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The associations between rapid response systems and their components with patient outcomes: A scoping review

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Abstract

Background: While rapid response systems have been widely implemented, their impact on patient outcomes remains unclear. Further understanding of their components—including medical emergency team triggers, medical emergency team member composition, additional roles in patient care beyond responding to medical emergency team events, and their involvement in "Do-Not-Resuscitate" order placement—may elucidate the relationship between rapid response systems and outcomes.

Objective: To explore how recent studies have examined rapid response system components in the context of relevant adverse patient outcomes, such as in-hospital cardiac arrests and hospital mortality.

Design: Scoping review.

Methods: PubMed, CINAHL, and Embase were searched for articles published between November 2014 and June 2022. Studies mainly focused on rapid response systems and associations with in-hospital cardiac arrests were considered. The following were extracted for analysis: study design, location, sample size, participant characteristics, system characteristics (including medical emergency team member composition, additional system roles outside of medical emergency team events), medical emergency team triggers, in-hospital cardiac arrests, and hospital mortality.

Results: Thirty-four studies met inclusion criteria. While most studies described triggers used, few analyzed medical emergency team trigger associations with outcomes. Of those, medical emergency team triggers relating to respiratory abnormalities and use of multiple triggers to activate the medical emergency team were associated with adverse patient outcomes. Many studies

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Declaration of Competing Interest

None.

Supplementary materials

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described medical emergency team member composition, but the way composition was reported varied across studies. Of the seven studies with dedicated medical emergency team members, six found their systems were associated with decreased incidence of in-hospital cardiac arrests. Six of seven studies that described additional medical emergency team roles in educating staff in rapid response system use found their systems were associated with significant decreases in adverse patient outcomes. Four of five studies that described proactive rounding responsibilities reported found their systems were associated with significant decreases in adverse patient outcomes. Reporting of rapid response system involvement in "Do-Not-Resuscitate" order placement was variable across studies.

Conclusions: Inconsistencies in describing rapid response system components and related data and outcomes highlights how these systems are complex to a degree not fully captured in existing literature. Further large-scale examination of these components across institutions is warranted. Development and use of robust and standardized metrics to track data related to rapid response system components and related outcomes are needed to optimize these systems and improve patient outcomes.

Keywords

Hospital rapid response team; Hospital mortality; Heart arrest; Review

1. Background

In the United States, over 200,000 cardiac arrests occur among hospital inpatients annually (Graham et al., 2015; Go et al., 2013). Rapid response systems were first conceptualized detect and respond to patients experiencing unrecognized or undertreated clinical deterioration, placing them at increased risk for in-hospital cardiac arrest (Lee et al., 1995; Winters et al., 2007; Raymond et al., 2016; Winters and DeVita, 2017). While rapid responses systems have been widely implemented in a variety of formats, the basic format consists of an afferent limb (detecting and triggering response to clinically deteriorating patients) and an efferent limb (respond and provide interventions to deteriorating patients) (DeVita et al., 2006). The efferent limb usually includes a team of clinicians who respond to triggers from the afferent limb to prevent further clinical deterioration and avoid adverse events, such as in-hospital cardiac arrests and hospital mortality. When these teams are triggered to respond, these responses are often referred to as events. While standardized nomenclature for these teams does exist (DeVita et al., 2006), in practice these terms are closely related and often used interchangeably (Winters and DeVita, 2017). For simplicity, here we will be using one term to refer to these teams who initiate the events that occur in the afferent limb of rapid response systems—medical emergency teams.

In-hospital cardiac arrest is a commonly examined outcome related to rapid responses system effectiveness, and some recent systematic reviews have reported that rapid response systems are generally effective in decreasing in-hospital cardiac arrests (Maharaj et al., 2015; Solomon et al., 2016), however, those results have not been universal in individual studies (Winters et al., 2013). Such inconsistencies have led to calls for more detailed analyses of various components of these systems (Winters et al., 2007; Maharaj et al., 2015; Hillman et al., 2005; Solomon et al., 2016; Winters et al., 2013). Further study of

the triggers in the afferent limb of the rapid response systems used to activate medical emergency team events, medical emergency team member composition, additional medical emergency team roles outside of events (including proactive rounding and continuing clinician education regarding recognition of clinical deterioration and rapid response system use), and the involvement of rapid response systems in "Do-Not-Resuscitate" order placement are commonly cited next steps in this field of research (Winters et al., 2007; Maharaj et al., 2015; Hillman et al., 2005; Solomon et al., 2016; Winters et al., 2013; Lyons et al., 2018; Nallamothu et al., 2018). Understanding these components in the context of more a traditionally studied outcome related to rapid response systems – in-hospital cardiac arrest – could help clarify how rapid response systems impact patient care overall. However, the extent to which the current rapid response literature has examined the roles each of these rapid response system components have played in affecting in-hospital cardiac arrest is unknown.

We conducted a scoping review to explore the extent to which current rapid response system literature examines key components of rapid response systems (triggers used to activate medical emergency team events, team member composition, additional roles of the team outside of events, and involvement of rapid response systems in "Do-Not-Resuscitate" order placement) and their associations with rapid response system impacts on in-hospital cardiac arrests. Although hospital mortality in another common outcome examined in rapid response system literature, the evidence in both recent reviews and individual studies has been far less conclusive regarding the effect of rapid response systems on hospital mortality (Chan et al., 2010; Jones et al., 2011). Therefore, in-hospital cardiac arrest was the primary outcome of interest in this review, and hospital mortality was explored as a secondary outcome of interest. The purpose of this scoping review is to explore recent literature studying rapid response systems and examine how these components of rapid response systems have been studied and are associated with in-hospital cardiac arrests and hospital mortality.

2. Methods

Scoping reviews are generally undertaken to gain an understanding of the extent, or "scope," of literature currently available for a given topic, facilitated by the use of broader research questions examining a variety of types of studies (Grant and Booth, 2009). Given the purpose of our review, a scoping review approach seemed most appropriate. We used the Patterns, Advances, Gaps, Evidence for practice, and Research recommendations framework, which expands upon the initial scoping review methodology proposed by Arksey and O'Malley by outlining a more systematic and consistent approach to analyzing and reporting scoping review data (Arksey and O'Malley, 2005; Bradbury-Jones et al., 2022).

2.1. Search strategy

In alignment with scoping methodology and our review, broad search strategies focusing on rapid response systems and in-hospital cardiac arrest were developed and performed in October 2022 with the aid of a professional medical informatician. PubMed, CINAHL, and Embase were searched using this strategy. To facilitate the most inclusive review

possible, search terms that focused terminology related to on rapid response systems and in-hospital cardiac arrests were used across databases. Details of the search strategy and terms used are provide in Table 1. Guided by subject matter expertise and the references of recent articles and relevant reviews, a hand search of current literature was also conducted. Studies published in peer-reviewed journals between November 2014 and June 2022 were considered for review. The date of November 2014 was chosen as a starting point since a previously completed meta-analysis on rapid response systems by Solomon and colleagues included literature through October 2014. While no limitations were placed on study location, only studies that published full-text reports in English were included. Studies reporting quantitative and qualitative findings were considered for review.

2.2. Article screening

To determine study eligibility for inclusion, a two-step screening process was performed. First, two independent reviewers screened the titles and abstracts of articles for relevance to the topics of interest and purpose of our review. This was followed by a full-text screening of potential studies to determine final eligibility for inclusion. Any discrepancies between reviewers were first discussed by the initial reviewers in an attempt to find a resolution, and a third reviewer was made available to resolve discrepancies if necessary.

Studies that did not focus on rapid responses systems or medical emergency teams as a primary variable of interest were excluded. Since impact on in-hospital cardiac arrests was our primary outcome of interest related to rapid response systems, articles that did not examine in-hospital cardiac arrests as a primary variable of interest were excluded. Studies not available in English language formats, focused on predominantly pediatric patient populations, did not include full-text reports of findings, or did not include original data, were also excluded.

2.3. Data charting and analysis

A data charting tool was developed and tested among the research team using methodological and subject matter expertise prior to use (Supplemental Table 1). Data elements of studies collected for analysis were as follows: first author, year of publication, location, study purpose, design rapid response system intervention, medical emergency team composition, additional roles ascribed to the medical emergency team outside of responding to and treating deteriorating patients, medical emergency team triggers or activation criteria reported, and relevant outcomes related to in-hospital cardiac arrests, hospital mortality, rapid response system activation, and “Do-Not-Resuscitate” order placement. These elements are detailed in Supplemental Table 1. In accordance with the Patterns, Advances, Gaps, Evidence for practice, and Research recommendations framework (Bradbury-Jones et al., 2022), a thematic analysis of key themes across studies was conducted and represented in the form of a patterning chart (Table 2). Study findings and thematic analyses were further synthesized to report major patterns, advances, gaps, evidence for practice, and research recommendations across the included literature (Bradbury-Jones et al., 2022). This final synthesis is detailed in Table 3.

3. Results

3.1. Key characteristics of included studies

After 52 duplicate articles were excluded from search results of the included databases, 745 articles were screened, resulting in 28 articles deemed eligible for inclusion. An additional 6 articles were deemed eligible for inclusion from the hand search, resulting in a final total of 34 articles deemed eligible for inclusion. See Fig. 1 for additional details of the screening process. Most studies reviewed fit within two categories: they examined the effects of rapid response implementation on patient outcomes (Roasio et al., 2022; Aitken et al., 2015; Al-Rajhi et al., 2016; Blotsky et al., 2016; Chen et al., 2015; Davis et al., 2015; Davis et al., 2015; Jung et al., 2016; Kawaguchi et al., 2015; Kim et al., 2017; Ludikhuize et al., 2015; Menon et al., 2018; Noyes et al., 2015; Pirret et al., 2015; Gong et al., 2020; Mankidy et al., 2020; Oh et al., 2018; Viana et al., 2021; Yang et al., 2020), or they described rapid response systems and their associations with patient characteristics and outcomes (Jung et al., 2022; Winterbottom and Webre, 2021; Avis et al., 2016; Bunch et al., 2019; Chan et al., 2016; Churpek et al., 2017; Jones et al., 2017; Kollef et al., 2017; Le Guen et al., 2015; Psirides et al., 2016; Silva et al., 2016; Smith et al., 2015; Stelfox et al., 2015; Sulistio et al., 2015). Generally, rapid response system implementation studies included scenarios in which the system implemented was the first iteration of its kind (Al-Rajhi et al., 2016; Blotsky et al., 2016), was replacing an existing system (Aitken et al., 2015), or added another tier of clinical experience or surveillance to an existing system (Davis et al., 2015; Kawaguchi et al., 2015; Pirret et al., 2015). The associations of rapid response system implementation with changes in-hospital cardiac arrests or hospital mortality were examined in 19 studies. While all these studies reported at least some form of observed decrease in-hospital cardiac arrests associated with rapid response system implementation, the statistical significance of these results were inconsistent across studies. Additionally, most implementation studies (15 of 19 studies) also performed statistical analyses to assess the associations of rapid response system implementation with changes in hospital mortality. Similar to in-hospital cardiac arrests, most of these studies reported some decrease in hospital mortality, however, the statistical significance of these findings was also inconsistent across studies.

Broad patterns of what rapid response system components were reported on in included studies were also assessed. A majority of studies (27 of 34) identified what rapid response system triggers were used (Roasio et al., 2022; Aitken et al., 2015; Al-Rajhi et al., 2016; Blotsky et al., 2016; Chen et al., 2015; Davis et al., 2015; Jung et al., 2016; Kawaguchi et al., 2015; Kim et al., 2017; Ludikhuize et al., 2015; Jung et al., 2022; Menon et al., 2018; Noyes et al., 2015; Pirret et al., 2015; Gong et al., 2020; Oh et al., 2018; Viana et al., 2021; Yang et al., 2020; Bunch et al., 2019; Churpek et al., 2017; Kollef et al., 2017; Le Guen et al., 2015; Psirides et al., 2016; Silva et al., 2016; Smith et al., 2015; Stelfox et al., 2015; Sulistio et al., 2015); additionally, a majority of studies (28 of 34) also included at least some details related to member composition of their medical emergency teams (Roasio et al., 2022; Aitken et al., 2015; Al-Rajhi et al., 2016; Blotsky et al., 2016; Chen et al., 2015; Davis et al., 2015; Davis et al., 2015; Jung et al., 2016; Kawaguchi et al., 2015; Kim et al., 2017; Ludikhuize et al., 2015; Jung et al., 2022; Menon et al., 2018; Noyes et al., 2015; Pirret et al., 2015; Gong et al., 2020; Mankidy et al., 2020; Oh et al., 2018; Viana et al.,

2021; Yang et al., 2020; Winterbottom and Webre, 2021; Avis et al., 2016; Bunch et al., 2019; Jones et al., 2017; Kollef et al., 2017; Le Guen et al., 2015; Smith et al., 2015; Stelfox et al., 2015; Sulistio et al., 2015). Conversely, relatively few studies (11 of 34) reported that the rapid response system had any other roles outside of responding to medical emergency team events (Davis et al., 2015; Davis et al., 2015; Jung et al., 2016; Kim et al., 2017; Jung et al., 2022; Menon et al., 2018; Noyes et al., 2015; Yang et al., 2020; Winterbottom and Webre, 2021; Avis et al., 2016; Silva et al., 2016), or on any roles the teams had in Do-Not-Resuscitate order placement or goals of care discussions (5 of 34) (Jung et al., 2016; Jung et al., 2022; Menon et al., 2018; Noyes et al., 2015; Yang et al., 2020). Table 2 further summarizes key characteristics for the included studies.

In examining the charting of data and patterns of key characteristics from included studies (Supplemental Table 1, Table 2), themes regarding each of the rapid response system components of interest emerged. The synthesis of these themes is summarized in Table 3 and in the subsequent sections below.

3.2. Triggers for medical emergency team event activation

Triggers used to activate events in the included studies could be broadly characterized into different types: cardiac abnormalities (e.g., tachycardia, bradycardia, hypotension), respiratory abnormalities (e.g., tachypnea, decreased oxygen saturation), and neurological abnormalities (e.g., altered mental status, seizures). Additionally, many studies also cited “staff concern” for the patient that could not be quantified by other objective criteria as a trigger. Some studies also cited additional triggers such as critical labs values and decreased urinary output (Al-Rajhi et al., 2016; Blotsky et al., 2016; Kim et al., 2017; Noyes et al., 2015; Oh et al., 2018; Viana et al., 2021; Yang et al., 2020; Bunch et al., 2019; Psirides et al., 2016). A few studies cited the use of early warning scores as medical emergency team event triggers (Ludikhuize et al., 2015; Jung et al., 2022; Menon et al., 2018; Pirret et al., 2015; Kollef et al., 2017; Psirides et al., 2016).

Of the 34 studies reviewed, 27 described criteria that comprised triggers used to activate medical emergency team events. Of these studies, 11 described institutional triggers with no further analyses (Roasio et al., 2022; Davis et al., 2015; Kawaguchi et al., 2015; Ludikhuize et al., 2015; Jung et al., 2022; Noyes et al., 2015; Gong et al., 2020; Oh et al., 2018; Yang et al., 2020; Kollef et al., 2017; Sulistio et al., 2015), and 9 studies reported frequencies of triggers used to activate medical emergency teams with no further analyses (Aitken et al., 2015; Al-Rajhi et al., 2016; Blotsky et al., 2016; Jung et al., 2016; Menon et al., 2018; Pirret et al., 2015; Psirides et al., 2016; Silva et al., 2016; Stelfox et al., 2015). We noted variability across studies in how triggers were described and reported. For example, some studies only provided narrative terms or descriptions of triggers, such as “loss of consciousness” or “nausea,” (Chen et al., 2015; Menon et al., 2018), while others provided precise physiological parameters for each trigger (Kim et al., 2017; Smith et al., 2015).

When data on medical emergency team triggers were reported, wide variability in the frequencies of triggers was observed across studies. The use of multiple triggers to activate medical emergency team events appeared to be common. When data was reported, multiple triggers were used at activate at least 10% of events, with some studies reporting use

in upwards of 70% of events. While most studies provided at least some description of institutional medical emergency team triggers, few studies statistically analyzed any associations between such triggers and patient outcomes related to medical emergency team events. Seven studies of the 27 studies that described triggers directly examined relationships of triggers to other study variables related to rapid response systems (Chen et al., 2015; Kim et al., 2017; Viana et al., 2021; Bunch et al., 2019; Churpek et al., 2017; Le Guen et al., 2015; Smith et al., 2015). The use of respiratory triggers and multiple triggers to activate a medical emergency team event were significantly associated with later stages of acute deterioration and mortality (Le Guen et al., 2015; Smith et al., 2015). Medical emergency team events activated using decreased in blood pressure as a trigger were also significantly associated with delays in activation and with patients in later stages of acute deterioration at the time of the event ((Chen et al., 2015), (Smith et al., 2015)). However, the variability in how medical emergency team triggers were studied and reported made comparisons across studies to elucidate patterns difficult. For example, Smith et al. reported that medical emergency team events activated for patients in later stages of acute deterioration were significantly associated with higher likelihood of hospital mortality, but that the use of decreases in levels of consciousness to activate events was not associated with these patients (Smith et al., 2015), while Chen et al. reported that decreases in Glasgow Coma Scale scores were significantly associated with delays in activating events, and that delayed events were significantly associated with increased hospital mortality (Chen et al., 2015). No additional information on the definitions used in either study to define these neurological changes is given, so the degree to which these findings contradict each other is unclear. Additional information on study details regarding triggers is given in Supplemental Table 1.

3.3. Medical emergency team member composition

Of the 34 included studies, 28 gave some detail regarding medical emergency team member composition at the institutions involved in the studies. Seven of the 28 studies explicitly described medical emergency teams with at least one dedicated team member (Kim et al., 2017; Jung et al., 2022; Mankidy et al., 2020; Yang et al., 2020; Winterbottom and Webre, 2021; Avis et al., 2016; Kollef et al., 2017). Generally, a dedicated member of a medical emergency team is a clinician assigned to the team with no other clinical responsibilities or assignments. Of these studies, 6 found some significant decrease in-hospital cardiac arrests associated with their rapid response system (Kim et al., 2017; Jung et al., 2022; Mankidy et al., 2020; Yang et al., 2020; Avis et al., 2016; Kollef et al., 2017). Two studies found some significant decrease in hospital mortality associated with their rapid response system (Jung et al., 2022; Kollef et al., 2017). Two studies found no association between rapid response system implementation and hospital mortality (Kim et al., 2017; Yang et al., 2020), and two studies did not examine hospital mortality (Mankidy et al., 2020; Avis et al., 2016). One study did not perform statistical analyses (Winterbottom and Webre, 2021).

While the inclusion of dedicated medical emergency team members seems to be associated with decreased incidences of in-hospital cardiac arrests, other patterns related to team member composition were difficult to ascertain due to the highly variable reporting of member composition across the studies reviewed. For example, Aitken et al. give a detailed

breakdown of multiple tiers of the team members who perform as a part of the medical emergency team and rapid response system (Aitken et al., 2015), however, Viana et al. mention that an intensive care unit physician leads the team, and while this phrasing implies there are additional team members, no additional details are given (Viana et al., 2021).

3.4. Additional medical emergency team roles in rapid response systems

Of the 34 studies reviewed, 11 described additional medical emergency team roles outside of responding to and caring for deteriorating patients were described. Those roles often consisted of medical emergency teams teaching clinicians to recognize deteriorating patients and activate medical emergency teams to intervene. In total, seven studies described additional education roles for their medical emergency team outside of responding to and caring for deteriorating patients (Davis et al., 2015; Davis et al., 2015; Kim et al., 2017; Yang et al., 2020; Winterbottom and Webre, 2021; Avis et al., 2016; Silva et al., 2016). While none of these studies directly assessed how these education roles were associated with outcomes, six reported the rapid response system was associated with some significant decrease in-hospital cardiac arrests or hospital mortality (Davis et al., 2015; Davis et al., 2015; Kim et al., 2017; Yang et al., 2020; Avis et al., 2016; Silva et al., 2016), and the remaining study did not statistically test data (Winterbottom and Webre, 2021). This pattern suggests that medical emergency teams who take on clinician educator roles may further impact how successful rapid response systems are at decreasing relevant adverse outcomes. Additionally, Smith et al. conducted a qualitative study involving semi-structured interviews with nursing executives to explore their perceptions of medical emergency teams and their impact on their hospitals (Smith and McSweeney, 2017). Most respondents (96%) reported that their medical emergency teams provided “real-time education” to staff throughout their hospitals, and most respondents perceived medical emergency teams having a positive influence on reducing in-hospital cardiac arrest rates (Smith and McSweeney, 2017).

Multiple studies also described the medical emergency team as having a responsibility to round proactively in noncritical care areas to help detect deteriorating patients (Roasio et al., 2022; Davis et al., 2015; Davis et al., 2015; Yang et al., 2020; Avis et al., 2016). Four studies found rapid responses systems were associated with some significant decreases in-hospital cardiac arrests or hospital mortality (Davis et al., 2015; Davis et al., 2015; Yang et al., 2020; Avis et al., 2016). Similar to educator roles, this pattern suggests those medical emergency teams that proactively round may affect how successful rapid response systems are at decreasing the incidences of in-hospital cardiac arrests and hospital mortality. However, one study specifically examined the implementation of proactive rounding in an existing rapid response system and found no significant associations with decreases in either in-hospital cardiac arrests or hospital mortality (Roasio et al., 2022). This contradictory finding highlights the importance of directly assessing the relationships such additional roles may have on patient outcomes related to rapid response systems.

3.5. Rapid response system involvement in goals of care discussions and “Do-Not-Resuscitate” order placements

Of the studies reviewed, five outlined rapid response system involvement in facilitating goals of care discussions and placement of “Do-Not-Resuscitate” orders (Jung et al., 2016;

Menon et al., 2018; Noyes et al., 2015; Yang et al., 2020). The only one of these studies to report data related to “Do-Not-Resuscitate” order placement was a study conducted by Yang et al., who found that there was a significant increase in “Do-Not-Resuscitate” order placement following the implementation of their rapid response system (Yang et al., 2020). In comparing pre-rapid response system implementation patient outcomes to post-implementation, the authors also found a significant decrease in preventable in-hospital cardiac arrests, but no significant difference in overall risk of in-hospital cardiac arrest or in overall risk of hospital mortality (Yang et al., 2020).

While they did not specifically describe formal involvement of rapid response systems in goals of care discussions, 10 additional studies reported data on “Do-Not-Resuscitate” order placement or goals of care discussions as they related to rapid response systems ((Chen et al., 2015; Davis et al., 2015; Davis et al., 2015; Pirret et al., 2015; Viana et al., 2021; Psirides et al., 2016; Silva et al., 2016; Smith et al., 2015; Stelfox et al., 2015; Sulistio et al., 2015)), and six of those studies statistically analyzed the relationship between placement of “Do-Not-Resuscitate” orders or goals of care discussion and medical emergency team events (Chen et al., 2015; Davis et al., 2015; Davis et al., 2015; Viana et al., 2021; Smith et al., 2015; Stelfox et al., 2015) with mixed findings. Three studies essentially found that older patients, patients with delayed event activation, or patients in later stages or deterioration had higher likelihoods of having Do-Not-Resuscitate orders placed during or following the medical emergency team event (Chen et al., 2015; Smith et al., 2015; Stelfox et al., 2015). However, three studies that primarily examined the association of rapid response system implementation with outcomes found no significant associations with changes in goals of care discussions or Do-Not-Resuscitate order placement (Davis et al., 2015; Davis et al., 2015; Viana et al., 2021). While it appears that increased “passages of time” (delayed event activations, increased age, later stages of deterioration) may be understandably associated with more rapid response system involvement in the placement of Do-Not-Resuscitate orders, the inconsistent findings between these six studies make it difficult to draw further conclusions, especially since none of these studies described how rapid response systems were involved in these discussions. This emphasizes the need to provide clear descriptions of what, if any, formal or informal rapid response system involvement in goals of care discussions so that findings across studies may be compared.

4. Discussion

A common criticism of rapid response systems is their seemingly inconsistent impact on in-hospital cardiac arrests and hospital mortality (Maharaj et al., 2015). This review confirms that those inconsistencies persist. However, in exploring the most recent literature, it is unclear if these inconsistencies are due to rapid response systems themselves having inconsistent impacts on adverse outcomes, or because data on rapid response system impacts on outcomes are inconsistently reported. In cardiopulmonary arrest research, the Utstein-style guidelines provide standardized methods of measuring and reporting relevant variables, which allow for comparisons of findings across studies (Idris et al., 2017). Similar Utstein-style guidelines have been suggested to define components of rapid response systems and report related data (DeVita et al., 2006; Peberdy et al., 2007). However, given the mixed findings involving and variable reporting of rapid response system data observed here, these

guidelines are not widely utilized. Further work to promote standardized reporting structure for rapid response systems and related adverse patient outcomes is warranted. Additionally, recent findings suggest that previously proposed Utstein-style reporting structures could be expanded to include additional important rapid response system components—including more details related to medical emergency team triggers, medical emergency team member composition, additional rapid response system roles, and rapid response system involvement in goals of care discussions—that may influence their effects on outcomes. Such reporting structures—and adherence to them—would allow for comparing findings across studies to help optimize the use of these systems to reduce in-hospital cardiac arrests and hospital mortality within healthcare systems.

4.1. Study of triggers used to activate medical emergency team events

We observed substantial variability in how medical emergency team triggers were studied and reported. Additionally, few of the included studies performed statistical analyses to directly examine associations between triggers and their effects on rapid responses systems, such as relevant outcomes and other related components. Because of this variability in reporting trigger data, comparing findings across studies proved difficult. However, few studies did report comparable findings related to respiratory triggers and the use of multiple triggers to activate events. These studies indirectly showed that respiratory triggers were associated with increased likelihood of hospital mortality, which supports other findings that have been previously reported (Shappell et al., 2018; Chen et al., 2010). Additionally, patients who had multiple triggers used to activate medical emergency team events have previously reported high incidences of in-hospital cardiac arrests and hospital mortality (Le Guen et al., 2015; Shappell et al., 2018; Chen et al., 2010; Bavare et al., 2017). Given the high incidence of multiple triggers being present at the time medical emergency teams are activated, and their association with adverse patient outcomes, further detailed exploration of the occurrence of multiple triggers is warranted. However, in the included studies, additional details regarding the patterns in which multiple triggers occurred was lacking.

Variability in reporting trigger data and the lack of associative analyses to elucidate which triggers or groups of triggers are associated with adverse outcomes limits the clinical usefulness of findings related to trigger use. The use and expansion of standardized reporting metrics is essential in uniformly reporting on triggers in such a way that findings may be compared across studies. In addition to the wider use of such reporting standards, future research needs to move beyond descriptive statistics and analyze relationships between triggers and rapid response system outcomes more directly. This should include detailed study of the use of multiple triggers to activate medical emergency team events. For example, the patterns in which multiple triggers are used to activate medical emergency team events should be identified and their relationships with patient outcomes studied.

4.2. Study of medical emergency team member composition

Reporting on medical emergency team member composition was highly variable in the included studies for review, which presents a challenge in understanding how team member composition can be leveraged to optimize rapid response systems. While the potential importance of medical emergency team composition has been acknowledged, there remains

no consensus on ideal composition or to make such a determination (Winters et al., 2013; Lyons et al., 2018). In addition to the findings recently reported by Dukes et al. that medical emergency teams with dedicated members, were associated with higher in-hospital cardiac arrest survival (Dukes et al., 2019), Nallamothu et al. also similarly reported that hospitals with high survival rates for in-hospital cardiac arrests tended to have dedicated, multidisciplinary teams who responded to in-hospital cardiac arrests instead of unit-based teams (Nallamothu et al., 2018). Our findings lend further support to these reports. Furthermore, the apparent impact dedicated members may have on improving outcomes related rapid response systems, in combination with the variability observed in how this vital information in reported, together highlight the urgent need for wide-spread use of standardized reporting mechanisms for rapid response systems so that medical emergency team member compositions can be described and compared consistently.

4.3. Study of additional medical emergency team roles in rapid response systems

In this review, multiple studies described rapid response systems as having additional supportive roles outside of responding to and caring for deteriorating patients. Most of the studies that described additional roles for medical emergency teams within rapid response systems found that medical emergency teams were associated with decreased incidence of either in-hospital cardiac arrests or hospital mortality. These findings are not necessarily surprising—additional education and proactive rounding may help rapid response systems and other clinicians to better monitor patients for early signs of acute clinical deterioration. Since skills may fade without regular use over time (General Medical Council 2019), clinicians could improve their recognition and handling of deteriorating patients if rapid response systems provide regular education and access to medical emergency team members' extensive knowledge and experiences with deteriorating patients.

Based on these findings, hospitals and health systems may want to consider clinician education and proactive rounding as additional responsibilities for rapid response systems to help reduce ih-hospital cardiac arrests and hospital mortality. However, all but one study that described additional roles did not directly assess these roles as they related to relevant adverse patient outcomes, and the one study that did found no significant associations. To resolve this discrepancy and help optimize rapid response system performance, additional research is needed that directly assesses how roles involving clinician education and proactive rounding within rapid response systems are related to the reduction of in-hospital cardiac arrests and hospital mortality.

4.4. Study of rapid response system involvement in goals of care discussions and "Do-Not-Resuscitate" order placements

The findings observed in some of the included studies highlight the need to recognize that not only are rapid response systems often involved in goals of care discussions with patients and their families, but they are also likely initiating these discussions for patients who would have benefitted from palliative care consults well before the medical emergency team event (Sulistio et al., 2015; Cardona-Morrell et al., 2016; Downar et al., 2013; Smith et al., 2014; Jones et al., 2012). By understanding how these systems may be used as a workaround in goals of care discussions, we can address current gaps in the continuum of patient care.

However, these associations between rapid response systems and Do-Not-Resuscitate order placement and goals of care discussions were not universal when tested.

Furthermore, while the associations between rapid response systems and goals of care discussions were variable, there was also substantial variation in how rapid response system involvement in such discussions and “Do-Not-Resuscitate” order placement was measured, making it difficult to reconcile conflicting findings. A recent expert consensus statement suggested that patients with medical emergency team triggers present should have goals of care documented (Subbe et al., 2019). The inconsistencies observed in how such goals of care were reported in this review support this recommendation, but we also suggest that a standardized method of reporting rapid response system involvement in goals of care discussions and “Do-Not-Resuscitate” order placement are essential to fully understand the associations between these systems with patient outcomes.

4.5. Future study recommendations

To determine the impact of rapid response systems on patient outcomes in future studies, the manner in which current research reports rapid response system performance, successes, and failures needs to be reevaluated and redefined. Some of these efforts are underway. Unexpected mortality is defined as in-hospital deaths occurring without preexisting “Do-Not-Resuscitate” orders and may be a more accurate method of assessing rapid response system impacts on patient outcomes (Hillman et al., 2005; Brunsveld-Reinders et al., 2016). Few studies included in this review examined unexpected mortality, with inconsistent findings. Future research into these systems needs to utilize standardized metrics that account for the dynamic and complex nature of rapid response systems, such as unexpected mortality, which would allow for study comparisons to inform best practices. Additionally, future rapid response system research should endeavor to improve collection and reporting of components of these systems. For example, for medical emergency team member composition, the Utstein-style template could be expanded to collect data on whether medical emergency teams have dedicated members, and provide clear parameters for determining this. Such a template should be routinely reviewed and updated based on the latest findings, and rapid response system researchers should reinforce the use of such templates during the peer-review process for publishing future rapid response system studies.

As is common in rapid response system research, many of the studies in this review were conducted within single hospitals or healthcare systems. While these studies add to rapid response system knowledge and are useful for local quality improvement initiatives, the variability between hospitals limits the generalizability of their findings. In addition to widespread use of standardized metrics for rapid response system components and related outcomes, future studies need to examine components on a large-scale across institutions. Such work has begun through registries such as the American Heart Association’s Get with the Guidelines-Resuscitation registry (Churpek et al., 2017; Shappell et al., 2018) and should allow for more generalizable findings for optimizing rapid response systems. For example, while a substantial proportion of medical emergency team events are often activated using more than one trigger and are generally associated with higher incidences of

adverse outcomes (Chen et al., 2015; Le Guen et al., 2015; Smith et al., 2015; Shappell et al., 2018; Bavare et al., 2017), research examining the use of multiple triggers to activate medical emergency team events is sparse. A large-scale examination of medical emergency team events activated using multiple triggers would allow for generalizable findings that more readily applied by researchers and clinicians.

5. Limitations

The findings presented in this review should be interpreted considering the following limitations. Variability in evaluating and reporting rapid response system components and outcomes made comparing results across studies difficult. Any comparisons made across studies should be interpreted with caution. Our interest in examining rapid response system components in the context of their relationships to in-hospital cardiac arrest and hospital mortality—outcomes that are traditional quantitatively reported—may have biased article selection in this review toward quantitative studies. Thus, qualitative studies exploring these relationships may be underrepresented. Finally, article selection was limited to articles published in English, thus excluding relevant articles published in other languages that may have affected our findings and limiting their generalizability.

Several studies involved retrospective chart reviews that did not report on measures taken to ensure the validity and reliability of patient data collected. Many studies only used descriptive statistics, limiting the interpretability of these results since their designs cannot account for mediating, moderating, or confounding variables that may have influenced their findings. As previously stated, many of the reviewed studies were conducted at single sites, limiting the generalizability of their findings. As wide variability in reporting on rapid response system characteristics presented difficulties in comparing and synthesizing findings between studies, these limitations further highlight the need for standardization of reporting variables.

6. Conclusion

To optimize the impact of rapid response systems and use them most efficiently, it is paramount that we fully characterize our goals and consistently study what elements help us achieve them. In this review, detailed examination of conflicting findings regarding the impact rapid response systems have on outcomes such as in-hospital cardiac arrests and hospital mortality highlighted inconsistencies in reporting data related to rapid response system components and outcomes. While unexpected hospital mortality is promising in defining rapid response system success more accurately, future rapid response system research must go even further and update and promote the use of Utstein-style standardized metrics for rapid response system components and outcomes that capture the dynamic nature of these systems. Consistent reporting related to rapid response systems is necessary to discern the true value and impact of these systems on patient outcomes by comparing findings across studies. Future studies must also further utilize large-scale rapid response system data collected across institutions in order to increase the generalizability of findings related to their components and outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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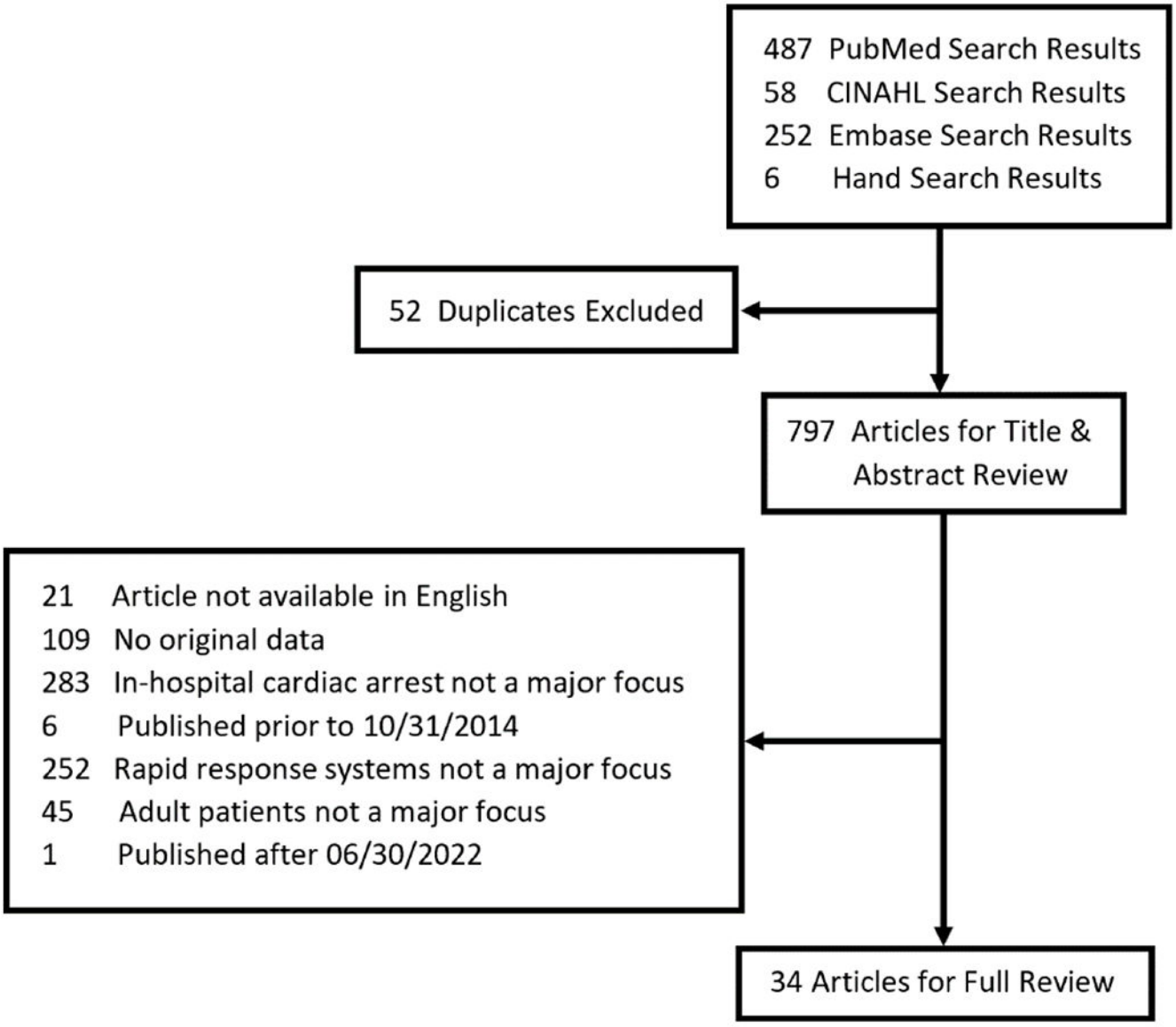

Fig. 1.
Diagram detailing literature search yield and selection criteria for article inclusion.

Table 1

Literature search terms used for key concepts across databases.

Key Concept	Search Strategy
Rapid response systems	Hospital rapid response team *
	Emergency medical services *
	Rapid response system +
	Medical emergency team +
	Cardiac crash team +
	Rapid response team +
	Emergency medical service +
	Emergency care +
Cardiac Arrest	Heart arrest *
	Cardiac arrest +
	Cardiopulmonary arrest +
	Cardiopulmonary resuscitation +
	Resuscitation +
Inpatient or In-hospital	Inpatient *
	In-hospital +
	Hospitalization +
	Hospitalized patient +
	Hospital patient +

* Indicates indexed MeSH term used.

+ Indicates keyword terms used to search titles and abstracts.

Table 2

Summary of major patterns and key themes across included studies.

Study	Location	Study Design	Outcomes						RRS Components Reported?			
			IHCA Statistically Tested?	Relationship to RRS?	Significant?	Hospital Mortality Statistically Tested?	Relationship to RRS?	Significant?	RRS Triggers	RRT Member Composition	RRS Additional Roles	RRS Involvement in DNR Orders
Aitken 2015	Australia	One group pretest-posttest	Yes	↓	No				X	X		
Al-Rajhi 2016	Canada	Pretest-posttest with comparison group	Yes	↓	No	Yes	↓	Mixed	X	X		
Allen 2019	Australia	Comparative Descriptive		No						X		
Avis 2016	United States	Trend analysis	Yes	↓	Yes						X	X
Blotsky 2016	Canada	One group pretest-posttest	Yes	↓	Mixed	Yes	Mixed	No	X	X		
Bunch 2019	United States	Comparative Descriptive	No			No			X	X		
Chan 2016	United States	Comparative descriptive	Yes	N/A	Mixed	Yes	N/A	Mixed				
Chen 2015	Australia	Cluster randomized control trial	Yes	N/A	No	Yes	N/A	Yes	X	X		X
Churpek 2017	United States	Descriptive correlational	Yes	N/A	Yes	Yes	N/A	Yes	X			
Davis 2015	United States	One group pretest-posttest	Yes	Mixed	Mixed	Yes	Mixed	Mixed		X	X	X

Study	Location	Study Design	Outcomes						RRS Components Reported?			
			IHCA Statistically Tested?	Relationship to RRS?	Significant?	Hospital Mortality Statistically Tested?	Relationship to RRS?	Significant?	RRS Triggers	RRT Member Composition	RRS Additional Roles	RRS Involvement in DNR Orders
Davis 2015	United States	One group pretest-posttest	Yes	Mixed	Mixed	Yes	↓	Yes	X	X	X	X
Gong 2020	China	One group pretest-posttest	Yes	↓	No	Yes	↓	Yes	X	X		
Jones 2017	Australia	Comparative descriptive	No	N/A		Yes	N/A	No		X		
Jung 2016	France	Pretest-posttest with comparison group	Yes	Mixed	No	Yes	Mixed	Mixed	X	X	X	
Jung 2022	South Korea	Trend analysis	Yes	Mixed	Mixed	Yes	↓	Yes	X	X	X	
Kawaguchi 2015	Japan	One group pretest-posttest	Yes	↓	No	Yes	↓	No	X	X		
Kim 2017	South Korea	One group pretest-posttest	Yes	↓	Mixed	Yes	↓	No	X	X	X	
Kollef 2017	United States	Trend analysis	Yes	↓	Yes	Yes	↓	Yes	X	X		
Kollef 2017	United States	Trend analysis	Yes	↓	Yes	Yes	↓	Yes	X	X		
Le Guen 2015	Australia	Descriptive correlational	Yes	N/A	Yes	Yes	N/A	Yes	X	X		
Ludikhuize 2015	Netherlands	One group pretest-posttest	Yes	↓	Yes	Yes	↓	No	X	X		

Study	Location	Study Design	Outcomes						RRS Components Reported?			
			IHCA Statistically Tested?	Relationship to RRS?	Significant?	Hospital Mortality Statistically Tested?	Relationship to RRS?	Significant?	RRS Triggers	RRT Member Composition	RRS Additional Roles	RRS Involvement in DNR Orders
Mankidy 2020	United States	One group pretest-posttest	Yes	↓	Yes					X		
Menon 2018	India	One group pretest-posttest	Yes	↓	Yes	Yes	↓	No	X	X	X	
Noyes 2015	United States	One group pretest-posttest	Yes	↓	Yes				X	X	X	
Oh 2018	South Korea	One group pretest-posttest	Yes	↓	Mixed	Yes	↓	No	X	X		
Pirret 2015	New Zealand	One group pretest-posttest	Yes	↓	Yes	No			X	X		X
Psirides 2016	New Zealand	Descriptive	No			No			X			X
Roasio 2022	Italy	One group pretest-posttest	Yes	↓	No	Yes	↓	No	X	X		
Silva 2016	Portugal	Descriptive correlational	No			Yes	↓	Yes	X		X	X
Smith 2017	United States	Qualitative	No									
Smith 2015	Australia	Comparative descriptive	No			Yes	↑	Mixed	X	X		X
Stelfox 2015	Canada	Descriptive correlational	Yes	N/A	No	Yes	N/A	Yes	X	X		X
Sulistio 2015	Australia	Comparative descriptive	No			No			X	X		X

Study	Location	Study Design	Outcomes						RRS Components Reported?			
			IHCA Statistically Tested?	Relationship to RRS?	Significant?	Hospital Mortality Statistically Tested?	Relationship to RRS?	Significant?	RRS Triggers	RRT Member Composition	RRS Additional Roles	RRS Involvement in DNR Orders
Viana 2021	Brazil	One group pretest-posttest	Yes	↓	Yes	Yes	↓	No	X	X		X
Winterbottom 2021	United States	Trend analysis	No	↓		No	↓			X	X	
Yang 2020	South Korea	One group pretest-posttest	Yes	↓	Mixed	Yes	↓	No	X	X	X	X

Table 3

Synthesized findings in accordance with the Patterns, Advances, Gaps, Evidence for practice, and Research recommendations Framework.

Pattern	Advances	Gaps	Evidence for practice	Research recommendations
Triggers Used to Activate Medical Emergency Team Events	Importance of including triggers in reporting seems to be widely recognized as most studies at least identified triggers used. Wide variability in the frequencies of types of triggers used were reported. Use of respiratory triggers and multiple triggers to activate medical emergency team events were common and seemed to be associated with adverse patient outcomes.	Few statistical analyses were performed to examine relationships between triggers and outcomes related to rapid response systems. Wide variability in how studies reported triggers creates difficulty in comparing findings. Additional details regarding the patterns in which multiple triggers occurred was lacking.	Variability in reporting trigger data and the lack of associative analyses to elucidate which triggers or groups of triggers are associated with adverse outcomes limits the clinical usefulness of findings related to trigger use.	Future research needs to move beyond descriptive statistics and analyze relationships between triggers and rapid response system outcomes more directly. The patterns in which multiple triggers are used to activate medical emergency team events should be identified and their relationships with patient outcomes studied. Scholarly journals need to enforce uniformity in the reporting data on rapid response systems, and reporting guidelines should be expanded to include more details related to rapid response system components.
Medical Emergency Team Member Composition	Most studies reported at least some information on team composition, indicating recognition of the importance of this component. Teams with at least one dedicated member seem to be associated with significant decreases in-hospital cardiac arrests.	Wide variability in how studies reported member composition creates difficulty in comparing findings.	Dedicated members of medical emergency teams should be considered to reduce incidence of in-hospital cardiac arrests.	Scholarly journals need to enforce uniformity in the reporting data on rapid response systems, and reporting guidelines should be expanded to include more details related medical emergency team member composition within rapid response systems.
Additional Roles of Rapid Response System Outside of Medical Emergency Team Events	When additional roles were described, educator roles related to helping clinicians better recognize clinical deterioration and use of the rapid response system were common. Proactive rounding was also common when additional roles were described.	Rapid response systems that described education efforts and proactive rounding as additional roles were commonly associated with either significantly decreased incidences of in-hospital cardiac arrest or hospital mortality. Almost all did not directly assess these roles as they related to relevant outcomes.	Additional rapid response system roles in clinician education and proactive rounding should be considered to reduce incidence of in-hospital cardiac arrests and hospital mortality.	Future research should further explore and directly assess how roles involving clinician education and proactive rounding within rapid response systems are related to the reduction of in-hospital cardiac arrests and hospital mortality.
Rapid Response System Involvement in Goals of Care Discussions and “Do-Not-Resuscitate” Order Placements	Studies that described rapid response system involvement in goals of care discussions and the placement of Do-Not-Resuscitate orders largely did not report data on this component. Conversely, the studies that did report this data did not describe to what extent rapid response systems were formally involved in these discussions. Patients with increased “passages of time” were more likely to have goals of care discussions related to medical emergency team events.	Almost none of the studies that described formal involvement of rapid response systems in goals of care discissions or Do-Not-Resuscitate order placement tested their relationships to relevant patient outcomes. Conversely, the studies that did assess those relationships did not describe how rapid response systems were intended to be involved. These inconsistencies make comparisons across studies difficult.	Findings related to increased “passage of time” being associated with more goals of care discussions represents a gap in adequate quality patient care, and should encourage clinicians to have these conversations with patients well before episodes of acute deterioration.	Clear descriptions of rapid response system involvement in these aspects of patient care are needed, along with more direct assessments of the their relationships with other components and outcomes related to rapid response systems. Scholarly journals need to enforce uniformity in the reporting data on rapid response systems, and reporting guidelines should be expanded to include more details related to rapid response system components.