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REVIEWS

ELECTROCARDIOGRAM CHARACTERISTICS AS PROGNOSTIC INDICATORS IN PULSELESS ELECTRICAL ACTIVITY: A SYSTEMATIC REVIEW

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ABSTRACT

Background: The incidence of patients presenting with pulseless electrical activity (PEA) is increasing. Much existing research has focused upon guidance for the termination of resuscitation, rather than to identify indicators of survivability. ECG-based phenotyping of PEA may aid clinicians with prognostication during resuscitation.

Methods: Systematic literature searches for articles containing key words within the MEDLINE, EMBASE, and CINAHL Plus databases were undertaken to identify literature investigating the relationship between ECG characteristics and prognosis in PEA. Risk of bias assessments were performed for each included study.

Findings: Ten studies were identified, containing a total of 9,979 patients. A narrow QRS width was demonstrated to be associated with ROSC in four out of the seven studies investigating this component. An increased QRS amplitude was also associated with ROSC, however, this was only investigated within one study. The relationship between QRS rate and ROSC was variable. Assessing combined ECG components may offer some prognostic insight with the presence of P waves, a QRS rate < 60 and QRS width < 120 ms linked to an increased likelihood of survival. A moderate risk of bias was found within all included studies.

Conclusion: The presence of ECG component changes may assist decision-making with the ongoing resuscitation strategy for patients with PEA. Several studies had missing ECG or patient outcome data therefore were at risk of bias due to incomplete patient inclusion. Further prospective research is needed to evaluate the use of ECG components to identify subgroups of PEA with a high likelihood of survival.

INTRODUCTION

In comparison to other cardiac arrest rhythms, the incidence of patients presenting to emergency medical services with pulseless electrical activity (PEA) is increasing. An audit of 48,707 patients with out-of-hospital cardiac arrest (OHCA) by Bergstrom et al. (2018) revealed in 1990-1995 12.5% of patients presented with PEA, which increased to 15.5% between 1996-2000, 18.2% in 2001-2005, 19.8% in 2006-2010, and finally 21.6% In 2011-2016 ($p < 0.0001$). Numerous reasons for this increase have been postulated, including increased beta-blocker and implantable cardioverter defibrillator use (Bunch et al., 2004; Youngquist et al., 2008), and the implementation of primary and secondary coronary artery disease prevention strategies decreasing incidence of ventricular fibrillation (VF) (Wang et al., 2009). Despite this, much existing research has focused upon the development of guidance for the termination of resuscitation, rather than to identify indicators of survivability (Coppola et al., 2021a).

PEA and asystole are often grouped together as “non-shockable rhythms” and consequently their treatment and associated outcomes are often reported together. There is now emerging consensus that differentiation should be made between these presentations to aid with the identification of patients with a favourable prognosis (Rabjohns et al., 2020; Elhalwagy et al., 2024). Furthermore, differentiation may also be possible in patients who present with PEA, as this represents a spectrum of underlying electrical and cardiovascular function (Elhalwagy et al., 2024). This ranges from pseudo-PEA–a low-output state with echocardiographic evidence of cardiac motion but no manually palpable pulses (Rabjohns et al., 2020), to “true PEA” with no mechanical cardiac activity (Elhalwagy et al, 2024). Point-of-care ultrasound (POCUS) is required to make a diagnosis of pseudo-PEA and is becoming frequently utilised in prehospital resuscitation. However, this is often limited to use by enhanced care resources and may not always be available in the initial stages of resuscitation. PEA differentiation through ECG-based phenotyping may provide clinicians with information to guide prognostication and decision-making during resuscitation, when other diagnostic tools are not available.

This systematic review aimed to determine and explore how ECG characteristics can serve as prognostic indicators in patients with PEA by identifying studies that examined the relationship between ECG features in PEA and clinical outcomes.

METHODS

This systematic review adheres to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). Electronic searches for articles containing key words within the MEDLINE, EMBASE, and CINAHL Plus databases were undertaken. The search terms used are displayed in Table 1. Inclusion and exclusion criteria are displayed in Table 2. These terms were validated by ensuring articles already known to be relevant to the subject could be identified. All search results were imported into Mendeley™ reference management software. Following duplicate removal, titles and abstracts were screened to identify articles for full-text review. Articles were selected for final inclusion following full-text review. A full-text review of all selected articles was undertaken by one reviewer to determine articles for final inclusion. Instances of unclear eligibility were discussed with the second reviewer. When consensus on inclusion could not be established, a third reviewer was available to decide on inclusion. The flow chart in Figure 1 provides a schematic of the screening process. The findings of articles selected for final inclusion were subjected to thematic analysis and discussed within a narrative synthesis

Data Items

The following data items were collected from articles that were selected for final inclusion: study type, number of participants, ECG components assessed, outcome data.

Search	Terms
S1	‘pulseless electrical activity’ OR PEA OR ‘electromechanical dissociation’OR EMD
S2	tachy* OR brady* OR rate OR complex* OR wide OR narrow OR QRS OR ‘p wave’ OR ‘t wave’ OR activity OR ECG OR EKG OR electrocard*
S3	‘ECG characteristics OR components
S4	‘narrow QRS’ OR ‘narrow complex’ OR ‘wide QRS’ OR ‘wide complex’
S5	prognos* OR outcome OR surviv* OR mortality OR death OR ROSC OR ‘return of spontaneous circulation’
S6	S5 AND S1
S7	S6 AND S2 AND S3 OR S4
S8	S6 AND S2 OR S3 OR S4

Table 1. Search strategy.

Included	Excluded
Case series, observational studies, randomised controlled trials, empirical research	Single-patient case reports
Adult patients	Neonatal or paediatric patients
English language	Animal studies
Within peer-reviewed journals	Use of non-standard ECG components
Published since 1 January 2014	Use of electrical or mechanical cardiac support during resuscitation
Describing ECG characteristics recorded during PEA cardiac arrest	Investigating the effects of medications
	Grey literature

Table 2. Inclusion and exclusion criteria.

ECG Component Normal Values

The following definitions were used: Normal heart rate (60-100 bpm), QRS duration (80-120 ms), PR interval (120-200 ms), QRS amplitude (3.0 mV), QTc interval (<500 ms).

Risk of Bias Assessment

The risk of bias of these studies was evaluated with the use of the relevant JBI risk of bias assessment tool for the study methodology (https://jbi.global/).

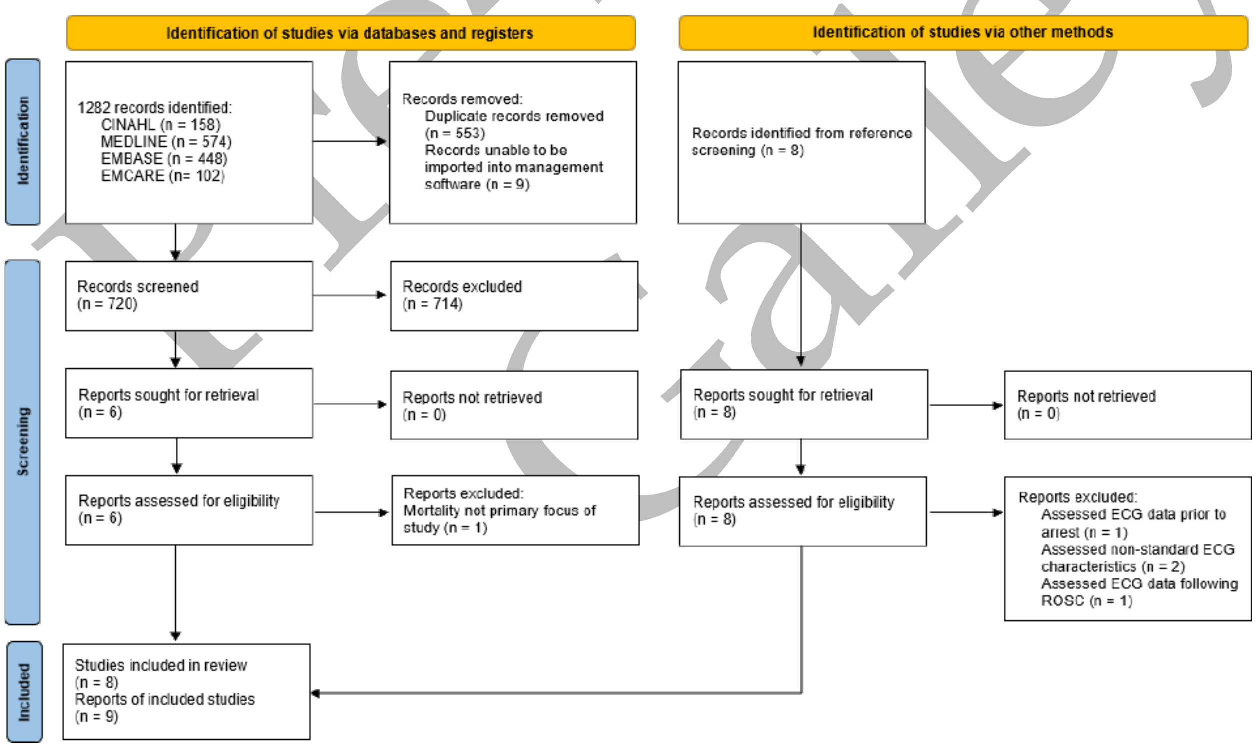

Figure 1: PRISMA flowchart.

Study	Study Type	Period	Sample Size	Setting	Age	% Female
Hauck et al. (2015)	Case series	2010 - 2013	262	OHCA	67 (mean)	48%
Bergum et al. (2016)	Case series	2009 - 2013	51	IHCA	75 (median [IQR 65–82])	43%
Ho et al. (2016)	Case series	2007- 2009	332	OHCA	71.8 (mean)	41.6%
Skjeflo et al. (2018)	Case series	2009 - 2012	74	IHCA	ROSC 65, No ROSC 78 (median)	24%
Weiser et al. (2018)	Case series	2013 - 2015	504	OHCA	70 ± 16 (mean ± SD)	45%
Nguyen et al. (2020)	Cohort study	2013 - 2017	176	IHCA	60 (mean)	30%
Kim et al. (2020)	Case series	2016 - 2018	576	OHCA	73 (median [IQR 61–81])	42%
Cournoyer et al. (2022)	Cohort study	2011 - 2015	7089	OHCA	70.7 (mean)	39.5%
Norvik et al. (2023)	Case series	2008 - 2021	298	IHCA	68 (median [IQR 57–78])	44%
IHCA = in-hospital cardiac arrest, OHCA = out-of-hospital cardiac arrest, SD = standard deviation, IQR = interquartile range, ROSC = return of spontaneous circulation						

Table 3. Study demographic details.

RESULTS

Study Characteristics

Application of the electronic database search strategy yielded a total of 1282 records. MEDLINE produced 574 results, EMCARE produced 102, and CINAHL Plus and EMBASE produced 158 and 448 results, respectively. After importing and duplicate screening using RefWorks™ (ProQuest, 2023), a total of 720 records were available for title and abstract screening. 714 records were removed via title and abstract screening. After obtaining the full texts of all articles, five were selected for final inclusion. One was excluded as mortality was not the primary focus of the study. Manual reference screening identified 8 additional articles, with four removed following full-text review. A total of nine reports from eight studies, comprising seven case series and two cohort studies, were identified. Study demographic details are displayed within Table 3. Two were cohort studies with comparator groups; Nguyen et al. (2020) compared patients with bradycardic and non-bradycardic PEA, and Cournoyer et al. (2022) compared the outcomes of patients with PEA and shockable rhythms. Bergum et al. (2016), Skjeflo et al. (2018) and Norvik et al. (2023) all reported on patients from the St. Olav's University Hospital cardiac arrest database. Five studies contained data on patients with out-of-hospital cardiac arrest, and four used data from inpatient cardiac arrest.

Risk of Bias

Overall, the risk of bias within all included studies was moderate. A detailed summary of their assessments is included within Appendix A and B. All but one study was unable to demonstrate complete inclusion of eligible patients due to missing data, and several were unable to clearly evidence consecutive inclusion of patients. The cohort study by Cournoyer et al. (2022) was the only study found to be at low risk of bias.

Synthesis

QRS Rate

The rate of QRS complexes was the most frequently evaluated ECG component of PEA, with nine reports assessing this (see Table 5). Four studies provided the QRS complex rates of survivors and non-survivors, and the remaining studies grouped results by variable intervals. The largest study identified was undertaken by Cournoyer et al. (2022),

Reference	Study aims (outcomes assessed)	Results/Findings	Study Strengths	Study Weaknesses
Hauck et al. (2015)	To determine if rate or QRS width correlated with outcome (STD with CPC 1 or 2)	• No statistically significant difference in HR or QRS width of survivors vs non-survivors	• Utilised a method that can be applied in the pre-hospital setting	• Retrospective. • 152 patients in initial database excluded due to missing data. • QRS >200 ms excluded. • Small total no. of survivors.
Bergum et al. (2016)	To evaluate the association between early ECG patterns and survival (ROSC, 1-hour survival, STD)	• No unique ECG patterns were associated with survival	• Prospective	• Single centre. • Small sample size.
Ho et al. (2016)	To assess the prognostic value of initial ECG characteristics (ROSC at admission, STD)	• No correlation found between ECG characteristics and survival	• Multi-centre. • Prospective enrolment	• Excluded trauma patients
Skjeflo et al. (2018)	To describe the development of ECG characteristics during ALS and their association with ROSC	• QRS width decreased and HR increased prior to ROSC • HR decreased and QRS width increased in those without ROSC	• Provides insight on dynamic changes to ECG components during resuscitation	• Single-centre, retrospective study
Weiser et al. (2018)	To evaluate the relationship between HR and survival (30-day survival, 30-day CPC 1 or 2)	• Higher initial HR (> 60) associated with increased odds of 30-day survival and CPC 1 or 2	• Adjusted for confounders. • Statistical significance reached	• Retrospective
Nguyen et al. (2020)	To determine the prevalence of bradycardic PEA and the relationship between this and respiratory arrest (survival of arrest event, STD)	• Bradycardic PEA arrests had higher STD than non-bradycardic PEA arrests.	• Used multiple hospital settings. • Comprehensive review of causes of arrest.	• Only one ECG characteristic assessed
Kim et al. (2020)	To investigate the relationship between QRS characteristics and outcomes (STD, STD with CPC 1 or 2)	• Narrow QRS and higher QRS amplitude associated with STD with good neurological function. • No difference seen in HR between groups	• Large sample size	• Undertaken in BLS-only system
Cournoyer et al. (2022)	To evaluate the association between initial PEA rate and favourable clinical outcomes (STD, STD with MRS 0-2)	• Higher initial HR is associated with STD and STD with good neurological function	• Multi-centre. • Large sample size.	• Non-cardiac aetiologies excluded. • Only HR assessed
Norvik et al. (2023)	To investigate how HR and QRS duration are related to the probability of ROSC	• Higher initial HR and increasing HR during ALS were associated with increased probability of ROSC. • Lower QRS width and decreasing QRS width during ALS associated with increased probability of ROSC.	• Multi-centre. • Prospective study.	• Difficulties in determining between episodes of ROSC/PEA without other signs of circulation may have overestimated ROSC

Table 4. Results of included studies.

which contained a total of 12,477 patients. These were grouped by rate in denominators of 20, from 1-20 up to > 120. A linear increase in odds ratio (OR) for survival with good neurological function was seen as QRS rate increased. Patients with a presenting QRS rate between 1 and 20 had an OR of survival with good neurological function (Modified Rankin Score 1-2) of 0.06 (95% CI [0.03, 0.11], $p < 0.001$). Conversely, those with a rate > 120 had an OR of 0.90 (95% CI [0.45, 1.81], $p = 0.77$), albeit this finding did not reach statistical significance. Interestingly, patients with a QRS rate greater than 100 shared a similar

Reference	QRS Rate	P Waves	QRS Width	QT Interval	QRS Amplitude
Hauck et al. (2015)	Assessed	Not Assessed	Assessed	Not Assessed	Not Assessed
Bergum et al. (2016)	Assessed	Assessed	Assessed	Assessed	Not Assessed
Ho et al. (2016)	Assessed	Assessed	Assessed	Not Assessed	Not Assessed
Skjeflo et al. (2018)	Assessed	Not Assessed	Assessed	Not Assessed	Not Assessed
Weiser et al. (2018)	Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Nguyen et al. (2020)	Assessed	Not Assessed	Assessed	Not Assessed	Assessed
Kim et al. (2020)	Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Cournoyer et al. (2022)	Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Norvik et al. (2023)	Assessed	Not Assessed	Assessed	Not Assessed	Not Assessed

Table 5. ECG components assessed.

likelihood of survival with good neurological function to those presenting in shockable rhythms.

Weiser et al. (2018) compared the rate of QRS complexes recorded during the first 60 seconds of available ECG data with the neurological function (Cerebral Performance Category [CPC] 1-2) of survivors of PEA at 30 days following cardiac arrest. Patients were stratified into four groups: 10-24 bpm, 25-39 bpm, 40-59 bpm and >60 bpm. 504 patients with PEA were included in the study, and 32 (6%) survived with a CPC score of 1-2. No survivors with good neurological function were seen in those with a QRS rate of 10-24. The number of survivors from the remaining groups were 7 (4%), 14 (9%) and 11 (15%) respectively (p = 0.001). After adjusting for confounding clinical factors, the odds of survival with good neurological function increased by 0.48 (95% CI [0.3, 0.77], p = 0.001) per 20 bpm grouping.

Conversely to the studies reporting an association between a faster HR and survival, Nguyen et al. (2020) demonstrated patients with bradycardic PEA, defined as a rate less than 60, had a higher incidence of both ROSC and survival to discharge than patients with non-bradycardic PEA (66.7%, n = 44 vs. 55.5%, n = 61 and 33.3%, n = 22 vs. 14.5%, n = 16). Following multivariate analysis, bradycardic PEA had an OR of 3.31 for survival to discharge (95% CI [1.41, 7.79], p = 0.006).

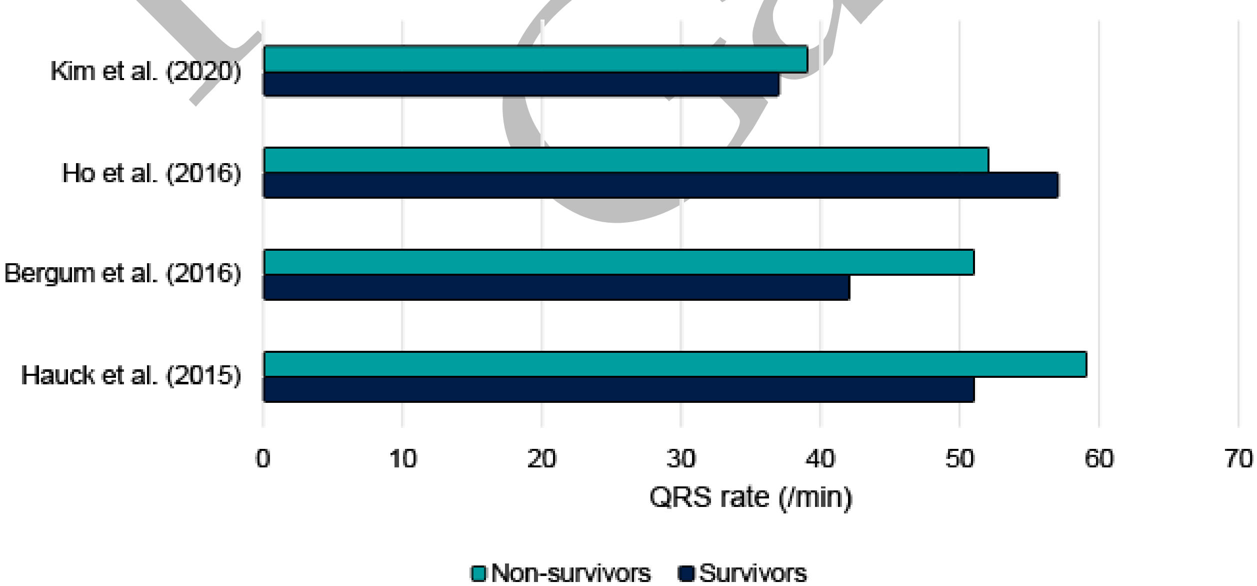

Figure 2: Studies reporting QRS rate (ungrouped).

In their analysis of 58 episodes of in-hospital PEA arrest, Bergum et al. (2016) reported a no-ROSC incidence of 60% (n = 35), with 29% (n = 17) 1-hour survival and 10% (n = 6) survival to discharge. The median QRS rate for those with no-ROSC was 51 (IQR 39-63), compared to 45 (IQR 41-54) in those who survived for 1 hour and 42 (IQR 34-94) in those who survived to discharge. Additionally, Hauck et al. (2015) also reported a lower QRS rate in survivors in 262 OHCA patients with PEA. Survivors were found to have a mean rate of 51 (95% CI [38.8, 63.2]) with non-survivors having a mean rate of 59.2 (95% CI [54.8, 63.6]).

A non-significant difference between the QRS rate of survivors and non-survivors was reported by Kim et al. (2020) in their evaluation of 576 OHCA patients. The median QRS rate for survivors was 37 (IQR 30-54) and 39 (IQR 29-55) in non-survivors ($p = 0.770$). Ho et al. (2016) also reported a non-significant difference (56.8 vs. 52.0, $p = 0.53$) in their study of 332 patients with PEA who were attended by EMS in Ottawa, Canada.

QRS Duration

QRS duration was assessed in seven studies. Three studies provided mean or median QRS duration, and four dichotomised their samples as greater or less than 120 ms. In their study of 576 patients Kim et al. (2020) reported survivors were more likely to have a QRS duration of less than 120 ms. 42 patients survived to hospital discharge, with 23 surviving with a favourable neurological outcome (CPC 1-2). 320 (55.6%) patients were found to have a median QRS width > 120 ms and 256 (44.4%) had a median QRS width < 120 ms. A QRS duration < 120 ms was associated with survival to discharge (71.4% vs 28.6%) and a favourable neurological outcome (69.6% vs 30.4%). After adjustment for variables, in patients with a QRS duration < 120 ms, the odds ratios for survival were 3.371 (95% CI [1.633, 6.960]), and 4.634 (95% CI [1.562, 13.144]) for survival with favourable neurological outcomes.

A prospective, multi-centre study of 332 patients by Ho et al. (2016) found no significant differences between the QRS duration of survivors and non-survivors (128.7 vs. 129.6 ms, $p = 0.95$). In patients with a QRS duration of > 120 ms the univariate odds ratio of ROSC

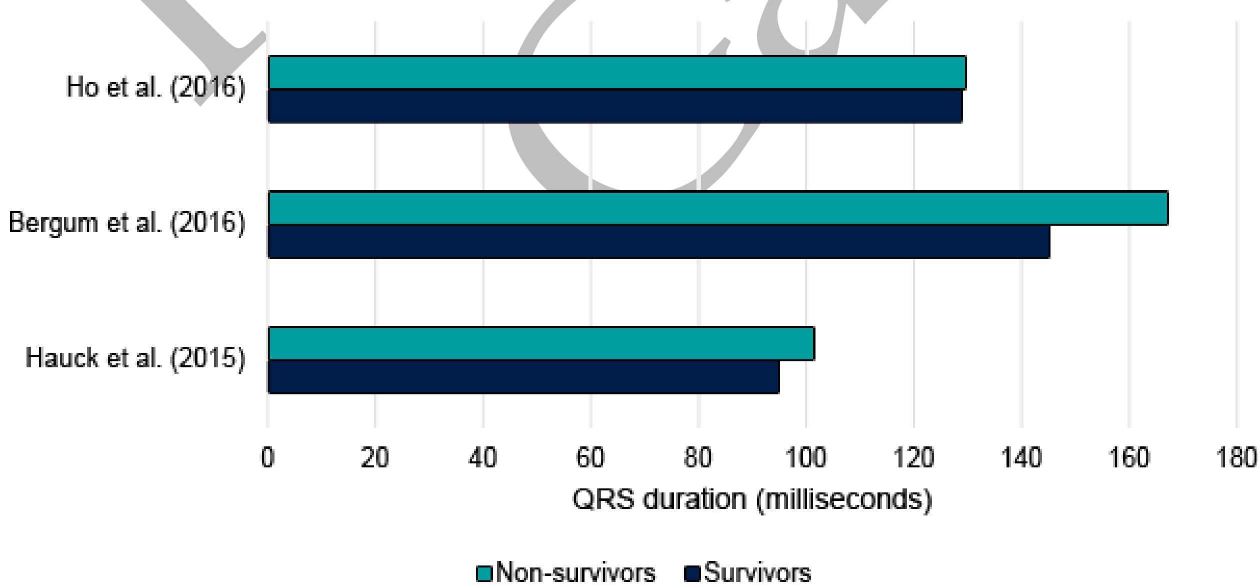

Figure 3: Studies reporting QRS duration (ungrouped).

was 0.67 (95% CI [0.41, 1.09], p = 0.11) and 0.98 (95% CI [0.38, 2.52], p = 0.97). Hauck et al. (2015) found the mean QRS duration of survivors was 94.8 ms (95% CI [79, 110.6]) compared to 101.4 ms (95% CI [95.3, 107.4]) in non-survivors. A similar finding of wider QRS widths in non-survivors was also demonstrated by Bergum et al. (2016), who reported a median QRS duration of 167 ms (95% CI [125, 209]) in non-survivors, 182 ms (95% CI [150, 235]) in those with 1-hour survival and 145 ms (95% CI [140, 174]) in those who survived to hospital discharge.

Changes in QRS Rate or Duration During Resuscitation

Skjeflo et al. (2018) studied 74 patients with in-hospital cardiac arrest and demonstrated decreasing QRS duration during ALS was significantly more frequent in patients who obtained ROSC compared to those declared dead. Patients from this study were also included in a larger multi-centre study of 298 patients analysed by Norvik et al. (2023), who extracted 559 ECG segments of PEA from ECG recordings taken during resuscitation and assessed QRS the duration within these to determine the likelihood of PEA transitioning to sustained ROSC (lasting > 20 minutes), temporary ROSC (lasting < 20 minutes) or other cardiac arrest rhythms. 145 segments ended with sustained ROSC, and 137 ended with temporary ROSC. This investigation found a decreasing QRS duration during resuscitation increased the odds of ROSC. The OR of ROSC was 1.26 (95% CI [1.13, 1.40], p < 0.001) per 40 ms decrease in QRS duration, with no differences seen between the QRS durations of patients who sustained a temporary or sustained ROSC.

Akin to the findings of studies investigating changes to QRS width during resuscitation, a similar relationship was seen between dynamic changes to QRS rate and patient outcome. When comparing the ECG characteristics of the initial monitored rhythm and final monitored rhythms of survivors, Skjeflo et al. (2018) found increasing QRS rate during resuscitation was a positive prognostic indicator for ROSC on scene. Finally, Norvik et al. (2023) found for every 40 bpm increase above 80 bpm, the OR of ROSC increased by 1.39 (95% CI [1.21, 1.58], p <0.001).

Other Components

An association between P waves and survival was demonstrated by Ho et al. (2016), who reported the presence of P waves in 67% (n = 12/18) of survivors and 52% (n = 163/314) of non-survivors. Conversely, a difference between survivors and non-survivors was not demonstrated by Bergum et al. (2016), who found P waves were present in 63% of patients with no ROSC, 76% of patients who survived for 1 hour, and 67% of patients who survived to discharge.

Bergum et al. (2016) was the only study to evaluate the QT interval and found a median QT interval of 494 (IQR 409-569) in patients with no ROSC, 540 (IQR 465-602) in patients who survived for 1 hour, and 528 (IQR 377-670) in those that survived to discharge. Similarly, median QTc intervals were 439 (IQR 376-508), 475 (IQR 426-509), and 513 (IQR 448-550) respectively.

Kim et al. (2020) found the median QRS amplitude of all survivors was 13 mm (95% CI [11, 18]) and was 10 mm (95% CI [7, 15]) in non-survivors. Subgroup analysis also revealed the median QRS amplitude of survivors with favourable neurological outcomes was greater than the median of all survivors (16 mm, 95% CI [12, 19] vs. 13 mm, 95% CI [11, 18], $p < 0.001$).

Combined Components

Ho et al. (2016) assessed the survival rate of 332 patients when QRS rate and width were combined. The survival rate of patients with a QRS rate of 60 or greater, in combination with a QRS duration of less than 120 ms, was 7.2% (95% CI [1.1, 13.4]). In comparison, in patients with a rate of less than 60 and a QRS duration of greater than 120 ms, the survival rate was 3.7% (95% CI [0.5, 6.9]). This study also evaluated the outcomes of patients with these two groups with or without P waves. 27.8% (n = 5/18) of survivors had a QRS rate > 60, duration < 120 ms and P waves present, compared to 17.2% (n = 53/314) of non-survivors. Similarly, patients with no P waves, QRS rate < 60 and QRS duration > 120, made up 11.1% (n = 2/18) of survivors and 30.3% (n = 90/314) of non-survivors.

No statistical details were provided by Bergum et al. (2016) who displayed their findings in a scatter plot. No discernible differences were seen, with a tendency towards slower rates (< 60) and QRS durations of greater than 120 ms in both survivors and non-survivors.

DISCUSSION

This systematic review found there is inconsistency amongst the findings of studies investigating the utility of ECG characteristics as outcome indicators. Patients with a normal or "narrow" QRS duration (< 120 ms) during initial presentation may have an increased likelihood of ROSC compared to those with "wide" QRS complexes (> 120 ms). An association between increased HR and survival was observed in several studies, however the numbers of survivors were low overall, thus limiting the statistical precision of these findings. Contradictory results favouring a lower HR were also reported in several studies. Similarly, the presence of P waves produced variable results. An increased amplitude of QRS complexes correlated with survival in the single study that evaluated this component.

The results of this review partly reflect the findings of a systematic review and meta-analysis of the association between QRS characteristics in PEA and patient outcomes by Kim et al. (2024), who reported a wide QRS (> 120 ms) was associated with greater odds of mortality than a narrow QRS (< 120 ms) (OR = 1.86, 95% CI [1.11, 3.11]). Conversely, the odds of mortality for patients with a QRS rate < 60/min was significantly higher than those with a QRS frequency > 60/min (OR = 1.90, 95% CI [1.19, 3.02]), whereas our review found variability in the association between QRS rate and prognosis. Whilst their analysis provides valuable insight and an indication that some ECG components may have an association with patient outcomes, it did not include studies assessing other ECG components of PEA, the relationship between combined ECG components, or the relevance of dynamic ECG changes during resuscitation and patient outcomes.

Our previous review on the use of ECG component assessment in PEA demonstrated they should not be used to determine the aetiology or requirement for specific interventions (Gander and Laws, 2025). Nonetheless, dynamic changes occurring during resuscitation may hold some potential for use in clinical decision-making. Patients who display a pattern of increasing HR and decreasing QRS width may be more likely to obtain a

ROSC. Additionally, the presence, or development of, P waves may also indicate a higher likelihood of ROSC. These findings may support the theory that QRS width represents the "the underlying physiological state of the myocardium" as proposed by Skjeflo et al. (2019), and decreasing QRS width during resuscitation may therefore represent improving myocardial condition and function in response to treatment. Further research should explore the assessment of ECG components in PEA at regular intervals throughout resuscitation to determine their accuracy as indicators of an impending ROSC or the impact of ALS interventions on these. The inclusion of adult patients with a known or highly suspected cardiac aetiology may help to evaluate the relationship between myocardial condition, ECG components and prognosis.

This review partly supports the observations of a mixed-methods study by Coppola et al. (2021b), who explored how senior clinical advisors made decisions regarding futility and the cessation of resuscitation in patients with PEA. Participants stated that ECG morphology was one aspect considered when making such decisions, with narrow complex PEA considered to be associated with survival and wide complex bradycardic PEA felt to be an indicator of a poor prognosis. Our study supports the role of QRS width assessment as a factor to support decision-making, however, the predictive value of HR is less well defined due to small sample sizes and conflicting results within the literature. Although singular observations of QRS width do not provide an adequate indication of survivability, observation of the trajectory of QRS width throughout resuscitation, by comparing the presenting width of complexes in the initial rhythm with subsequent recordings, may provide an easily assessable source of information prognostic information for clinicians. This information should be interpreted in conjunction with other clinical findings when informing decisions regarding ongoing resuscitation. Additionally, ECG component assessment should not detract from the delivery of high-quality CPR and other procedures during resuscitation. Therefore, when possible, it is advised that these are obtained by obtaining a rhythm printout during pulse checks for interpretation after CPR is resumed.

An additional factor to consider in the relationship between ECG characteristics and survival is the presence of pseudo-PEA. As a degree of coronary perfusion is maintained in this state, it may be hypothesised that the presence of "normal" ECG components is more likely. This subset of PEA carries a higher survival rate than true PEA (Tsou et al., 2017; Elhalwagy et al., 2024). Therefore, it is possible some survivors of PEA had pseudo-PEA and thus contributed to higher survival rates in cases with ECG characteristics closer to normal values. Further studies should be undertaken using ultrasonography to evaluate the relationship between ECG characteristics and the presence or absence of mechanical cardiac activity.

When interpreted during resuscitation, QRS complex rate may also be influenced by other factors including the administration of medications. Adrenaline administration every 3-5 minutes is a recommended treatment for patients with PEA (Soar et al., 2021). Skjeflo et al. (2019) demonstrated patients with PEA who received adrenaline during resuscitation displayed a pattern of increasing HR prior to both ROSC and death. In cases of pseudo-PEA due to low cardiac output, the chronotropic and inotropic effects of adrenaline may improve systemic blood pressure and generate a palpable pulse. This may explain the correlation seen between increasing HR and ROSC in several studies.

Patients presenting with PEA often have a different clinical course and mortality rate to those with asystolic presentations (Norvik et al., 2022; Unneland et al., 2023; Elhalwagy et al. 2024). This review has highlighted several subgroups of PEA, such as those with narrow QRS complexes, have higher survival rates than others and may benefit from tailored resuscitation attempts. For example, if QRS duration represents the physiological condition of the myocardium, as proposed by Skjeflo et al. (2018), distinction between phenotypes of PEA stratified by ECG characteristics, may help to identify patients who will benefit from physiology-guided resuscitation. This may include titrated vasopressin or noradrenaline to augment cardiac output in cases of pseudo-PEA (Elhalwagy et al., 2024).

LIMITATIONS

Due to time and resource constraints, only literature published in the English language was included. Whilst this did not lead to the exclusion of any articles during the screening process, the use of English-language search terms may have led to the omission of relevant articles. Furthermore, due to time constraints, subject matter experts were not contacted to identify further literature. To aid with understanding practical application, this systematic review excluded reports utilising complex ECG component assessment that is not traditionally available to clinicians or easy to assess during resuscitation, such as techniques also involving transthoracic impedance or impedance circulation component assessment. This led to the exclusion of four studies that may offer further diagnostic or predictive insight. The inclusion of both IHCA and OHCA may have introduced significant clinical and methodological heterogeneity in several areas including patient presentation, bystander CPR, and intra-arrest diagnostics or treatments. This may therefore limit the comparability of findings across studies. Finally, the definitions of ROSC varied between studies. This may create additional inconsistency in the reported relationships between ECG characteristics and ROSC, as patients may have received additional interventions before the outcome was measured.

CONCLUSION

This review has found the QRS width and rate are the most frequently investigated ECG components in PEA. A narrow QRS width during resuscitation was demonstrated to be associated with ROSC in four of the seven studies evaluating this component. Studies evaluating the relationship between QRS rate and ROSC produced variable results. Combinations of ECG components may also offer some prognostic insight. A pattern of an increasing rate with decreasing QRS width during resuscitation was reported to be more prevalent in survivors. Additionally, a higher QRS amplitude was also found to be associated with survival within one study. The presence of these ECG changes may assist decision-making with the ongoing resuscitation strategy for patients with PEA. Overall, the level of evidence of studies included within this systematic review was low, due to their retrospective, non-comparative methodologies. Most studies were also at risk of bias due to incomplete patient inclusion due to missing ECG or patient outcome data. Further prospective research is needed to evaluate the use of ECG components to identify subgroups of PEA with a high likelihood of survival.

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APPENDIX A: RISK OF BIAS ASSESSMENT RESULTS – CASE SERIES

Reference	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Overall Risk of Bias
Hauck et al. (2015)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Moderate
Bergum et al. (2016)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Moderate
Ho et al. (2016)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Moderate
Skjeflo et al. (2018)	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes	Moderate
Weiser et al. (2018)	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes	Moderate
Kim et al. (2020)	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes	Moderate
Norvik et al. (2023)	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes	Moderate

- Q1: Were there clear criteria for inclusion in the case series?
- Q2: Was the condition measured in a standard, reliable way for all participants included in the case series?
- Q3: Were valid methods used for identification of the condition for all participants included in the case series?
- Q4: Did the case series have consecutive inclusion of participants?
- Q5: Did the case series have complete inclusion of participants?
- Q6: Was there clear reporting of the demographics of the participants in the study?
- Q7: Was there clear reporting of clinical information of the participants?
- Q8: Were the outcomes or follow up results of cases clearly reported?
- Q9: Was there clear reporting of the presenting site(s)/clinic(s) demographic information?
- Q10: Was statistical analysis appropriate? (Munn et al., 2020)

APPENDIX B: RISK OF BIAS ASSESSMENT RESULTS - COHORT STUDIES

Reference	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Overall Risk of Bias
Nguyen et al. (2020)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Moderate
Cournoyer et al. (2022)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Low

- Q1: Were the two groups similar and recruited from the same population?
- Q2: Were the exposures measured similarly to assign people to both exposed and unexposed groups?
- Q3: Was the exposure measured in a valid and reliable way?
- Q4: Were confounding factors identified?
- Q5: Were strategies to deal with confounding factors stated?
- Q6: Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?
- Q7: Were the outcomes measured in a valid and reliable way?
- Q8: Was the follow up time reported and sufficient to be long enough for outcomes to occur?
- Q9: Was follow up complete, and if not, were the reasons to loss to follow up described and explored?
- Q10: Were strategies to address incomplete follow up utilized?
- Q11: Was appropriate statistical analysis used? (Moola et al., 2020)