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Incorporating Point of Care Ultrasound in Cardiac Arrest and Pulseless Electrical Activity

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Purpose Statement

Cardiac arrests are responsible for approximately 350,000 deaths in the United States each year. Etiologic factors include cardiac arrhythmias, valvular heart disease, cardiac tamponade, pulmonary embolism(s), and more. Cardiopulmonary resuscitation (CPR) attempts to reestablish spontaneous circulation, but, unfortunately, only has a 20% in-hospital survival rate. This literature review will analyze guidelines and recent literature on the benefit of using cardiac ultrasound during resuscitation in in-hospital settings with the goal of improving cardiovascular and neurologic outcomes. Specific sonographic findings that help aid in identifying possible causative and reversible factors of cardiac arrest will also be discussed.

Abstract

Objectives

For decades, cardiac arrests have had a high mortality and morbidity rate despite medical interventions. Statistically, shockable rhythms (ventricular fibrillation, ventricular tachycardia) have had a better prognosis than non-shockable rhythms, which includes pulseless electrical activity (PEA) and asystole[1]. The reversible mechanical causes of PEA and the role of point-of-care cardiac ultrasound (POCUS) in their diagnosis and management will be discussed. This paper also focuses on the appearance and interpretation of these sonographic findings in order to guide clinicians in their medical management, goal of returning spontaneous circulation (ROSC), and estimating patient prognosis.

Methods/ Evidence Acquisition

A search of “POCUS cardiac arrest” and “cardiac arrest in PEA” was conducted on PubMed and collectively yielded 615 results. After narrowing the search on PubMed to “point of care ultrasound in cardiac arrest and PEA,” eleven results appeared. Additional filters for causes of PEA included “point of care ultrasound” and “cardiac tamponade” in order to further narrow the results for specific objectives of this paper. Other resources include Web of Science and Google Scholar.

Results and Discussion/ Evidence Synthesis

In the United States, patients presenting with cardiac arrest have a 10.6% survival rate to hospital discharge[2]. Pulseless electrical activity is a common initial rhythm in cardiac arrest rhythm and tends to be caused by the H’s and T’s of Advanced Cardiac Life Support (ACLS), a mnemonic used to help in remembering the major causative factors of PEA[3]. Based on the REASON trial, a multicenter, non-randomized prospective study, ultrasound identified findings that responded to

non-ACLS interventions such as thrombolytics and a pericardiocentesis, with 51% of patients achieving ROSC compared to 14.3% achieving ROSC[4]. 3.8% of patients with cardiac activity on POCUS survived to hospital discharge compared to 0.6% of patients who had no cardiac activity on ultrasound[4].

Conclusions

To improve the ROSC and hospital discharge rates, POCUS should be further promoted and incorporated into PEA resuscitation protocols in order to quickly visualize and efficiently manage the reversible causes of PEA. Patients with cardiac activity visualized on POCUS had longer resuscitation attempts, frequent interventions and higher rates of ROSC than patients who had cardiac standstill on their primary ultrasound[5]. The benefits and limitations of incorporating POCUS into resuscitation efforts for patients presenting with PEA are also identified.

Resuscitation Medicine

At least 350,000 people each year will suffer a cardiac arrest in the United States, culminating to one death every ninety seconds[6]. Prolonged anoxia, neurological damage, reversible myocardial ischemia, and the inability to restore spontaneous circulation are the unfortunate consequences of cardiac arrest that resuscitation medicine attempts to minimize and to correct[6]. Cardiac arrest is defined as the "cessation of mechanical heart function and effective blood circulation" and can be induced by cardiac and non-cardiac etiologies (neurologic, respiratory, hemodynamic)[1,7]. Cardiac arrest can be categorized as shockable (ventricular fibrillation, ventricular tachycardia) or non-shockable (pulseless electrical activity, asystole) rhythms [1]. Statistically, survival to hospital discharge with shockable rhythms is 50% compared to only 10% in non- shockable rhythms[8]. Successful post-resuscitation survival depends on improving the likelihood of return of spontaneous circulation (ROSC), which is dependent on early recognition, the duration of resuscitation, CPR quality and rapid cardiac rhythm recognition in order to effectively and efficiently guide management[1].

Studies have shown that resuscitation attempts longer than 15 minutes decreases the efficacy of cardiac arrest interventions leading to prolonged ischemia and potential irreversible organ dysfunction[1]. Survival to hospital discharge occurs in 10.6% of patients, but only 8.4% are discharged with favorable functional status[2, 7]. Unfortunately, there have been no guidelines or standard recommendations on the reliable identification of patients who are more likely to survive resuscitation efforts or when to continue or terminate resuscitation interventions[9]. The incorporation of point of care ultrasound into current resuscitation algorithms for non- shockable rhythms may improve ROSC and survival. Bedside cardiac ultrasound is 96.2% sensitive and 34% specific in diagnosing reversible cardiac arrest causes due to PEA [10]. Studies have demonstrated that the consecutive application of ultrasound has a positive predictive value of 46.5% in predicting no ROSC and cardiac standstills, which then increases to 85.7% around six minutes and finally, to 100% at a 10-minute serial ultrasound[11]. The Aichinger study had further demonstrated that cardiac standstill on ultrasound has a positive predictive value of 86% as a predictor of death and this cardiac presentation can be used to aid clinicians in deciding when to cease resuscitation interventions[11]. Furthermore, point of care ultrasound in cardiac arrests (POCUS- CA) has served as a predictor of patient outcome and ROSC probability can be predicted with the detection of cardiac activity on POCUS, culminating to a 60.3% sensitivity and a 91.5% specificity for ROSC[7]. ROSC rate is greater than 50% if cardiac activity is detected on ultrasound[7]. POCUS should be incorporated as a standard into current resuscitation guidelines for cardiac arrest due to PEA. This paper will integrate recent studies and literature demonstrating the statistical and mortality benefits presenting as successful resuscitation attempts in pulseless electrical activity (PEA).

Background

Current resuscitation guidelines outlined within the American Heart Association focus on the rapid recognition, effective CPR, defibrillation, ROSC and the treatment of underlying cardiac arrest cause[1]. Currently, CPR guidelines recommend performing POCUS when a clinician suspects a reversible cause of cardiac arrest in patients who present with non- shockable rhythms[1]. However, there is no available standardized cardiac arrest algorithm that incorporates bedside, point of care echocardiography for clinicians to utilize in their management of cardiac arrest patients. Assimilating ultrasound into CPR efforts dates back to the 1980s when the usage of transesophageal echocardiography was first used to evaluate for reversible causes of arrest[12].

Then in 1995, Heidenreich had observed that POCUS provided only adequate imaging in 36% of cases[13]. However, overall, ultrasound has advanced and is now 93% sensitive in diagnosing cardiac arrest causes[14].

POCUS in Cardiac Imaging

POCUS- CA is a vital diagnostic and prognostic tool that aids resuscitation teams in identifying treatable mechanical causes of arrest, guiding management and aiding in the decision to terminate resuscitation. Ultrasound has become the modern stethoscope and with the steadfast incorporation of this imaging modality into all aspects of medicine its increased accessibility and portability have only helped to improve ROSC rates and resuscitation efforts in cases of PEA. The American Society of Echocardiography and American College of Emergency Physicians states that POCUS "has become a functional tool to expedite the diagnostic evaluation of the patient at the bedside and to initiate emergent treatment and triage decisions by the emergency physician"[4]. Cardiac ultrasound provides clinicians with information regarding cardiac motion in pulseless patients, regardless of their cardiac rhythm[15]. In general, a phased array probe is preferred for cardiac imaging due to its versatility and size allowing it to fit between the intercostal spaces when performing a transthoracic echocardiogram (TTE)[16]. Specifically, a single convex or micro convex transducer is preferred or alternatively, a phased array plus a linear array probe should be rapidly available for image acquisition[17]. Sonographically, the core images obtained in cardiac arrests are the subxiphoid and parasternal views[16]. However, parasternal views are preferred due to their sharper cardiac image quality and faster image acquisition time compared to subxiphoid views[16]. However, it is important to note that in time-sensitive cardiac imaging, images need to be diagnostic, not perfect, which is the main goal of

POCUS. During emergency cases, clinicians are looking for rapid information that would help them decide next steps in management. Conversely, image acquisition in cardiac echocardiography tends to be more detailed and thorough utilizing various positions and Doppler techniques. Supplementary views include lung and IVC views in addition to deep vein thrombosis and Focused Assessment with Sonography in Trauma (FAST) exam views, which are assessed depending on the suspected etiology and clinical presentation[16]. Primarily, a sonographic exam during a cardiac arrest is performed during the 10-second pulse checks, but it is imperative that CPR interventions are not delayed or interrupted due to sonographic interventions[13]. Despite this limitation, POCUS and cardiac arrest algorithms have advanced tremendously due to research. Research has demonstrated the efficacy of safely integrating ultrasound into CPR when it is performed during the first rhythm assessment and during pulse checks[13].

Recent studies from the Sonography in Hypotension and Cardiac Arrest in the ED have provided statistical evidence as to the benefit of incorporating POCUS into resuscitation efforts. Patients with cardiac activity on ultrasound had longer and more advanced resuscitation attempts, averaging at 27.3 minutes compared to patients with no cardiac activity, averaging at 11.51 minutes[7]. These longer resuscitation attempts directly correlated with aggressive resuscitation pursuits such as endotracheal intubation and epinephrine administration[7]. Patients with cardiac activity were 95.23% more likely to get an endotracheal tube and 100% of patients received epinephrine[5]. Patients with no cardiac activity were only 46.54% and 82.39% likely to get an endotracheal tube and epinephrine, respectively[5]. No cardiac activity indicated the reduced likelihood of achieving ROSC (19.5%) with a p value <0.001, while those with cardiac activity had a 76.19% chance of ROSC[5]. These aggressive resuscitation treatments in patients with sonographic cardiac activity also meant an increased percentage of patients surviving to hospital admission at 33.3% compared to 6.9% and a hospital discharge rate of 9.5% versus 0.6% in patients who had no cardiac activity on POCUS[5]. POCUS can be used as a predictor of outcome when evaluating cardiac motion as a way to assess patient prognosis and to aid in the continuation or termination of resuscitation efforts[11]. Studies have demonstrated that the absence of cardiac motion on ultrasound results in unsuccessful ROSC attempts in 82% of patients[11].

Cardiac image acquisition may be achieved through a transthoracic echocardiogram (TTE) or a transesophageal echocardiogram (TEE). Transesophageal echocardiography is the favored mode of echocardiography due to its superior image quality, particularly when assessing posterior structures such as pulmonary veins, the left atrium and the mitral valve[13]. Studies have demonstrated that TEEs influence diagnoses in 78% of cardiac arrest cases and influence management in 67%[4]. However, transthoracic echoes are the most commonly used primary imaging modality for POCUS-CA[4]. Unlike TEEs, TTEs cannot be used to evaluate cardiac activity during active resuscitation, limiting their usage to prior to starting resuscitation attempts or during pulse checks[10]. A 3-5 MHz phased array transducer is most commonly used in order to achieve these primary cardiac POCUS views: parasternal long axis, parasternal short axis, subxiphoid and the apical 4C view[7].

TEEs are commonly used in patients who are already intubated, such as ICU patients, in cardiac arrest. TEEs are 93% sensitive, 50% specific and have an 87% positive predictive value for determining causes of arrest[4]. Image quality is exceptional due to the shorter distance sound waves have to travel between the transducer and the area(s) of interest and the lack of intervening lung or bone tissue[4]. A 5-7 MHz transducer is commonly used and the maximum penetrating depth is about 19-20 cm[4]. The recommended TEE view during a cardiac arrest is the mid- esophageal 4C view[4]. This involves inserting the probe into the mid- esophageal level in order to evaluate right and left ventricular function, size and perfusing rhythm[4]. However, during a cardiac arrest it is more important for the obtained images to be diagnostic rather than of higher image quality. TEE allows for constant sonographic visualization and assessment of cardiac contractility during compressions and procedures such as cardioversion[4]. TEEs also have a very low incidence of complications when performed by a trained clinician or sonographer, however possible complications include pharyngeal and esophageal lacerations or perforations, hematoma(s) and bleeding[4].

Pulseless Electrical Activity (PEA)

PEA is a type of cardiac activity in which patients have organized electrical activity with diminutive QRS complexes that is evident on EKG, but the patient lacks a palpable pulse and cardiac motion on POCUS[2]. The weak contractile function of the heart, despite an organized electrical rhythm, results in inadequate cardiac output and hence an unpalpable pulse[7]. Over the last two decades, PEA has increased in prevalence accounting for a 35-40% increase in in-hospital cardiac arrest presentations[2]. The management of PEA focuses on the underlying cause and echocardiography has become a standard diagnostic tool in EDs and ICUs. PEA etiologies can be categorized into these groups: the 5 H’s- hypokalemia/ hyperkalemia, hypothermia, hypovolemia, hypoxia and hydrogen ions or an acidosis and the 5 T’s- cardiac tamponade, tension pneumothorax, thrombosis (coronary or pulmonary), toxins and trauma[3]. Recent research has demonstrated that POCUS is 86.96% sensitive and 54.55% specific for predicting cardiac activity in PEA[10]. Data from the Real- time Evaluation and Assessment Sonography Outcomes Network Registry has reported that POCUS is effective in differentiating between organized and disorganized rhythms in 76% of patients with PEA[13]. Patients with this presenting rhythm are 4.35x more likely to experience ROSC[2]. An observational study involving 149 patients had demonstrated that 70.4% of patients were successfully resuscitated versus 45.1% when bedside echocardiography had detected cardiac activity[18]. Furthermore, the REASON trial, a non-randomized, prospective study, was conducted with 793 patients and revealed that 54% of patients on their initial ultrasound had PEA and of that 54%, 51% of patients had achieved ROSC and 3.8% survived to hospital discharge because a reversible cause was identified by ultrasound[4]. Kedan had also analyzed a trial that incorporated 11 studies for a total of 414 patients that demonstrated the positive patient outcomes when ultrasound was incorporated into the resuscitation efforts of PEA patients[11]. 58.8% of those patients who had cardiac motion on POCUS had met the criteria for a positive outcome defined as ROSC, survival to hospital admission or a 24-hour survival[11]. On the other hand, only 13.8% of patients without cardiac motion had a positive outcome[11]. This study represents the possibility of using ultrasound as a clinical tool in helping clinicians make a decision regarding when to terminate resuscitation efforts. Furthermore, applying bedside echocardiography at the beginning of resuscitation attempts has been associated with successful outcomes[18]. A prospective, observational study involving adults ≥ 18 years old who presented to the emergency department with cardiac arrest demonstrated that PEA was found in 34.4% of patients and of those patients, 68.2% were successfully resuscitated compared to the national average of 10%[17]. This study had a high successful resuscitation rate due to the detection of cardiac activity at the beginning of resuscitation interventions with ultrasound[17]. Cardiac activity was detected in 70.4% of patients and was absent in 45.1%[17]. The presence of cardiac motion on ultrasound in predicting ROSC had a statistically significant p value of 0.017 demonstrating the positive correlation between the presence of cardiac motion and the probability of ROSC[11]. Furthermore, patients with cardiac standstill on echo did not survive regardless of their presenting electrical rhythm[17]. The presence or absence of cardiac standstill has a 100% positive predictive value for death and a negative predictive value of 58%[17]. Thus, the presence or absence of cardiac motion is another piece of clinical evidence that can aid in clinicians in determining further management and whether or not to terminate resuscitation interventions.

Cardiac Tamponade

Cardiac tamponade is a life- threatening emergency that results as a consequence of a pericardial effusion[16]. Pericardial effusions impede cardiac contractility due to a reduction of cardiac preload along with an increase in pressure and fluid accumulation within the pericardial sac[16]. However, it is crucial to note that the presence of cardiac tamponade depends upon the rate of fluid accumulation rather than the total volume[16]. In acute cases, small effusions tend to be the cause of cardiac tamponade and subsequent cardiac arrest[16]. During cardiac arrest cases, the presentation of findings consistent with cardiac tamponade on ultrasound do not need further diagnostic exploration. Time is essential to improve the odds of ROSC, thus the resuscitation team can move on to quickly and efficiently managing the pericardial effusion with a pericardiocentesis[4]. POCUS has a success rate of more than 90% and a low rate of complications when utilized for the management of pericardial effusions during cardiac arrests [4]. A 2018 prospective observational study involving 177 patients had demonstrated that 4% of the patients had cardiac tamponade and of those patients, ROSC was achieved in 25% after a pericardiocentesis[4].

Echocardiography is the imaging modality of choice required to establish a pericardial effusion diagnosis with a sensitivity of 96% and a specificity of 98%[4]. There was an observational study that had trialed the use of POCUS in the management of cardiac arrest patients within 20 Emergency Departments across the United States and Canada known as the REASON trial. That trial found that ultrasound was able to identify pericardial effusions in 34 out of 793 patients (4%)[4]. Furthermore, the overall survival rate to hospital discharge was 15.4% when ultrasound was used compared to the 1.3% overall survival rate for all cardiac arrest patients[4]. When beginning the bedside exam during a cardiac arrest, a pericardial effusion is best seen in either a parasternal long or subxiphoid view[4]. A 5-10 MHz phased array probe is recommended due to its versatility and superior image resolution[4]. Pericardial fluid appears as an anechoic space between the pericardium and epicardium[7]. Pericardial effusions tend to be echo-free, unless the fluid accumulation is secondary to inflammation, infection or trauma[7].

Sonographic findings with high specificity for tamponade include diastolic right ventricular collapse, systolic right atrial collapse and or a plethoric IVC, a dilated IVC, which reflects elevated central venous pressure and demonstrates a <50% change in diameter during respiration[19]. Despite its high specificity, this finding is not assessed for in cases of cardiac arrest due to the patients' inability to protect their airway and lack of respiration. Right atrial systolic collapse and right ventricular diastolic collapse can be referred to as the sonographic finding, "invisible little man bouncing on a trampoline"[4]. The chambers collapse because the intracavitary pressure transiently falls below pericardial pressure[19]. Only effusion in the pericardial sac coupled with right ventricular collapse is indicative of true cardiac tamponade, regardless of the thickness of the fluid layer[15]. Not all fluid surrounding the heart is tamponade. Once the surrounding fluid has become significant enough to cause damage to cardiac structures it results in cardiac and hemodynamic compromise and is subsequently termed as tamponade. The subcostal view is ideal in visualizing right atrial and right ventricular collapses[19]. Thus, the collapse of a cardiac chamber in the presence of sonolucent fluid within the pericardium on ultrasound is highly suggestive of cardiac tamponade. To rule out cardiac tamponade, the absence of any cardiac chamber collapse has a >90% negative predictive value[19]. Thus, other cardiac arrest causes under ultrasound guidance should be investigated.

Upon sonographic evaluation of hemodynamically unstable patients, discretion is advised when distinguishing between pericardial and pleural effusions due to the differences in management. A definitive diagnosis can prove challenging due to the similarities in sonographic appearances and their close proximity to the heart and lungs[7]. Pericardial effusions are anterior to the descending aorta and above the pericardial reflection in the parasternal long axis view[7]. Effusions are located below the pericardial reflection nearfield and adjacent to the heart[7]. Pleural effusions are posterior to the descending aorta and located below the posterior pericardial reflection[7]. A common sonographic misinterpretation is mistaking the epicardial fat pad for an effusion. The epicardial fat pad is located below the anterior pericardial reflex within the pericardial sac[7]. The parasternal window helps to differentiate an epicardial fat pad and an effusion[7]. An isolated anterior location suggests a fat pad more than an effusion[7].

Pulmonary Embolism(s)

Five percent of cardiac arrests are caused by a PE with a leading presenting rhythm of PEA in 63% of patients and 32% with asystole[4]A deep vein thrombosis is the most common cause of a PE accounting for 90-95% of cases[20]. Other etiologies include endocarditis involving intracardiac masses with mobile elements, thrombi attached to indwelling lines and right sided cardiac tumors such as myxomas[20]. PEs are the third most common cause of vascular death after myocardial infarctions and strokes and is the leading preventable cause of death in hospital patients[20]. CT pulmonary angiography (CTPA) is the diagnostic imaging study of choice for patients with a suspected PE, but performing a CTPA in cardiac arrest patients is not realistic or timely. Instead, combining lung and cardiac ultrasound is suggested in patients with a suspected PE[21]. Cardiopulmonary ultrasound for PEs have a 77% sensitivity and a 99% specificity[21]. Ultrasound is also safer and a non- invasive imaging modality without any contraindications that can be readily available for bedside use[21]. Prompt analysis of a PE through POCUS allows for the immediate administration of IV thrombolytics, which are rapid and effective as recommended by ACLS guidelines[15]. However, thrombolytics help to resolve right ventricular outflow tract obstruction and does not guarantee conversion back to sinus rhythm. Bradycardia or a heart block is more frequently seen. The REASON trial had noted that patients had a 6.7% survival rate to hospital discharge after the administration of thrombolytics[4].

Abnormal structural cardiac findings on ultrasound suggestive of a PE are indirect indicators of a potential obstruction of the pulmonary vasculature. Current sonographic protocols for a PE during non- shockable cardiac arrests emphasizes the presence of a dilated right ventricle with a flattened left ventricle, which are findings that are associated with increased pressures or obstruction within the pulmonary circuit[7]. A dilated right ventricle, commonly assessed in a 4 chamber view, can also be referred to as “D- shaped,” which is commonly associated with PEs and volume overload[7]. Acute right ventricular dilatation occurs only after a few minutes of arrest due to the translocation of blood from the systemic circulation to the right side of the heart[7]. However, caution must be advised because a dilated right ventricle may also be associated with arrhythmias, respiratory failure and circulatory failure[16]. Sonographic assessment that is performed to help increase or decrease a PE suspicion involves measuring right ventricular wall diameter[16]. A thin wall diameter < 5 mm is suggestive of an acute cause, particularly a PE, if evaluated early in the cardiac arrest[16]. A study performed in an ICU involving 161 patients who presented with a cardiac arrest demonstrated the ability of ultrasound to reliably detect right ventricular pressure overload with the presence of a “D- shaped” septum in 14% of patients and the solitary presence of right ventricular dilatation was seen in 24.8% of patients[22].

Tension Pneumothorax

Tension pneumothorax is a life- threatening condition that can cause cardiovascular collapse and subsequent cardiac arrest if not recognized and treated promptly. A tension pneumothorax occurs when a “one- way valve” is created between the lung and the pleura[23]. This unidirectional airflow leads to an accumulation of air within a pleural cavity with each inspiration causing a subsequent increase in intrathoracic pressure and eventual collapse of the ipsilateral lung[23]. If the tension pneumothorax is not recognized and managed quickly and efficiently, consequences such as hypoxemia, respiratory acidosis and compromised cardiac output may lead to cardiac arrest and death[24]. Tension pneumothoraces are most commonly seen after traumatic chest injuries, invasive procedures (lung biopsies, thoracentesis, pacemaker insertion) or in patients on mechanical ventilation[23]. When patients present with non-shockable cardiac arrest, clinicians must consider a pneumothorax on their differential. A chest CT is the most reliable imaging study for diagnosing a pneumothorax, but in an emergency, time is of the essence and bedside, point of care ultrasound is preferred[24]. In addition to confirming a diagnosis of pneumothorax, ultrasound may be used to guide acute interventions to increase the chance of resuming a stable rhythm and ROSC[7].

Ultrasound is 94% sensitive and 100% specific for diagnosing a pneumothorax[7]. Evaluation should begin in the second intercostal space using a high frequency linear probe starting at the subxiphoid view[4,15]. There are two immediate ultrasound findings that the sonographer or lead clinician should search for when evaluating for a tension pneumothorax. The primary sonographic finding includes the presence or absence of a lung point[7]. A lung point is indicative of a totally collapsed lung and it is the only highly specific sign that confirms a pneumothorax[7]. The most common location to assess for lung sliding and the absence of a lung point is in the fourth and fifth intercostal spaces along the mid-clavicular line[4]. A prospective study involving 66 consecutive pneumothorax cases had compared the efficacy of ultrasound versus CTs in efficiently diagnosing a lung point[14]. Overall, ultrasound had a 66% sensitivity and 100% specificity vs a 75% sensitivity and 100% specificity for CTs[14]. The other sonographic findings include the presence or absence of lung sliding aka the “gliding sign,” which is a slight to and fro movement of the echogenic pleura during respiration[15]. The presence of the “gliding sign” excludes the pneumothorax differential, while its absence confirms its diagnosis with high accuracy[15]. Absent lung sliding between visceral and parietal pleura has a 92% sensitivity and a 99% specificity[4].

Study Summarization Tables

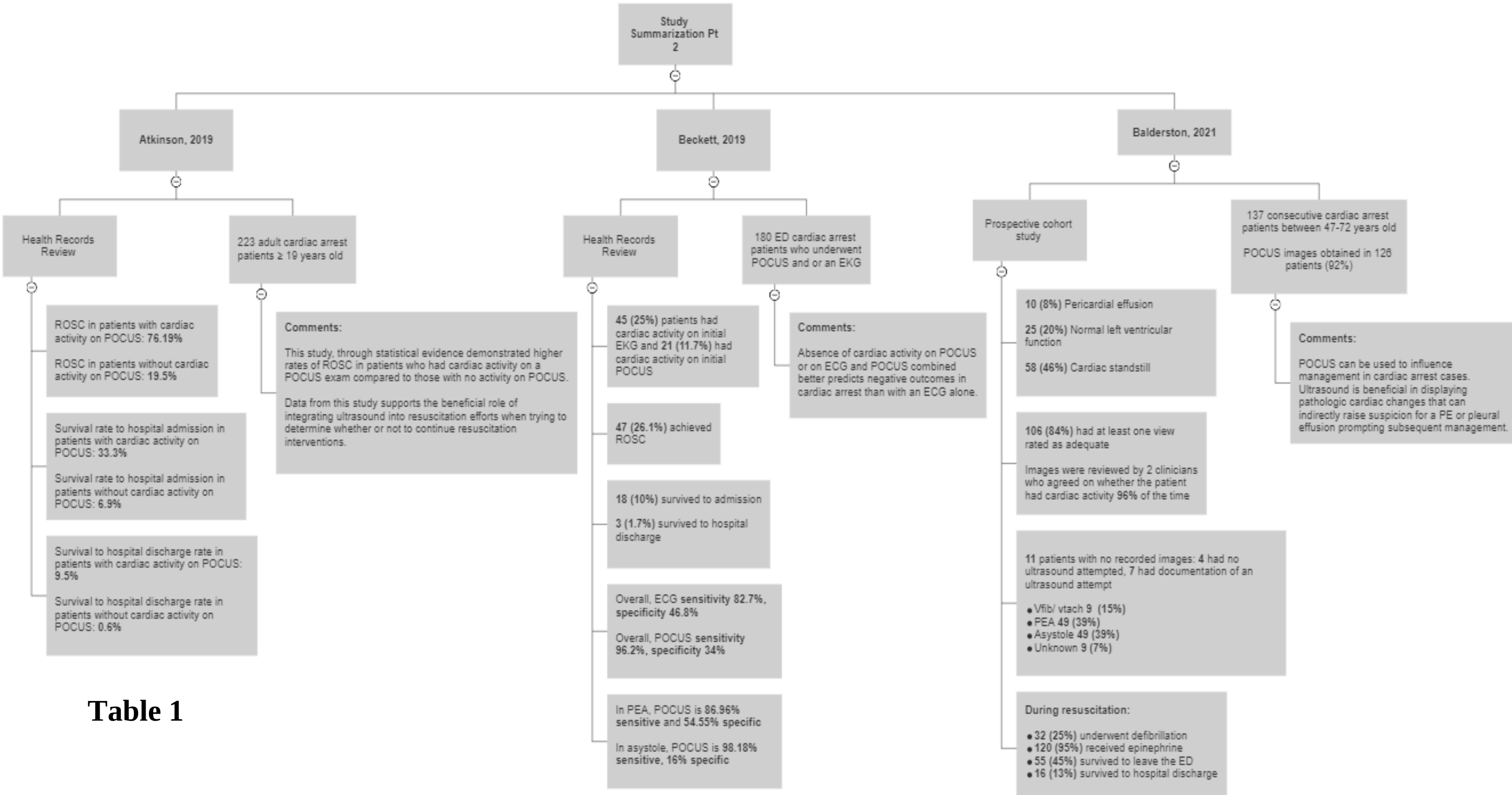

Table 1

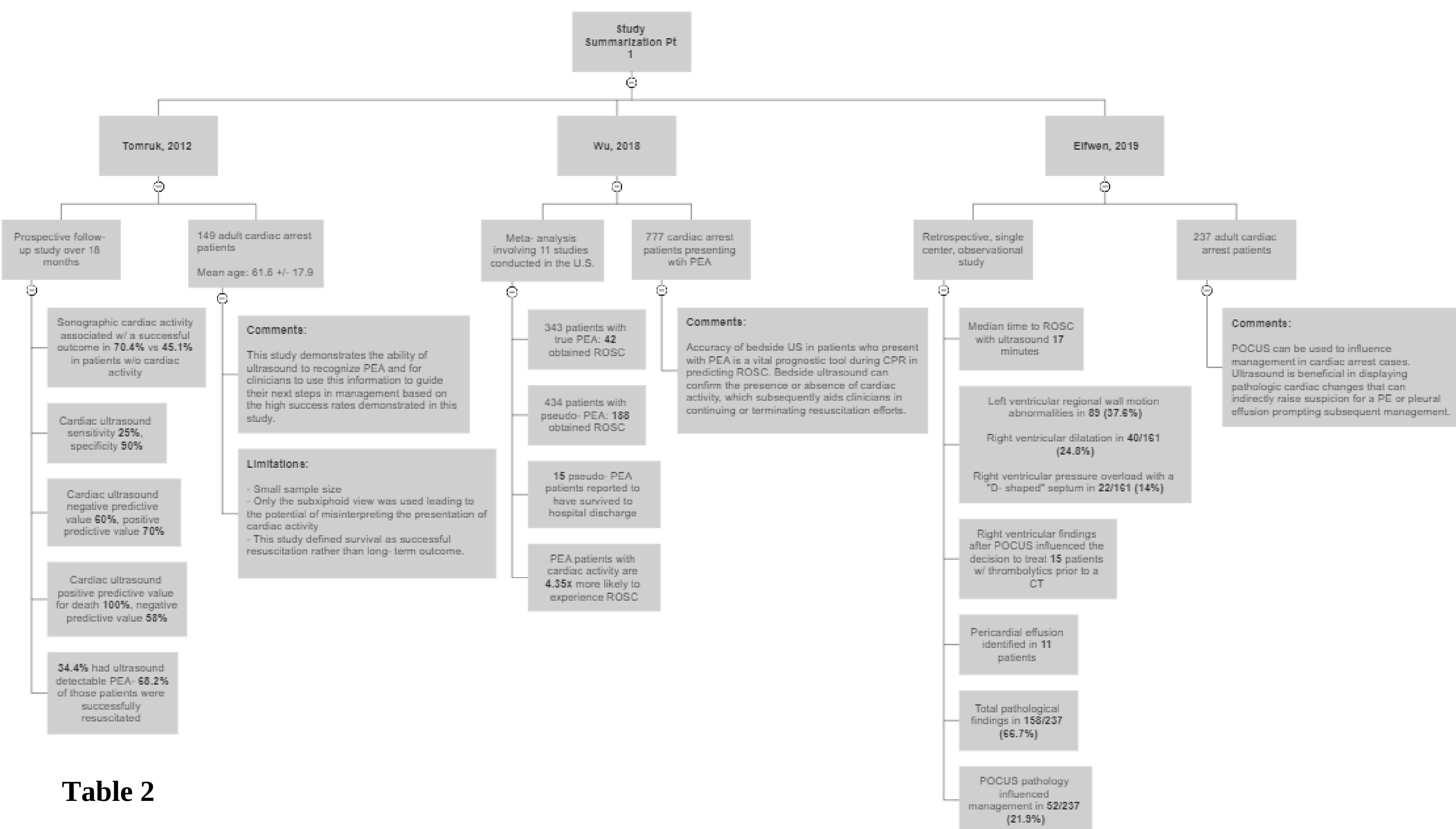

Table 2

Ultrasound during Chest Compressions

Optimal chest compressions, ventilation and early defibrillation are essential components of CPR[3]. Ultrasound provides the ability to adjust the location of the providers' hands and subsequent compression force in order to optimize chest compressions[17]. High quality compressions are associated with ROSC and survival[7]. Improper hand positioning can compress the ascending aorta, aortic root or the left ventricle outflow tract; anatomical locations that are crucial for the delivery of blood with each manual compression[7]. The CPR guidelines of the American Heart Association state that compressions should be performed midline over the lower half of the patients sternum[25]. However, recent research incorporating radiological studies have suggested that compressions over the lower half of the sternum often results in outflow obstruction 74% of the time[25]. This is indicative that compressions directly over the left ventricle may improve survival[25]. This optimal area of compression can be predetermined by locating the mid left- ventricle in the long axis with TTE in the parasternal or long axis view[25].

A pilot study had evaluated the capability of POCUS in improving chest compressions in a very small patient population of 6 non- traumatic cardiac arrest patients[26]. The study revealed that 50% had correctly performed compressions, while in the other half, there was partial left ventricle compression or narrowing of the aorta[26]. In the three patients with incorrectly executed CPR, ultrasound was used to guide changes in hand placement, which improved left ventricle contractility[26]. As a result, ultrasound provides real- time observation of compressions and the relaxation of the cardiac chambers[7]. The subxiphoid view is preferred during compressions because the clinician can position the transducer prior to the pulse check pause, which is usually accessible during compressions[7].

Within emergency departments, the “Cardiac Arrest Sonographic Assessment (CASA)” protocol is a structured algorithm for POCUS- CA aimed to reduce the difference in CPR pulse check duration between pre and post-intervention periods[27]. CPR pulse checks involving POCUS were 4.0 seconds shorter in the post- intervention than the pre- intervention group[27]. CPR pause durations were 3.1 seconds shorter when the transducer was placed on the chest prior to stopping CPR[27]. The average CPR interruption time went from 19.8 to 15.8 seconds[7]. CPR pause durations were also 3.1 seconds shorter when an ED ultrasound fellowship trained faculty performed the ultrasound compared to non- ultrasound fellowship faculty[27]. Ultimately, the proportion of pulse checks with ultrasound increased from 64% pre- intervention to 80% post-intervention[27]. Incorporating the CASA algorithm into cardiac arrest cases significantly reduced the duration of CPR interruptions and thus should be used as a framework to incorporating ultrasound into current resuscitation guidelines.

Limitations of Ultrasound in Resuscitation

Understanding sonographic limitations during resuscitation attempts is imperative to understanding how to efficiently and safely incorporate ultrasound into resuscitation algorithms. Cardiac ultrasound should be incorporated as a stepwise assessment technique with each pulse check[4]. A significant limitation to POCUS- CA is that image acquisition must be completed during pulse checks, thus increasing unnecessary delays in chest compressions[13]. However, this delay may be reduced with role clarity[13]. A prospective cohort study had demonstrated that ultrasound trained clinicians had shorter compression pauses by 4 seconds with an average of 17 seconds compared to 11-second pauses when ultrasound was not used[4]. Pauses also tend to be longer when the person leading the resuscitation is also performing the ultrasound[9]. According to

Blyth, pause duration was almost always less than 10 seconds when the individual performing the ultrasound was an independent member of the team[9]. It would be in the best interest of the resuscitation team to have an echocardiographer on the team for these emergent situations in order to effectively and efficiently acquire the diagnostic images.

Furthermore, because ultrasound is operator dependent, interpreting errors is possible, which is impacted by the ultrasound training status of the clinician and their image interpretation[9]. However, current research has demonstrated that variability in clinician interpretation is due to the lack of a universal definition of cardiac standstill[4]. Definitions range from the cessation of mechanical heart function, variable or undefined cardiac movements, any myocardial kinetic activity and more[1,7,28]. A cross-sectional convenience sample survey of 127 physicians who have access to POCUS in their practice were asked to identify whether or not a patient was in cardiac standstill with fifteen 20-second ultrasound clips[28]. This study revealed that regardless of the ultrasound training level or physician specialty, ambiguity and difficulty in interpreting cardiac activity during an arrest demonstrated only moderate agreement between the subspecialties with the highest agreement among fellows and lowest agreement amongst critical care physicians[28]. The physicians were unable to make a decision within the twenty-second time limit for only 5% of the presented cases concerning the more subtle sonographic presentations of cardiac standstill[28]. Thus, the development of a clear cardiac standstill definition would improve the quality and consistency of cardiac arrest research by helping to standardize echocardiography at the bedside.

Conclusion

Over the decades, cardiopulmonary resuscitation interventions and guidelines have evolved, but successful resuscitation rates such as survival to hospital discharge have remained minimal, hovering around 10.6%[2]. Bedside echocardiography has shown promise as a fundamental cardiac arrest tool. Ultrasound provides clinicians with the opportunity to directly visualize potential mechanical causes, guide further management and the ability to visualize the cardiac response to resuscitation interventions with real- time imaging. Cardiac motion visualized on ultrasound is the best predictor of ROSC and survival and can be used as a prognostic tool when trying to determine whether or not to continue resuscitation efforts[12]. In order to increase successful resuscitation rates, current resuscitation guidelines for non-shockable rhythms should be revised and should integrate ultrasound as a standard diagnostic tool to assist clinicians in their management of cardiac arrest patients presenting with pulseless electrical activity.

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