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Review article

# Outcome of adult patients attended by rapid response teams: A systematic review of the literature☆

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ABSTRACT

*Background:* An abundance of studies have investigated the impact of rapid response teams (RRTs) on in-hospital cardiac arrest rates. However, existing RRT data appear highly variable in terms of both study quality and reported uses of limitations of care, patient survival and patient long-term outcome.
*Methods:* A systematic electronic literature search (January, 1990–March, 2016) of the PubMed and Cochrane databases was performed. Bibliographies of articles included in the full-text review were searched for additional studies. A predefined RRT cohort quality score (range 0–17) was used to evaluate studies independently by two reviewers.
*Results:* Twenty-nine studies with a total of 157,383 RRT activations were included in this review. The quality of data reporting related to RRT patients was assessed as modest, with a median quality score of 8 (range 2–11). Data from the included studies indicate that a median 8.1% of RRT reviews result in limitations of medical treatment (range 2.1–25%) and 23% (8.2–56%) result in a transfer to intensive care. A median of 29% (6.9–35%) of patients transferred to intensive care died during that admission. The median hospital mortality of patients reviewed by RRT is 26% (12–60%), and the median 30-day mortality rate is 29% (8–39%). Data on long-term survival is minimal. No data on functional outcomes was identified.
*Conclusions:* Patients reviewed by rapid response teams have a high and variable mortality rate, and limitations of care are commonly used. Data on the long-term outcomes of RRT are lacking and needed.


## Introduction

Rapid response teams (RRTs) and medical emergency teams (METs) form the efferent limb of rapid response systems providing clinical assessment and, if needed, intensive care interventions and timely transfers to a higher level of care for deteriorating ward patients.[1] European resuscitation guidelines have acknowledged the rapid response system as an essential element of in-hospital resuscitation,[2] and recent systematic reviews and meta-analyses have reported significant reductions in in-hospital cardiac arrests and hospital mortality after the introduction of rapid response systems.[3–5]

Most studies on RRTs either focus on hospital-wide mortality rates and reductions in the incidence of in-hospital cardiac arrests (IHCAs),[3–5] or outcomes in specific sub-cohorts of patients reviewed by RRT (e.g., RRT patients treated with non-invasive ventilation[6] and outpatients reviewed by RRT[7]). Information about the long-term outcomes of patients reviewed by RRTs is limited, and the data appear variable, despite the publication of the Utstein-style statement in 2007 by the International Liaison Committee on Resuscitation (ILCOR) for uniform reporting on RRTs.[8]

The aim of this study was to systematically review the current literature on the outcomes of patients reviewed by RRTs. To this end, we specifically aimed to focus on the implementation of limitations of medical treatment (LOMT), transfers to intensive care units (ICUs), ICU mortality, hospital mortality, 30-day mortality and 180-day mortality rates of RRT patients.

## Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[9] The checklist and flow diagram were used,

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and PRISMA-Protocols was further applied to the reporting of this systematic review study protocol.[10]

*Search protocol and eligibility criteria*

A literature search was conducted on the 1st of March, 2016 using the PubMed and Cochrane Database of Systematic Reviews (January, 1990–March, 2016). The following key words were utilised: 'medical emergency team' OR 'rapid response team' AND 'outcome' OR 'survival' OR 'implementation'. Complete data on the electronic searches are presented in Appendix A. Bibliographies of the articles selected for full text review were hand searched for potentially eligible studies.

Paediatric studies and non-English studies were excluded. Studies reporting only outcomes of minor sub-cohorts of patients reviewed by RRTs were also excluded. Due to the known heterogeneity in the RRT literature,[3–5] before–after trials and randomised controlled trials (RCTs) on RRTs were included if a satisfactory amount of data on RRT reviews and the outcomes of RRT patients was reported.

*Study selection*

TT conducted the initial electronic searches, screened the records for duplicates and selected articles for full text analysis based on the titles and/or abstracts. Based on full texts, TT and JT further excluded articles not meeting the inclusion criteria and independently reviewed the remaining articles. JT conducted the search of the bibliographies of all articles that were included for full text review, evaluated new articles meeting the inclusion criteria and presented these articles to TT for independent review.

*RRT cohort outcome quality score*

Despite the fact that many RRT studies are of before–after design or RCTs, the data gathered on RRT cohorts themselves are always of observational design, either prospective or retrospective. Because an applicable tool for quality and bias assessment for studies in this review was difficult to find, the authors of this article generated a quality score using the Utstein-style ILCOR statement recommendations as a basis (Table 1).[8] This 'RRT cohort quality score' (range 0–17) does not necessarily reflect the overall quality of the study (the main objective in such studies is often not the documentation of general RRT patient characteristics and outcomes; see above); it evaluates the quality (methodology, factors associated with internal and external validity) related to the documentation of RRT activity and patients reviewed by RRT.

**Table 1**
RRT cohort quality score.

| Evaluation criteria | Score (0–17) |
|---|---|
| Study type | 2 |
| Prospective observational (2) | |
| Retrospective observational (1) | |
| RRT definition/staffing reported | 1 |
| General RRT—patient profile outlined | 1 |
| RRT activation criteria reported | 1 |
| The reason for RRT activation reported | 1 |
| Time intervals reported (1 point each) | 2 |
| Afferent limb failure | |
| Time from call to RRT arrival | |
| Outcome data reported (1 point each) | 7 |
| ICU transfers/RRT activations reported | |
| ICU mortality of RRT patients transferred to ICU | |
| Total hospital mortality of RRT patients transferred to ICU | |
| Hospital mortality of RRT patients left on ward | |
| Total hospital mortality of RRT patients | |
| 30-day mortality of RRT patients | |
| 180-day mortality of RRT patients | |
| Neurological outcome of RRT patients discharged alive | 1 |
| Quality of life of RRT patients discharged alive | 1 |

RRT, rapid response team; ICU, intensive care unit.

*Data collection*

TT and JT independently extracted all relevant data from the included articles, including the data on main outcomes, and utilized the developed score for quality assessment using Microsoft Excel 2011®. In cases of disagreement between TT and JT, MS provided an independent third review to provide consensus.

*Assessment of bias in included studies*

The developed 'RRT cohort quality score' assessed several factors that are possible sources of bias in the included studies (Table 1). Key sources of bias are also addressed verbally in the results section.

*Definitions*

A rapid response team (RRT) was defined as any external response unit (physician led or not) providing assessment for a deteriorating patient in a hospital. Liaison nurse activity (providing scheduled visits for patients) was not considered a RRT intervention,[11] and these types of visits were excluded from the extracted data if identified. 'RRT activations' refers to the number of times the team was activated, and 'RRT patients' to the number of different patients seen by RRT. Limitations of medical treatment (LOMT) included all 'do-not-resuscitate' orders and 'no intensive care'/'do not intubate' orders. Using the extracted data, LOMTs and ICU transfers were adjusted to the number of RRT activations, and hospital-, 30-day and 180-day mortality rates to the number of patients reviewed by the RRT. The Utstein-style ILCOR statement recommendations were used as a basis for the general definitions.[8]

*Statistics*

Data are presented as numbers and/or percentages as appropriate. Meta-analysis was not conducted due to (1) the observational methodology used in RRT cohort documentation and (2) the heterogeneity among the included studies. However, medians with quartiles and ranges were calculated for the quantitative outcome data in order to present some general conclusions from the included studies combined with a pooled data presentation. Intra-class correlation coefficient (ICC) with a 95% confidence interval was used to test inter-rater agreement in the RRT patient outcome quality score. SPSS version 20 for Windows (SPSS Inc., Chicago, IL, USA) was used.

## Results

*Study selection*

A total of 377 articles were initially identified by the described search strategy. Fig. 1 presents the PRISMA flowchart; 29 studies were assessed as eligible for this systematic review.[12–40] Twelve of the included studies were found directly through electronic searches and 17 studies were identified through the hand search.

*Study characteristics*

Table 2 presents the general characteristics of the included studies. Data on the RRT cohort were prospectively collected in 17 studies.[12,14,16–18,20,22,24–26,28–30,32,36,38,39] Four studies

**Table 2**
Summary of characteristics of the included studies.

| Study | Setting | Design (observational if not otherwise indicated) | Main objective of the study | RRT active before study (months) | Time period RRT activations recorded (months) | RRT reviews (n)/RRT patients (n) | RRT reviews (n)/1,000 hospital admissions | RRT patient outcome quality score | Comments and main sources of bias |
|---|---|---|---|---|---|---|---|---|---|
| Al-Qahtani et al. 2013[12] | Tertiary hospital | Prospective | Before-after trial; impact of RRT on IHCAs and hospital mortality | 0 | 36 | 2879/2879 | 18.2 | 8 | RRT conducted follow-up visits automatically until stabilization; no data on interventions provided |
| Barwise et al. 2016[13] | Tertiary hospital | Retrospective | Identify whether delays in RRTactivation contributed to worse patient outcome | 58 | 12 | 2261/1725 | 16.8 | 11 | 418 adult RRT reviews excluded (outpatients, no authorization) |
| Beitler et al. 2011[14] | Tertiary hospital | Prospective | Before-after trial; impact of RRT on IHCAs and hospital mortality | 0 | 24 | 855/740 | 10.8 | 8 | Hospital survival for 23 patients was unknown |
| Boniatti et al. 2010[15] | University hospital | Retrospective | Describe reasons for RRT activation and their association with outcome | 3 | 18 | 1051/901 | 22.6 | 7 | Patient characteristics unknown |
| Boniatti et al. 2014[16] | University hospital | Prospective | Determine if delays in RRT calls are associated with outcome | 21 | 18 | 1481/1148 | 40.0 | 9 | Same hospital as in Boniatti et al.[15]. Different study period |
| Buist et al. 2002[17] | Tertiary hospital | Prospective | Before-after trial; impact of RRT on IHCAs and hospital mortality | 24 | 12 | 152/124 | 5.3 | 5 | No data on activation reasons or interventions |
| Calzavacca et al. 2008[18] | Tertiary hospital | Prospective | Identify factors associated with outcome of RRT patients | 65 | 12 | 1217/900 | 20.4 | 8 | ALF analysis included only daytime reviews (n = 251) |
| Calzavacca et al. 2010[19] | Tertiary hospital | Retrospective | Characteristics of patients receiving multiple RRT reviews | 59 | 24 | 2237/1664 | 18.6 | 8 | Same hospital as in Calzavacca et al.[18]. Includes the patients from this study also |
| Chan et al. 2008[20] | Tertiary hospital | Prospective | Before-after trial; impact of RRT on IHCAs and hospital mortality | 0 | 20 | 376/376 | 15.1 | 9 | No data if revisits occurred |
| Coventry et al. 2013[21] | Tertiary hospital | Retrospective | Evaluate RRT reviews to patients with treatment limitations | NR | 9 | NR/1258[a] | NR | 7 | Other than general ward RRT reviews excluded (number unknown) |

Table 2 (*Continued*)

| Study | Setting | Design (observational if not otherwise indicated) | Main objective of the study | RRT active before study (months) | Time period RRT activations recorded (months) | RRT reviews (n)/RRT patients (n) | RRT reviews (n)/1,000 hospital admissions | RRT patient outcome quality score | Comments and main sources of bias |
|---|---|---|---|---|---|---|---|---|---|
| Dacey et al. 2007[22] | Community hospital | Prospective | Before-after trial; impact of RRT on IHCAs and hospital mortality | 0 | 12 | 356/344 | 20.9 | 7 | Outcome data provided for intubated/NIV-patients only (n = 72) |
| Herod et al. 2014[23] | Tertiary hospital | Retrospective | Analyze long-term RRT operational trends | 120 | 144 | 19,030/NR | Increased from 18 to 30 | 7 | Data reported only as changes over time |
| Hillman et al. 2005[24] | Multicenter (23 hospitals) | Randomized controlled trial | Investigate if RRT system reduces IHCAs and hospital mortality | 0 | 6 | 1886/NR[a] | 8.6 | 4 | No data on RRT activations/patients. RRT data from the 12 intervention hospitals |
| Jäderling et al. 2011[25] | Two-centre | Prospective | Compare RRT cohorts in two different hospitals | 6 and 60 | 24 | 3063/2207 | 23.9 | 8 | Australian hospital same as in Calzavacca et al. 2008. Includes the patients from this study also |
| Jäderling et al. 2013[26] | University hospital | Prospective | Evaluate RRT with focus DNR patients | 0 | 70 | 2189/1818 | 9.8 | 10 | Same hospital as the Swedish hospital in Jäderling et al.[25]. Includes the patients from this study also |
| Karpman et al. 2013[27] | Tertiary hospital | Retrospective | Before-after trial; impact of RRT on outcome of ward patients transferred to ICU | 0 | 30 | 1498/NR | 10.3 | 4 | Same hospital as in Barwise et al. 2016. No data on repeated reviews, RRT activations or patient characteristics |
| Kenward et al. 2004[28] | General hospital | Prospective | Evaluate the activity and impact of RRTone year after implementation | 0 | 12 | 130/130 | 2.4 | 7 | No revisits were reported |
| Konrad et al. 2009[29] | University hospital | Prospective | Before-after trial; impact of RRT on IHCAs and hospital mortality | 2 | 12 | 689/540 | 9.3 | 10 | Same hospital as the Swedish hospital in Jäderling et al.[25]. Last nine months include the patients from this study also |
| Laurens et al. 2011[30] | Regional hospital | Prospective | Before-after trial; impact of RRT on IHCAs and hospital mortality | 0 | 24 | 269/269[a] | 6.2 | 11 | Four revisits documented but not analyzed |
| Le Guen et al. 2015[31] | Tertiary hospital | Retrospective | Analyze characteristics of RRT calls resulting in ICU admission | 84 | 48 | 3004/2163[a] | 14.5 | 8 | 394 cardiac arrest calls included |
| Ludikhuize et al. 2015[32] | Multicenter (12 hospitals) | Prospective | Before-after trial; impact of RRT on IHCAs and hospital mortality | 17 | 0 | 685/NR | 7.0 | 7 | No data on revisits reported |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Morris et al. 2012[33] | University hospital | Retrospective | Evaluate if RRT physician experience influences patient outcome | 0 | 47 | 1642/1404 | 20.3 | 6 | Surgical patients (42% of hospital admissions) were excluded) |
| Santiano et al. 2009[34] | Multicenter (6 hospitals) | Retrospective | Compare RRT calls triggered by 'subjective' and 'objective' criteria | NR | 12 | 3189/NR[a] | 56.5 | 4 | No data on repeated reviews or patient characteristics |
| Smith et al. 2015[35] | University hospital | Retrospective | Compare RRT reviews with different duration of hospitalization before the review | 84 | 60 | 3640/2663 | 24.6 | 7 | Same hospital as in Le Guen et al.[31]. First 48 months include the patients from this study also |
| Sørensen et al. 2015[36] | University hospital | Prospective | Study outcomes of RRT patients using MAELOR tool | 71 | 9 | 253/206 | NR | 6 | 55 patients with treatment limitations excluded |
| The ANZICS-CORE MET dose investigators 2013[37] | Multicenter (35 hospitals) | Retrospective | To estimate the in-hospital mortality of patients subject to RRT review | NR | NR | 99,377/70,924[a] | 20.6 | 2 | 35/102 RRT hospitals participated the study. Unknown whether cardiac arrests were included |
| Tirkkonen et al. 2013[38] | University hospital | Prospective | Impact of automated monitoring and activation delays on mortality of RRT patients | 12 | 12 | 569/458 | 7.6 | 11 | 60 RRT reviews for non-general ward patients excluded |
| Tirkkonen et al. 2015[39] | University hospital | Prospective | Code of conduct and ethics of DNR decisions implemented by RRT | 40 | 16 | 774/640 | 11.1 | 9 | 55 RRT reviews for patients with pre-existing treatment limitations excluded. Same hospital as in Tirkkonen et al.[39] |
| Young et al. 2008[40] | Two-centre | Retrospective | Compare RRT activity and outcomes between two hospitals in Sydney | 164 and 68 | 12 | 1341/982[a] | 36.3 | 8 | RRT reviews for non-general ward patients excluded (number unknown) |

RRT, rapid response team; IHCA, in-hospital cardiac arrest; MAELOR, multidisciplinary audit and evaluation of outcomes of rapid response; DNR, do not resuscitate; ICU, intensive care unit; NIV, non-invasive ventilation.

[a] IHCAs included in RRT activations.

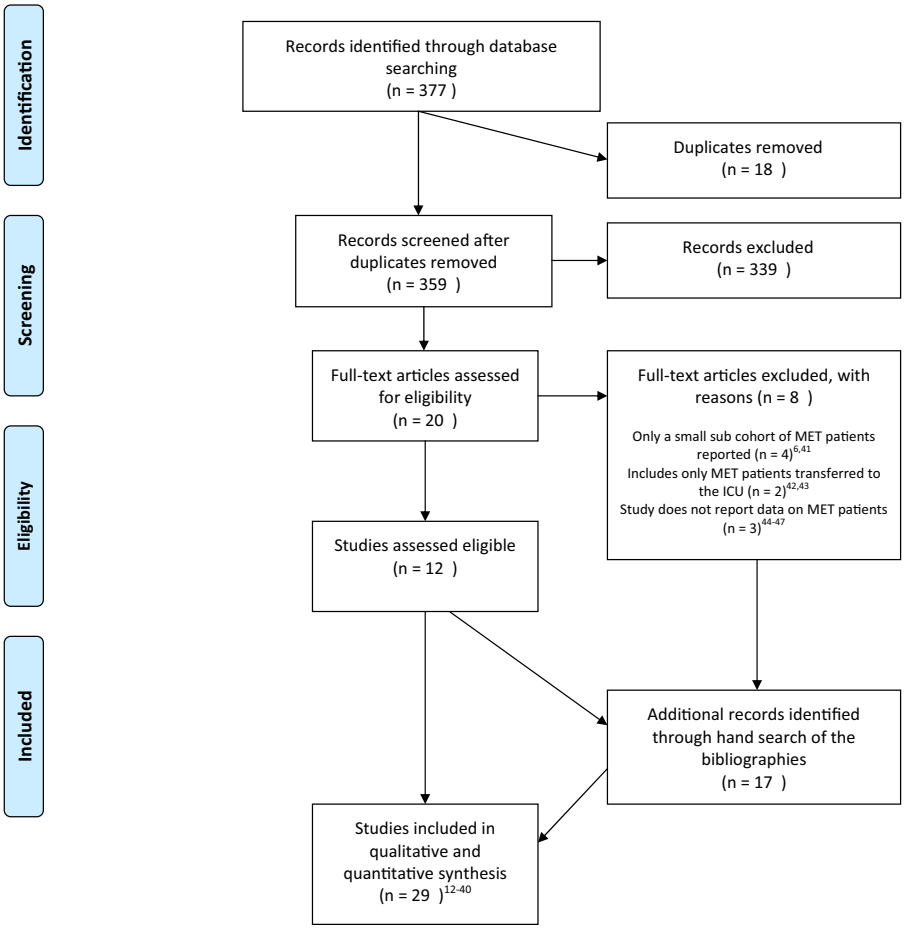


**Fig. 1.** The PRISMA flowchart of the selection process[6,12–47].

were of multicenter design,[24,32,34,37] two studies were conducted in two separate hospitals[25,40] and 23 studies were conducted at a single institution (of which 20 were university/tertiary hospitals).[12–23,26–31,33,35–39] Nine studies were before–after trials[12,14,17,20,22,27,29,30,32] whose main objective was to compare cardiac arrest and mortality rates before and after the implementation of RRT; one RCT study[24] implemented RRT to 12 hospitals (11 acting as controls) with the same objective, and 19 studies focused on analysing RRT cohorts from different aspects[13,15,16,18,19,21,23–26,28,31,33–40]. Studies originated from the following countries: Australia (12),[17–19,21,23,24,30,31,34,35,37,40] the United States (6),[13,14,20,22,27,33] Sweden (3),[25,26,29] Finland (2),[38,39] Brazil (2),[15,16] Denmark (1),[36] the Netherlands (1),[32] Saudi Arabia (1)[12] and the United Kingdom (1)[28].

RRT had been implemented at a median of 7.5 (0.0, 58.75) months before the study period had begun, and the length of the observational period was a median of 17 (12, 28.5) months. The 29 studies together included 157,383 RRT activations, with a median activation rate of 15.9 (9.3, 21) activations per 1000 hospital admissions.

### *Risk of bias within studies*

As described in the preceding paragraph, 12 studies were of retrospective design, and 10 studies' main focus was not related to the patients reviewed by RRT. The quality score of the studies ranged from 2 to 11, with a median score of 8 (6.5, 9) (Table 2). The ICC was 0.97 (95% CI 0.94–0.99) signifying excellent agreement between the quality score reviewers. Several studies lacked basic information on RRT activity precluding the generalizability of the results. Four studies did not report the RRT definition/staffing,[18,28,34,37] five studies did not present reasons for RRT activations,[17,24,27,36,37] 20 studies reported neither of the time intervals related to RRT responses[14,15,17,19–22,24–28,31–37,40] and six studies lacked basic demographic data on RRT patients.[12,24,27,33,34,37] Individual main sources of bias within the studies are summarised in Table 2. Six hospitals published 12 of the studies included in this review,[13,15,18,25,31,38] and study periods overlapped with previous publications in five studies.[19,25,26,29,35] Two studies included RRT patients ≥15 years,[22,40] and one study RRT patients ≥14 years.[34] Seven studies did not distinguish code blue calls from RRT reviews.[21,24,30,31,34,37,40]

### *Outcome of patients reviewed by RRT*

The main outcomes of RRT patients in the included studies are presented as percentages in Table 3. The most common documented outcomes were LOMT decisions, ICU transfers and hospital mortality rates (number of the reporting studies: 18, 25 and 17, respectively). Eight studies reported the outcomes of RRT patients transferred to the ICU. Six studies reported 30-day mortality rates. Only two studies had documented the long term outcome of RRT patients (180-day mortality), with highly variable survival rates, although both studies were conducted in the same hospital.[26,29] One study reported percentages of LOMT decisions and ICU transfers only as changes over time.[23] None of the studies reported functional outcomes or quality of life of patients reviewed by RRT.

**Table 3**
RRT patient outcomes in the included studies.

| Study | LOMT decisions by RRT/RRT activations | Patients transferred to ICU by RRT/RRT activations | ICU mortality of patients transferred to ICU by RRT | Hospital mortality of patients reviewed by RRT | 30-day mortality of patients reviewed by RRT | 180-day mortality of patients reviewed by RRT |
|---|---|---|---|---|---|---|
| Al-Qahtani et al. 2013[12] | 9.3 | 40 | 31 | NR | NR | NR |
| Barwise et al. 2016[13] | NR | 50 | 6.9 | 12 | 17 | |
| Beitler et al. 2011[14] | NR | 43 | NR | 24 | NR | NR |
| Boniatti et al. 2010[15] | 2.9 | 47 | NR | NR | 47 | NR |
| Boniatti et al. 2014[16] | 9.9 | 32 | NR | NR | 46 | NR |
| Buist et al. 2002[17] | 8.6 | NR | NR | 32 | NR | NR |
| Calzavacca et al. 2008[18] | 7.2 | 16 | NR | 31 | NR | NR |
| Calzavacca et al. 2010[19] | 6.3 | 13 | 35 | 34 | NR | NR |
| Chan et al. 2008[20] | 2.1 | 41 | 28 | 19 | NR | NR |
| Coventry et al. 2013[21] | NR | 8.3 | NR | 29 | NR | NR |
| Dacey et al. 2007[22] | 9.8 | 23 | NR | NR | NR | NR |
| Herod et al. 2014[23] | Decreased from 7–8 to 3–4 | Remained at 12–15 | NR | NR | NR | NR |
| Hillman et al. 2005[24] | 5.6 | NR | NR | NR | NR | NR |
| Jäderling et al. 2011[25] | 9.5 | 12 | NR | NR | 29 | NR |
| Jäderling et al. 2013[26] | 14 | 22 | NR | 26 | 29 | 43 |
| Karpman et al. 2013[27] | NR | 56 | NR | NR | NR | NR |
| Kenward et al. 2004[28] | 25 | 11 | NR | 60 | NR | NR |
| Konrad et al. 2009[29] | NR | 22 | NR | NR | 8.0 | 16 |
| Laurens et al. 2011[30] | 19 | 20 | 21 | 26 | NR | NR |
| Le Guen et al. 2015[31] | NR | 13 | 30 | 24 | NR | NR |
| Ludikhuize et al. 2015[32] | 4.4 | 43 | NR | NR | NR | NR |
| Morris et al. 2012[33] | NR | 49 | NR | 26 | NR | NR |
| Santiano et al. 2009[34] | NR | 18 | NR | NR | NR | NR |
| Smith et al. 2015[35] | 4.2 | 8.2 | NR | 19 | NR | NR |
| Sørensen et al. 2015[36] | 12 | 32 | NR | NR | NR | NR |
| The ANZICS-CORE MET dose investigators 2013[37] | NR | NR | NR | 24 | NR | NR |
| Tirkkonen et al. 2013[38] | 7.4 | 27 | 13 | 26 | NR | NR |
| Tirkkonen et al. 2015[39] | 7.6 | 24 | NR | 17 | NR | NR |
| Young et al. 2008[40] | NR | 10 | 34 | 25 | NR | NR |
| Summary | | | | | | |
| Studies that reported outcome (N)[a] | 18 | 25 | 8 | 17 | 6 | 2 |
| Median ($Q_1$, $Q_3$) | 8.1 (5.6, 9.9) | 23 (13, 41) | 29 (17, 33) | 26 (24, 29) | 29 (17, 46) | NC |
| Range | 2.1–25 | 8.2–56 | 6.9–35 | 12–60 | 8.0–39 | 16 and 43 |
| Available data from all reporting studies combined[b] | 7.9 (1,824/23,234) | 25 (9,185/36,938) | 22 (772/3,449) | 24 (21,465/88,238) | 30 (2,462/8,339) | 37 (870/2,358) |

Data are presented as percentages if not otherwise indicated. LOMT, limitations of medical treatment; ICU, intensive care unit; RRT, rapid response team; NC, not calculated; NR, not reported.

[a] Data from Herod et al.[23] could not be included.

[b] Percentage is calculated after combining data from all studies reporting the particular outcome and the exact numbers are presented in parenthesis.

A median of every twelfth patient received a LOMT as a result of the RRT review; on the other hand, every fourth was transferred to ICU, of which every third died in the ICU (Table 2). Ranges for these outcomes were wide (2.1–25%, 8.2–56% and 6.9–35%). The median

hospital mortality rate was 26%, and the median 30-day mortality rate was 29%, with similarly wide ranges (12–60% and 8.0–39%). When data from all studies reporting the outcome in question were pooled, the results were within two units of the calculated medians (except for the ICU mortality, median 29% vs. pooled 22%, and 180-day mortality, as described previously).

## Discussion

### *Key findings*

In this systematic review we aimed to summarise the current knowledge on outcome of patients reviewed and treated by RRTs. The available data suggests that RRT calls regularly result in LOMT decisions and, on the other hand, intensive care unit admissions. RRT patients are in the poorest condition among hospitalized patients with high in-hospital and 30-day mortality rates. The lack of data on long term and functional outcomes and for RRT patients is striking. Outcome data quality regarding RRT patients in the 29 studies included in this systematic review is generally modest, and the high risk of bias should be taken into consideration before drawing strong conclusions.

### *Limitations of medical treatment*

One of the functions of RRT is to initiate LOMT discussions when appropriate.[8] This is a task with inherent complexity, given the cultural and legal differences between countries and other barriers related to parent unit staff and relatives.[48,49] Nevertheless, RRTs seem to actively participate in LOMT decisions; even some of the earlier papers reported percentages of LOMT reviews as high as 8.6 and 25.[17,28] On the other hand, some later studies, such as Boniatti et al. and Chan et al., have reported very low rates of LOMT decisions by RRT; a high portion of the reviews resulted in a transfer to the ICU.[15,20] In these studies, the 'RRT dose'[50] (activations per 1000 hospital admissions) was high, and RRTs may have reviewed patients in better condition. Had barriers been breached with timely ICU-level assessments or did RRTs implement LOMTs in undesirable prearrest situations? Further studies on the situations in which LOMTs are implemented by RRTs are warranted, but obviously RRTs take part in end of life discussions, as proposed in papers defining RRTs.[8,51]

### *ICU admissions*

One core purpose of RRTs is to reduce documented delays in transfers to intensive care,[52,53] and beneficial results in general ward to intensive care-cohorts have been documented.[43] Barwise et al., Karpman et al. (same hospital, different time periods) and Morris et al. reported that half of the RRT reviews resulted in an ICU admission, where Coventry et al. and Smith et al. found that less than 10% of the reviewed patients were transferred to intensive care.[13,21,27,33,35] All of these studies were published in 2012 or after, included over 1200 RRT activations and were conducted in university/tertiary hospitals. Geographical variation seems evident; the studies with the lowest transfer rates were conducted in the Australia and the studies with the highest ICU admission rates were conducted in the US. Similar difference was observed within the other studies from these countries.[14,17–20,22–24,30,31,34,37,40] Cultural differences influence practices, and this may also influence ICU mortality rates. One would expect that high ICU transfer rates would result in lower ICU mortality, as in the study by Barwise et al.[13] but several studies have reported the opposite.[12,20,31,40] This underlines, how careful one should be with one's interpretations; fact is that just the admittance to ICU is dependent on local circumstances, such as critical care capacity and how critical care is assessed justified or futile.[54] Overall, the ICU mortality rates of patients admitted after RRT review were higher than the overall ICU mortality rates in recent multicenter studies.[55–58] It seems that patients transferred to ICUs by METs are in the worst condition of any in these departments. In fact, Jäderling et al. found that crude ICU mortality rates were almost twice as high among patients transferred to the ICU by RRT than the 'conventionally transferred' general ward patients.[43] However, the difference in 30-day mortality rates was not observed after adjustment for confounding factors.

### *Mortality and morbidity*

The hospital mortality rate of RRT patients seems comparable to that of ICU patients in general, despite the fact that, according to our results, the majority of RRT patients are left on wards without any treatment limitations.[58] The studies included in this review reported similar hospital mortalities of RRT patients despite high[20,35,40] or low[17,26,30,38] RRT activation rates, although it could be expected that with high activation rates the RRT would attend more frequently low-risk patients with minimal risk for in-hospital death. The more relevant survival outcomes, such as time-fixed mortality, were rarely reported. It could be argued that rapid response systems should aim to reduce 30- or 90-day mortality rates of hospitalized patients, not just IHCAs and in-hospital mortality rates. Strikingly, we did not identify studies reporting on quality of life at any point after RRT review, which is the outcome most relevant to the patients themselves.

### *Study implications*

In 2014 Jones published a national review article on short-term outcomes of RRT patients in Australia, urging more data on outcomes of RRT patients.[59] To our knowledge, this is the first international systematic review to investigate the short- and long-term outcomes of patients reviewed by RRTs, although almost three decades have passed since the first reports of rapid response systems. RRTs have since been implemented in all inhabited continents, but still little is known about the long-term outcomes of RRT patients. Fortunately, more data has already been presented; after our literature search was conducted, Psirides et al. reported fixed outcomes of MET patients from 11 New Zealand hospitals over a two week period.[60] Future studies should evaluate the functional outcomes and morbidity of patients attended by RRT during their hospitalization. Associations with the most desired and clinically relevant outcomes are often the hardest to demonstrate, but they should be investigated because RRTs are not without costs.

### *Limitations*

This review has limitations in addition to the previously presented sources of bias within the individual studies included in this review. First, the included studies have several inherent limitations that decrease their external validity. The RRT activation criteria are known to vary greatly between hospitals.[61–63] Some hospitals utilized single parameter track and trigger systems with different activation thresholds, and other institutions had implemented early warning scores.[24,29,32,36] The composition of RRTs differed between the centers, and the level of experience of the team physician was either attending or resident.[20,32,33,38] There were 10 studies in this review that reported data on RRT patients immediately after the implementation process,[12,14,20,22,24,26–28,30,33] where seven studies examined mature RRTs with over five years in practice.[19,23,25,31,35,36,40] In addition, some hospitals, such as district general hospitals,[22,28,30] may not be able to provide all the necessary interventions for RRT patients. The fact that studies in this review originated from multiple continents both increases and

decreases this review's external validity. Although we present comprehensive data, the comparability of the results is questionable. Another limitation is that our electronic search strategy might have been suboptimal; over half of the studies were identified through hand searching of bibliographies, and we did not include the term 'critical care outreach team' (CCOT) in the search. Although CCOT often refers to a team facilitating transfers from ICUs to general wards,[44,64,65] the term may also refer to an actual RRT. We excluded non-English-language papers and paediatric studies, although the strongest evidence on rapid response systems comes from paediatric settings.[5] However, our search highlights how scattered the data on RRT cohorts are. Very few studies' primary aim was to document data on patients reviewed by RRTs; rather, data on RRT patients were primarily focused on sub-cohorts or were reported as secondary findings.

## Conclusion

Data on the outcomes of patients reviewed by RRTs are highly variable in the literature. The quality of the existing data is modest. On average, every twelfth patient receives LOMT after a RRT review; on the other hand, every fourth RRT review results in an ICU transfer. The ICU mortality of admitted RRT patients is high; nearly one third of patients die in intensive care. Three quarters of patients reviewed by RRT are discharged alive, but little to no data exists on their long term-outcomes or quality of life.

## Conflict of interest statement

All authors declare that they have no conflicts of interest.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2016.12.023.

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