dangerous as there was no benefit yet a strong concern that both myocardial necrosis and stimulation of a parasympathetic storm could result.[9]

The stance the AHA took against shocking asystole was primarily based off a retrospective analysis study that was published in 1993. Known as the countershock study, the study looked at six urban emergency medical services where paramedics were staffed. Patients with the initial presentation of asystole were grouped into two groups, one was the control that received no shock while the other was the experimental that received at least one defibrillation as soon as asystole was interpreted. The outcomes were measured in multiple areas such as return of spontaneous circulation and if they were discharged successfully from the hospital. The study concluded that of the 194 patients who were in the study, 0 of 77 patients in the experimental group were discharged from the hospital while 2 of the 117 in the control group were. They concluded that delivering a shock in asystole does not improve mortality – it may worsen mortality and cause further complications if the patient survives, such as additional myocardial

necrosis.[10] For over the past two decades, the treatment of most cardiac arrests has remained largely unchanged.

A similar observational, retrospective study from 1995 to 1999 cemented the current guidelines of the AHA after only 3% of the participants who were shocked while in asystole survived to hospital discharge. Well below the national average of 8% at the time.[11] With no large-scale studies supporting the benefit of defibrillating asystole, the guidelines set forth decades ago remain current as of today.

There are times when the heart is generating organized electrical activity that is failing to produce a pulse. This is called pulseless electrical activity, or PEA. In PEA, there is a disconnect in the electromechanical coupling within the heart. Common causes of PEA can be remembered as the Hs and Ts, those being the following: hypoxia, hypovolemia, hydrogen ion excess, hypoglycemia, hypothermia, hyper/hypokalemia, toxins, tamponade, tension pneumothorax, thrombosis, and trauma. The objective of this paper will not be assessing the effectiveness of defibrillation in trauma patients but will assess limited data of defibrillation of patients in PEA that is not due to trauma.

PEA can present itself in a wide variety of rhythms, most maintaining the ability to perfuse if the dissociation between the electricity and mechanical contraction is fixed. For this reason, defibrillation has historically served little to no role in the management of PEA as there is no need to 'reset' the rhythm of the heart. Conditions such as pseudo-PEA exist where there are ventricular contractions and detectable pressure in the aorta, but not enough pressure is generated to palpate a pulse in a peripheral artery. It could be counterproductive to attempt defibrillation of a patient in this setting. However, since PEA accounts for roughly 20% of sudden cardiac deaths outside of the hospital setting, and 68% of deaths in-hospital – majority

due to pulmonary embolism – I will assess the impact on mortality of defibrillating patients who at one point were in PEA. Current outcomes for all cardiac arrests due to PEA is an 89% mortality. The 2020 AHA guidelines for the treatment of PEA is epinephrine every 3-5 minutes with CPR, but no defibrillation.[12]

After an extensive review of various articles from Google Scholar and PubMed, I was unable to find any peer-reviewed articles that addressed both early and late defibrillation of a patient in PEA. In large part due to PEA being caused by disorders unrelated to electrical conduction within the heart, it is agreed upon in the medical community since the introduction of defibrillation that shocking PEA would not be beneficial. Treatment is dedicated to reversing the causes of PEA and administration of high-quality CPR with epinephrine. One metanalysis article highlighted the 2-5% out-of-hospital survivability of those who initial rhythm was PEA. The article also investigated the mortality of over one million cases where an initial non-shockable rhythm converted into a shockable rhythm. It concluded that those who were initially in asystole had higher odds of pre-hospital return of spontaneous circulation of around 47% when compared to those who were in PEA initially.[13]

Defibrillation of Ventricular Arrhythmias

Early defibrillation will be defined as the delivery of a shock within 3 minutes of initiation of CPR. In an analysis of the advances of CPR, Wanis Ibrahim concluded that "early defibrillation is critical for survival…the most frequent initial rhythm is witnessed SCA is V-fib".[14] The reasoning for the benefit of early defibrillation is the frequent presence of V-fib as the initial rhythm and the quick deterioration of V-fib into the non-shockable arrythmia, asystole. The results were clearly demonstrated by a study conducted from 1977 to 2001 in Washington. This observational study looked at patients age of 18 and older who had cardiac arrest out-of-

hospital. In the study of over 12,000 patients who were treated by EMS, 4,190 were categorized as having a witnessed cardiac arrest with the initial arrhythmia as V-fib. The rhythm of V-fib was identified by technicians who were trained at the paramedic level. With prompt external defibrillation administered within 3 minutes, admission to the ICU was over 50% of the patients (N=2281). Of those who were admitted, 1,343 were discharged alive. Common reasons for those who had mortality while in the ICU were listed as anoxic brain injuries and heart failure. In this group, prompt CPR was initiated along with administration of epinephrine at 1mg.[15] In the same study, there were roughly 2,400 patients who had an initial witnessed arrest where the rhythm was asystole or pulseless electrical activity. Of the 2,400, 562 were admitted to the ICU with 161 being discharged alive. Appendix attachment #2 is the flowchart attached in the study. This study was conducted over the course of a 25 years and observed no drastic changes in the mortality rate year-to-year.

In-patient cardiac arrests are found to have a 15-20% increased survival rate compared to outpatient. These statistics are further increased if the patient has cardiac arrest during the daytime hours. Faster response times, trained staff at recognizing when a patient is in cardiac arrest, and availability of additional resources used to treat the arrhythmia all help increase the odds of survival. In a group of 151,071 patients who experienced in-hospital cardiac arrest, 18.6% survived to hospital discharge without significant neurological deficits.[16] These patients had prompt CPR and defibrillation started within the 3-minute window. When the study was further broken down into patients that had cardiac arrest at night versus those who had cardiac arrest during the day, there was a noticeable difference in mortality. During the day, survival rate over the 15-year study went from 16% to 25.2%, while at night the survival rate went from 11.9% to 21.9%. It is thought the higher nurse-to-patient ratio during the night along with overall

decrease in work performance during nighttime hours factors in with the ability to recognize cardiac arrest promptly, therefore leading to a delay in treatment.

Early defibrillation has previously been defined as the delivery of a shock within the first 3 minutes of initiation of CPR. It goes without saying that if the shock is delivered after 3 minutes, it is classified as late defibrillation. Late defibrillation is currently rare in the field of medicine as there are no known protocols that I am aware of that call for late defibrillation if the patient is known to be in V-fib or pulseless V-tach. The possible exception is a severe hypothermic victim, but the protocols vary department to department. Reasons for late defibrillation are often due to delay in identifying a shockable rhythm and lack of a defibrillator to deliver the shock. Hospitals and EMS crews train repeatedly for cardiac arrest codes, but events do not always unfold like they do in a textbook. Human error, lack of resources, and unwitnessed arrests may all delay the delivery of the first shock. In a cohort study of 57,312 patients from an in-patient setting with witnessed arrests, survival rate was 31.6% when initiation of CPR with defibrillation was over 2 minutes, compared to a survival rate of 40.5% when CPR and defibrillation were delivered within 2 minutes.[17] To go from 31.6% to 40.5% is a 27% increase in survival rate, a significant value when the survival rate in general for someone in cardiac arrest is extremely low. See appendix attachment #3 for a chart comparing probabilities of survival depending on time to initiate CPR. When defibrillation was delayed over 9 minutes, the survival rate was as low as 17.1%. This data focused primarily on adult patients who were also given doses of epinephrine. But when the survivors were broken down into the timing of when they received epinephrine, there wasn't a statistically significant difference between survival rates.[17]

One unique finding was in pediatrics who had cardiac arrest. Unlike adults, pediatrics tend to have cardiac arrest secondary to respiratory arrest. Due to the easy fatigability of pediatrics, prolonged respiratory problems can quickly result in cardiac arrest. When a shock is delivered to the heart, it was found that the timing of the first defibrillation was not associated with both return of circulation and an increased survival rate. In a study of 477 pediatric patients, the survival rate of those who were first defibrillated within 2 minutes was recorded at 39% while those who were defibrillated after 2 minutes had a survival rate of 34%.[18] Assuming that most of the pediatrics went into cardiac arrest due to a respiratory problem, it makes sense that defibrillation won't correct the problem. The heart heavily relies on aerobic respiration, so prolonged hypoxic periods quickly cause dysfunction. Without supplementing oxygen, the heart will not be able to switch back to aerobic respiration to provide fuel for the cells that initiate normal rhythms. Airway and breathing management are currently listed as the first line intervention if a pediatric has bradycardia and is of utmost importance during cardiac arrest. In the United States, it is estimated that there are 6,000 pediatric cardiac arrests within hospitals each year.[18]

AED Use

The use of an AED in the treatment of cardiac arrest has had profound impacts on survival rates. In a small observational study of witnessed cardiac arrest where V-fib was the initial rhythm, AED use within 5 minutes resulted in only a 33% mortality rate.[19] The sample size was only 18 patients but is consistent with similar studies that show the benefits of prompt AED use. When an international team of researchers studied out-of-hospital cardiac arrests in the United States of America and Canada, they analyzed the cases where an AED was utilized promptly by a bystander. Of the 49,555 witnessed cardiac arrests, 19% of those arrests had an

AED be used promptly. 66% of those victims survived to hospital discharge after being shocked by a bystander. When the patient had to wait for EMS to be treated with the initial shock, there was a 32.7% survival rate. Without a bystander using an AED promptly, more than 70% of the patients had a mortality.[20]

The studies that look at the use of an AED by the public are often defined as early defibrillation as the setting of the cardiac arrest is usually in public place, so arrests are typically witnessed. It is important to note that for the first several minutes, there are no advanced interventions being performed such as a fluid bolus or medication administration. Straight BLS care from bystanders was sufficient for almost two thirds of the victims. Dr. Myron Weisfeldt has stated that he estimates over 1,700 lives are saved in the United States each year by bystanders who use an AED. The statistics above demonstrate the that the use of an AED nearly doubles the victim's odds of survival.

For every minute of delay in defibrillating a patient who is in V-fib or pulseless V-tach, their survival rate decreases by 10-12%.[21] The retrospective study performed recently in Stockholm showed that when CPR was initiated prior to EMS with defibrillation, the survival rate was 10.5%. Without the initiation of CPR, about 4% of patients survived to be discharged from the hospital. The arrests were witnessed by a bystander and EMS was promptly called, but there was an average response time of 8 minutes.[21] As referenced above, the 8-minute delay of EMS to arrive on scene could result in an 80-96% decreased survival rate if no CPR is being performed.

Additional Factors Affecting Mortality

It is important to note that in addition to defibrillation, high quality CPR is vital for success. Highlighted in appendix attachment #4, perfusion of the coronary arteries when

compressions are not being performed is zero. With no blood flow to the cardiomyocytes, they are incapable of contracting and generating an electrical charge. The build-up of waste products and the switch to anaerobic respiration leads to acidosis, which accelerates the inability for a cell to take up products like oxygen and glucose. The American Heart Association continues to advocate the benefits of CPR as soon as possible due to the reduction of survival by 10-12% for every minute it is withheld.

Ventilation with oxygen is under heavy debate, as some studies conclude that there is an adequate amount of oxygen in the lungs and blood stream to perfuse the organs for several minutes after an arrest. Other studies indicate that supplemental oxygen may ensure the cells remained primed for when they begin functioning. It is difficult to say what will be the future of ventilations during CPR due to the lack of studies that isolate a change in only one of the core interventions – compressions, ventilations, defibrillation, and medication administration such as epinephrine. One study that did an in-depth analysis of ventilation during CPR concluded that assisted ventilation may not always be beneficial. It may worsen outcomes by decreasing the times doing compression and leading to hyperventilation. Hyperventilation can result in displacement of carbon dioxide and excessive air entering the stomach, both harming the patient. With air entering the stomach, the pressure that builds on the upper esophageal sphincter may cause the back of gastric contents, resulting in vomiting and aspiration of the contents. The lack of carbon dioxide leads to an altered pH level within the body, further causing problems with the diffusion of oxygen into the tissues.[22]

Epinephrine is thought to improve coronary and cerebral perfusion by improving contractility of the heart and systemic vascular resistance. Its use has been controversial since its introduction but has currently become a staple in the 2020 AHA guidelines for cardiac arrest.

The theory is that the administration of a medication like epinephrine will help improve the chance of return of spontaneous circulation, also known as ROSC. This comes at a risk as the potential harmful effects of epinephrine on intracranial pressure and damage to the cardiomyocytes is not fully researched.[23] The adverse reactions are often difficult to measure because if they are present, we are unsure if it is due to the administration of epinephrine, or the time spent in cardiac arrest that led to a buildup of toxic byproducts in the brain and heart. Still, studies have demonstrated that epinephrine is associated with a significant higher likelihood of return of spontaneous circulation at 23.1%, and survival to hospital discharge at 36.3%.[23] In the studies that look at epinephrine, many concluded that although epinephrine is beneficial for achieving return of spontaneous circulation, it had little to no effect on improving neurological outcome.[24]

It appears that the use of epinephrine, adequate ventilation, and high-quality compressions all decrease mortality during cardiac arrest. Because these are now all considered standard of care in any cardiac arrest, it is difficult to determine to what extent one of these interventions has on mortality. Add in the patient's underlying medical illnesses and the effect of defibrillation on mortality, it is easy to see why the studies, although present and very thorough with their research, struggle to eliminate all other confounding variables.

Potential Problems With Defibrillation

Like anything in medicine, everything comes with a chance of risks. Perhaps the most studding problem I encountered came from the lack of experience of the trained hospital staff. In a prospective observational study in Italy that assessed the knowledge level health care professions regarding CPR and early defibrillation, over 55% of the surveyed doctors and nurses reported they did not feel comfortable using a defibrillator.[25] The large percent is a shocking

number as it is the expectation and law for every health care provider to be Basic Life Support certified. The staff felt their skills on both CPR and defibrillation were not appropriate. This lack of knowledge and experience is also found out-of-hospital in nonmedical professionals. Although more justifiable, the outstanding lack of knowledge of basic CPR and access to AEDs may be drastically increasing the mortality by delaying the delivery of a shock within 3 minutes of cardiac arrest. When a bystander is both knowledgeable about CPR and able to use an AED, there is a double survival rate with hospital discharge. (Site D) Showing a promising step in reducing the mortality of cardiac arrest, bystander CPR with AED use has statistically proven its benefits. The major problem is the lack of public access to defibrillation in the out-of-hospital cardiac arrest patients. Fewer than 5% of out-of-hospital arrests have the use of an AED by a bystander.[26] Having worked on multiple rural EMS services, there is a saying that "time is tissue" when CPR is not being performed. The response time from station to scene time at Colfax Rescue Squad where I work is far beyond the 3-minute period that defibrillation has been proven to work. Without trained bystanders, mortality will continue to be high for anyone that has cardiac arrest without prompt care.

Bystanders and even medical professionals who are trained in CPR have continuously expressed concern of accidental shocking of themselves while they defibrillate the patient. It is logical to think that if the defibrillation has enough joules to reset someone's heart, it would be capable of transmitting a that same amount of energy through an extremity of the person performing CPR if they happen to be touching the patient during the shocking period. In a 2016 study that looked at the utilization of hands-on-defibrillation, it was found that "nitrile pads and neoprene gloves prevented 99% of shocks detectable by the caregiver". Of the 1% who did feel

the shock, only a brief tingling sensation and paresthesia was noted by the caregiver for up to 24 hours.[27]

An extensive concern with the use of defibrillation is the adverse reaction of having the rhythm of V-tach or V-fib turn into asystole and myocardial necrosis.[28] Delivering enough of a charge to cause all cardiomyocytes to depolarize yet not enough damage that causes permanent damage to the heart is a complex problem that has no definitive answer. There are many suggestions, notably from the AHA that states a charge of 200J for defibrillation of biphasic monitors does not provide measurable myocardial necrosis, but the studies are often found to be inconclusive as it is difficult to determine if the myocardial necrosis came from the lack of blood flow to the heart during the cardiac arrest period, or if it came because of defibrillation. The excess charge from the defibrillation may alter the conformation of biomolecules, therefore permanently altering the structure of them. Combined with the disruption of the cell membrane from artificially altering the placement of the ions, it is easy to see how excessive defibrillation can cause myocardial damage.

The hope after defibrillating is the sinoatrial node will start initiating impulses again, causing the heart to beat in a normal sinus rhythm. The worst outcome of defibrillation is if the rhythm changes from the shockable V-tach/V-fib into a non-shockable rhythm such as asystole. Asystole occurs usually as a deterioration of the initial non-perfusing ventricular rhythms and represents the cessation of all electrical activity in the heart. Victims who present and deteriorate to asystole have a hospital discharge rate of 0-2%.[29] It is this breathtaking low number that may scare some providers. Even when done properly, defibrillation can cause the rhythm to convert to asystole as all cells within the heart have just depolarized; they are incapable of depolarizing for some time until they have repolarized. This time period can vary from milliseconds to seconds to

being permanent. If no cell or group of cells in the heart initiate the rhythm after defibrillation, then there will be an absence of all electrical activity. With this being said, it is still crucial to remember that the patient was previously in a lethal arrhythmia if they needed to be defibrillated.

As stated above, the act of no defibrillation on these lethal arrhythmias proved to have a much higher mortality rate than if we were to defibrillate. With no resuscitation efforts such as CPR and defibrillation, V-fib and pulseless V-tach are almost certain to deteriorate into asystole as the cardiomyocytes continue to die due to lack of perfusion.[14] In medicine, the golden rule is to do no harm. Many times, this translates to picking the solution that does the least harm with the most benefit for the patient.

Methods

Several databases were used to search for literature that addressed my thesis question. The primary databases that were used are Google Scholar and PubMed, but multiple peer-reviewed articles were also found using Science Direct and UpToDate. The literature searches were completed between June 15th and July 9th, 2021. Key words that were used to retrieve relevant literature in the search for articles were “Defibrillation”, “Return of Spontaneous Circulation”, “Cardiac Arrest”, “Treatment of Cardiac Arrest”, and “Cardio-pulmonary Resuscitation”. Although there were thousands of articles for me to select from, I quickly narrowed them down by focusing on the articles that were published within the past 3 years. Some articles were included that were published further that 3 years ago as it was necessary to better understand the progression of how cardiopulmonary resuscitation changed over the years. The abstract of articles was used to help determine the appropriateness towards my thesis question. Articles with limited text were excluded from this paper, as were those that are written in languages other than English due to the inability to accurately translate them. Several articles

that did not have full text available online had to be requested through the Augsburg Lindell Library.

The inclusion criteria included articles that focused on treatment of nontraumatic cardiac arrest in all ages, if mortality was measured, and if the article listed the arrhythmia that was being treated. The literature articles incorporated many types of studies which immensely helped strengthen this paper. The types of studies included are retrospective and prospective observational studies, prospective interventional trials, randomized controlled trials, meta-analyses, systemic reviews, and clinical practice guidelines of resources like UpToDate and American Heart Association. Each study and its data were reviewed for its accuracy and pertinence to my thesis.

Data interpretation was performed by the author of this paper, with all relevant data being summarized in text. Also included are the graphs and tables which are attached in the appendix section. In-text citations are used in this paper to help guide the reader in identifying where factual information was derived from. Each table and article that is contained in this paper has been cited in the reference section in compliance with AMA style. No expert interviews were conducted.

Discussion

The literature discussing the treatment of cardiac arrest has been thoroughly researched for decades. The rise in acute coronary syndrome in the United States correlates with an increase in cardiac arrests each year, making the literature more important. Determining the ideal treatment is key to reducing mortality in those who have this often lethal disorder. Defibrillation, high quality CPR, and epinephrine administration continue to be integrated in the current AHA guidelines for cardiac arrests who are in V-tach or V-fib. Finding the ideal balance of these three

interventions, along with addition medications and procedures that could reduce mortality, requires evidenced based medicine over decades.

As discussed by Luo S, Zhang Y, et al, defibrillation of asystole is considered dangerous as there has statistically been no decrease in mortality while causing myocardial necrosis and a parasympathetic storm. Oliver TI, et al supported harmfulness of defibrillation in asystole after publishing that 0% of the patients in the experimental group that received at least one defibrillation while in asystole survived to discharge the from the hospital. The national average for survival in patients with an initial rhythm of asystole was 8% at the time. The known pathophysiology of asystole supports the evidence showing the impracticality of this intervention since there is no electrical activity to begin with. Unfortunately, the studies failed to state if late and/or early defibrillation were performed.

The limited statistical evidence collected for the treatment of PEA makes it difficult to incorporate this arrythmia amongst the other causes of cardiac arrest. Having concluded that defibrillation has no place in the treatment of PEA shortly after the AHA was founded, there were no studies finding data that addressed defibrillation in those with PEA. Luo S, et al did discuss the mortality after defibrillation in those who had an initial rhythm of PEA that converted to a shockable one, finding that only 2-5% of them survived to be discharged from the hospital. Patients who presented in asystole that were then defibrillated once the rhythm converted to a shockable one had a 47% survivability rate.

The core of this literature review revolved around the use of defibrillation, specifically in those with V-tach and V-fib who were shocked either “early” or “late”. The strongest statistically relevant article was by Ibrahim WH, et al who concluded that defibrillation within 3 minutes of cardiac arrest resulted in only a 50% mortality. This study was supported by the Uchenna R.

Ofoma, et al study where they observed a 15-20% increased survival rate in patients who arrested inside a health care facility. The early defibrillation by trained staff separated them from the control groups of out-patients. The immediate recognition of cardiac arrest with defibrillators within walking distance allow patient's a considerable reduction in mortality. When care and defibrillation is delayed, the odds of survival also diminish. Bircher NG, et al demonstrated this with a 27% increase in mortality when defibrillation was delayed by over 2 minutes when the initial rhythm was either V-tach or V-fib. All literature except for one reviewed demonstrated statistical evidence that early defibrillation of shockable rhythms resulted in a drastic reduction in mortality, with greater reduction being obtained the sooner defibrillation is administered. The exception was in a pediatric trial where the increase in mortality as defibrillation was 12% after defibrillation was delayed by more than 2 minutes. This slight increase in mortality is surprising after finding that for every minute of delay in defibrillating an adult patient who is in V-fib or pulseless V-tach, their survival rate decreases by 10-12%.

Ross A. Pollack, et al demonstrated the effectiveness of AEDs in their role to reduce mortality. A 33% mortality was recorded when an AED was used within 5 minutes of a witnessed cardiac arrest. Those who survived had over a 66% chance to successfully discharge from the hospital. Without the use of an AED, mortality rate was 67.3% when the patient had to wait for EMS to arrive on scene to deliver the first shock.

Only being mentioned in one article, I believe that more thought should be given to the potential of misinterpreting fine V-fib as asystole. I've seen firsthand new paramedics misdiagnosis fine V-fib as asystole, leading to the wrong treatment algorithm. After seeing the benefits defibrillation has on reducing mortality, it is crucial that the medical society ensures that each rhythm is interpreted correctly. A new method to help solve this potential problem is the

use of ultrasound during cardiac arrest. Easy to use and noninvasive, ultrasound can reliably pick up cardiac movements in real time.

Conclusion

The management of patients in cardiac arrest is constantly changing as new evidenced-based practice is being taught. However, defibrillation has remained a core intervention in certain cases as it has proven its reduction on mortality in numerous clinical trials. Large governing bodies such as the AHA have stated that early defibrillation combined with high quality CPR provides the best outcome for a patient who is in cardiac arrest. The presence of AEDs in public places has further reduced overall mortality, speaking of the importance to have bystanders trained on how to correctly use it.

Despite the advancements that have been made, the mortality rate remains almost 90%. Defibrillation is proven to reduce mortality, but I am unsure if solid evidence exists for the other interventions performed during CPR, such as the administration of epinephrine and antiarrhythmics at their current dosing and frequency, or the ratio of compressions to ventilations. Further research should be conducted on these interventions to find the ideal treatment. Making every high schooler become CPR certified prior to graduation and increasing public access to AEDs would also help decrease mortality while introducing students to the field of medicine at a young age. The increase in number of medical providers, from EMTs to doctors, would help save some of the millions of lives lost each year to cardiac arrest. Preventing coronary artery disease by reducing risk factors and increasing patient education would further drive mortality rates down. If the history of medicine has taught us anything, it is that the future practice of medicine will be far different than our present practice.

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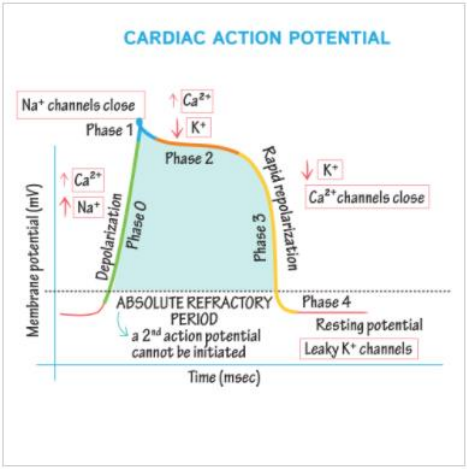
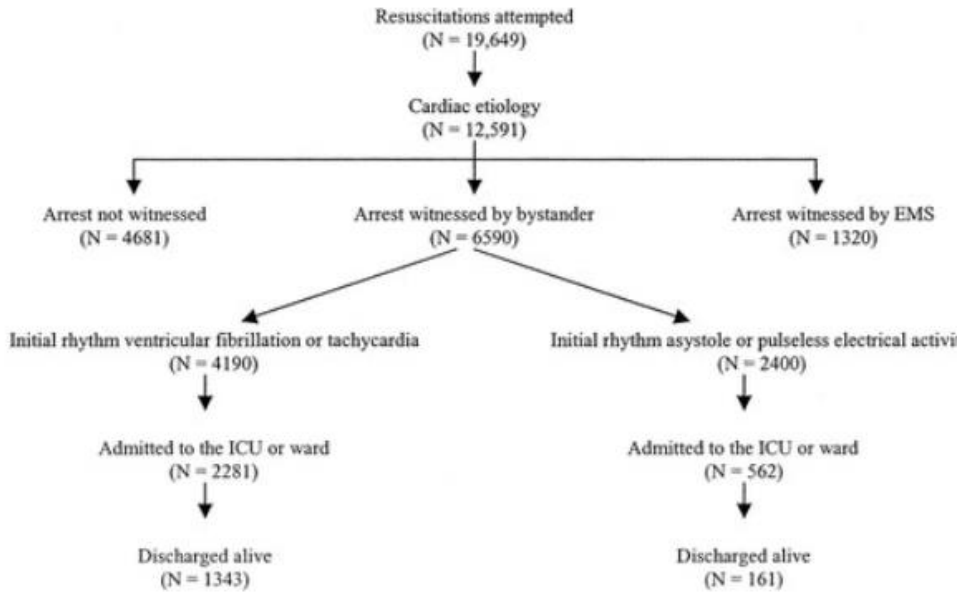
Appendix

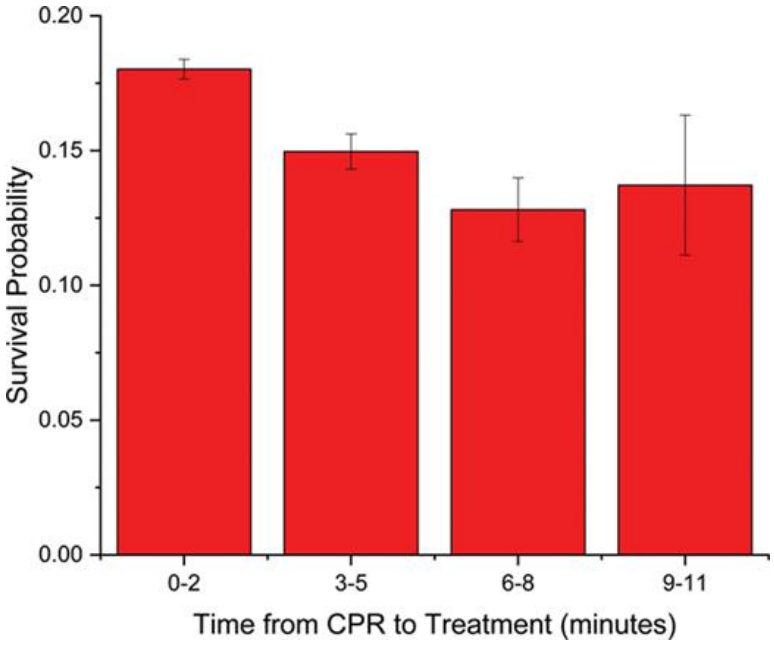
Appendix #1: Cardiac Muscle Action Potential.[7]



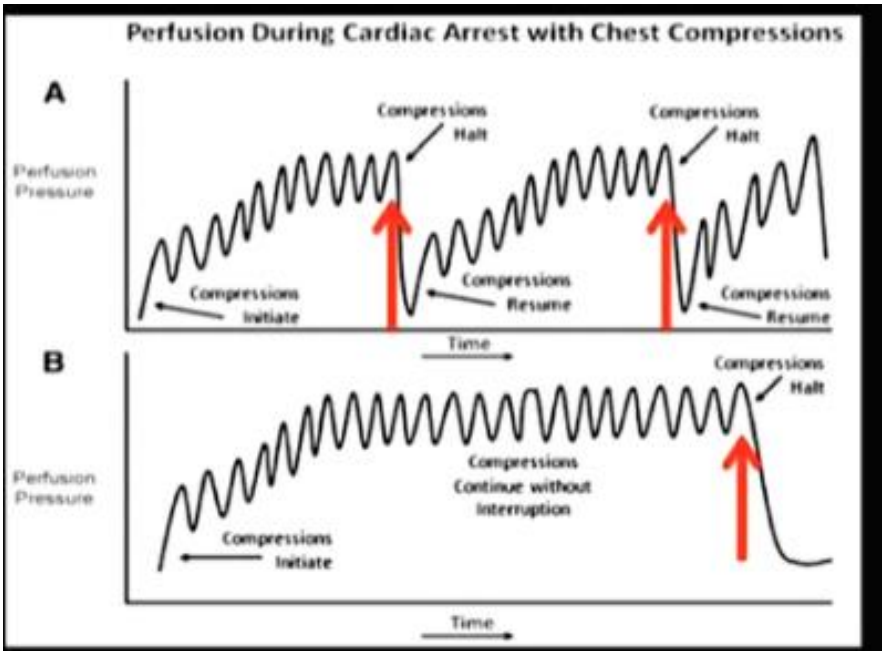
Appendix #2: EMS-Treated Cardiac Arrests.[15]



Appendix #3: Survival Probability vs Time to Initiate CPR.[21]



Appendix #4: CPR Perfusion Over Time.



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