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Characterising Variation in Composition and Activation Criteria of Rapid Response and Cardiac Arrest Teams: A Survey of Medicare Participating Hospitals in Five American States

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Characterising Variation in Composition and Activation Criteria of Rapid Response and Cardiac Arrest Teams:

A Survey of Medicare Participating Hospitals in Five American States

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Conflicts of Interest: None

Abstract

Objectives:

To characterise the variation in composition, leadership, and activation criteria of rapid response and cardiac arrest teams in five north-eastern states of the United States of America.

Design:

Voluntary 50 question survey of acute care hospitals in north-eastern USA.

Setting:

Acute care hospitals in New York, New Jersey, Rhode Island, Vermont, and Pennsylvania.

Participants:

Out of 378 hospitals, contacts were identified for 303, and 107 surveys were completed.

Results:

Out of 378 hospitals, contacts were identified for 303, and 107 surveys were completed. All but two hospitals had an RRT, 70% of which changed members daily. The most common activation criteria were clinical concern (95%), single vital sign abnormalities (77%), and Early Warning Score (59%). 81% of hospitals had a dedicated cardiac arrest team.

RRT composition varied widely, with respiratory therapists, critical care nurses, physicians and nurse managers being the most likely to attend (89%, 78%, 64%, and 51% respectively). Consistent presence of critical care physicians was uncommon and both cardiac arrest teams and teams were frequently led by trainee physicians, often without senior supervision.

Trial Registration:

The study was approved by the New York University School of Medicine's Institutional Review Board.

Conclusions:

As the largest study to date in the USA, we have demonstrated wide heterogeneity, rapid team turnover, and a lack of senior supervision of RRT and cardiac arrest teams. These factors likely contribute to the mixed results seen in studies of RRTs.

Article Summary:

Strengths and Limitations:

- This is the largest study of its kind and the only study of RRT and cardiac arrest team composition in the USA
- Gives an understanding of the characterisation of RRT and cardiac arrest team structure and function
- Only represents Medicare participating hospitals in five states
- The 35% response rate further limits study

Funding:

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflicts of Interest:

None of the authors have any conflicts of interest to declare.

Keywords: Critical care; resuscitation; rapid response team

Abbreviations: RRT: rapid response team; USA: United States of America; IHI: Institute for Healthcare Improvement; ICU: Intensive Care Unit; ACGME: Accreditation Council for Graduate Medical Education; HIPAA: Health Insurance Portability and Accountability Act of 1996

Introduction:

The use of Rapid Response Teams (RRTs) is now well established throughout the United States of America (USA), Europe, Australia and Canada, in part due to their inclusion in the Institute for Healthcare Improvement (IHI) 5 Million Lives Campaign. [1] Although no criteria have been formally defined, the IHI defines an RRT as "a team of clinicians who bring critical care expertise to the bedside." In practice the composition of each RRT likely varies by hospital, based on local resources and requirements. Once activated, the goal of the RRT is to rescue sick or deteriorating patients to prevent further decompensation and to facilitate appropriate and timely treatment, as well as rapid and appropriate escalation of care. Each RRT may be a multidisciplinary team with representatives from internal medicine, critical care and nursing, as well as other allied healthcare professionals. [2 3]

Evidence behind RRTs is far from robust, with some studies showing reductions in rates of unexpected hospital deaths and out of intensive care unit (ICU) cardiac arrest after the establishment of an RRT [4-10] and others failing to demonstrate significant improvement. [2 11 12] The effectiveness of an RRT might be intrinsically linked to its composition, as provider expertise possibly influences the ability to promptly stabilise, resuscitate and triage a deteriorating patient. Most of the published literature, however, is focused on the impact on patient outcomes after implementation of an RRT in a single hospital or healthcare system, with little attention to RRT composition. To our knowledge, there have been no studies which have looked at variation in the composition, availability, or activation criteria for such teams in the USA.

We sought to survey acute care hospitals in five north-eastern states: New York; Pennsylvania; Rhode Island; Vermont; and New Jersey in order to establish the current practice with regards to RRT and cardiac arrest team members, availability and activation criteria.

Methods:

The study was reviewed and approved by the New York University School of Medicine's Office of Science and Research Institutional Review Board (i17-01584).

Acute care hospitals in New York, Pennsylvania, Rhode Island, Vermont, and New Jersey were identified from the publicly available Medicare database (data.medicare.gov). If contact details were not already known to team members or available online, hospitals were contacted by telephone by study team members in order to identify a contact person involved in RRTs and cardiac arrests. Study team members contacted hospital personnel in a systematic fashion: initially contacting the nursing administration department; then the hospitalist or Medicine division; then Chief Residents of the Internal Medicine program (if available); and finally, the Chief Nursing Officer of the hospital. Once an appropriate contact was identified, an anonymous survey email was sent via the Health Insurance Portability and Accountability Act of 1996 (HIPAA) compliant REDCap web application. After two weeks, a reminder email was sent if the survey had not been completed.

To minimise the risk of duplicate surveys being completed, each survey contained a unique link, and only one valid link was sent to each hospital at a time. The survey consisted of fifty

questions, which were a mixture of multiple choice and free text answers, all of which had to be completed to submit the survey. The survey collected baseline hospital information as well as information on RRT and cardiac arrest team activation criteria, the method by which the individual members were contacted, leadership and individual team makeup.

Patient Involvement:

Patients were not involved in this research project.

Results:

Characteristics of the Study Hospitals:

Three hundred and seventy-eight acute care hospitals were identified from the Medicare database and RRT contacts were identified for 303 of these (80%) using the methods above. One hundred and seven surveys were completed, the majority from New York and Pennsylvania, a response rate of 35%.

Out of the hospitals that responded, 59 (55%) reported a university affiliation. All but two hospitals had an ICU (Table 1). Seventy-two hospitals (67%) had a training program approved by the Accreditation Council for Graduate Medical Education (ACGME) in either Internal Medicine, Anaesthesia, or Critical Care.

Characteristics of Participating Hospitals

		n	Percentage
University Affiliation	Yes	59	55%
	No	48	45%
Financial Structure	Private	54	50%
	Public	53	50%
Inpatient Beds	0-100	14	13%
	100-500	58	54%
	>500	35	33%
ICU Beds	0	2	2%
	1-20	50	47%
	21-50	31	29%
	>50	24	22%
ACGME Training Program	Internal Medicine Residency	69	64%
	Anaesthesia Residency	39	36%
	Critical Care Fellowship	51	48%

Table 1: Characteristics of participating hospitals. ICU: Intensive Care Unit, ACGME: Accreditation Council for Graduate Medical Education.

RRT Activation Criteria and Availability:

Of the 107 hospitals, 105 had an RRT. One of the two hospitals without an ICU also did not have an RRT. One hundred and four of the 105 RRTs were available 24 hours a day. RRTs were dispatched by overhead call in 75 hospitals (71%), pager in 71 hospitals (68%) and by phone in 24 hospitals (23%). Over half of the RRTs were called out with more than one modality, the most common of which was a combination of pager and overhead call in 49 hospitals (47%).

RRT Characteristics			
		n	Percentage
24h RRT		104	99%
RRT Calling Criteria	Clinical Concern	100	95%
	Vital sign	81	77%
	EWS	62	59%
RRT Called Over	Overhead	75	71%
	Pager	71	68%
	Phone	24	23%
	Pager and Overhead	49	47%
RRT Team Members Change	Daily	73	70%
	Weekly	15	14%
	Monthly	4	4%
	Rarely	13	12%

Table 2: RRT characteristics, including availability of RRT, activation criteria, mechanism of dispatch, and variation in individual team members. RRT: Rapid Response Team.

Membership Turnover:

Turnover of the RRT was high, with team members changing daily in 70%. The majority of hospitals had multiple activation criteria for RRTs, the most common of which were clinical concern (95%), vital sign abnormalities (77%), and Early Warning Scores (EWS) (59%) (Table 2). Less common activation criteria included family member concern (2%), alcohol withdrawal scores (1%), falls (1%), and lack of intravenous access (1%).

RRT Composition:

RRT composition varied widely with most hospitals having representatives from multiple disciplines including physicians, nursing management, respiratory therapy and pharmacy. Respiratory therapists, critical care nurses, physicians and nurse managers were the most common healthcare professionals to always attend RRTs (89%, 78%, 64%, and 51% respectively) (Figure 1). Sixty-seven hospitals (64%) always had a physician of some specialty present at the RRT. Attending physicians were always part of the RRT in 40 hospitals (38%), occasionally present in 56 (53%), and never present in 9 (9%). Critical care physicians, whether attending or fellow, always attended RRTs in 20% of hospitals and never attended in 25%.

RRT Leadership:

RRTs were led by an attending physician in 31%, a trainee physician in 41%, a nurse in 12%, and a nurse practitioner or physician assistant (PA) in 10%. The remaining 6% were led by any physician present at the RRT (5%), or an emergency department physician (1%), (Table 3). In 35 out of the 69 hospitals with an ACGME internal medicine residency (51%), RRTs were led by internal medicine residents, in six of these hospitals (17%) internal medicine attending physicians also always made up part of the RRT, presumably in a supervisory role.

Team Leader by Specialty

		Rapid Response		Cardiac Arrest	
		n	**Percentage**	**n**	**Percentage**
Internal Medicine	NP/PA	11	10%	5	6%
	Resident	35	33%	33	38%
	Attending	22	21%	18	21%
Critical Care	Fellow	5	5%	6	7%
	Attending	10	10%	17	20%
	Nurse	13	12%	2	2%
Anaesthesia	Resident	0	0%	0	0%
	Attending	0	0%	0	0%
Other	Family Medicine Resident	3	3%	1	1%
	ED Physician	1	1%	1	1%
	Variable Providers	5	5%	4	5%

Table 3: Individual who was reported to usually lead the RRT and cardiac arrest team by specialty and training level. NP: Nurse Practitioner, PA: Physician Assistant, ED: Emergency Department.

Cardiac Arrest Teams:

Eighty-seven hospitals (81%) had a dedicated cardiac arrest team. The most common method to call a cardiac arrest team was overhead (91%), followed by pager (68%) and phone (9%). Sixty percent of hospitals used both overhead call and pager. As with RRTs, membership of cardiac arrest teams varied widely (Figure 2). Senior physicians were slightly more likely to lead cardiac arrests (40% of cardiac arrest teams compared to 31% of RRTs) with critical care attendings leading 20% of cardiac arrest teams compared to 10% of RRTs and nurses leading only 2% of cardiac arrests (Table 3).

Discussion:

Rapid Response Teams aim to provide rapid deployment of skilled healthcare professionals to the bedside of a critically unwell patient in order to simultaneously assess, triage, and intervene to prevent further deterioration. For such an intervention to be effective, patients must be identified early in their clinical course, correctly diagnosed and expeditiously treated. While there has been broad adoption of the RRT model, there is no clear guideline-based "best practices" statement regarding team structure, dynamics or activation criteria, which may contribute to the variability in the effectiveness reported by single-centre studies of RRTs.

We here report the results of the first study in the USA, demonstrating significant inter-hospital variations in the activation, constitution and functioning of RRT and cardiac arrest teams.

The choice of activation criteria is paramount to the success of the team. Ideally, such criteria allow for accurate and early identification of patients while avoiding excessive false alarms. We found that the most commonly used activation criteria were clinical concern and single vital sign abnormalities. Early warning scores, which are calculated from routinely collected vital signs, are extensively studied and have been shown to outperform single vital sign abnormalities in predicting adverse clinical outcomes. [13] Introduction of EWS has been associated with reduction in cardiac arrest rates and inpatient mortality. [14-21] Despite the evidence supporting the use of EWS to reduce adverse clinical outcomes, we found that they were only used in 59%

of centres in this survey. Broader adoption of EWS as a trigger for activating RRTs might help in standardizing the way deteriorating patients are identified early in their trajectory.

Almost all RRTs were available around the clock, however team membership varied considerably and RRT members changed daily in the vast majority. The effect of frequent team turnover in RRTs has not been studied, but one-off teams are known to perform particularly poorly and the beneficial effects of increasing team familiarity is well described in fields outside of medicine. [22 23] Given this, maintaining a consistent RRT with familiar members may improve team dynamics. Individual hospital requirements and resources will certainly impact on their ability to support such a team. An RRT huddle at the beginning of each shift, describing individual roles and responsibilities, may help to preserve team dynamics and efficient communication despite this turnover. [24]

One of the appealing features of RRTs is the rapid delivery of skilled healthcare practitioners and critical care expertise to the bedside, in essence a projection of ICU level of care to the medical floors. In practice, we found that lack of consistent attending physician presence was commonplace, even in hospitals where RRTs were led by resident physicians with only one to three years of postgraduate experience. Although some studies have suggested that the addition of an senior critical care physician to the RRT does not improve mortality, [25 26] the inclusion of an attending critical care physician ensures attending supervision of the RRT or cardiac arrest, improves documentation, and is associated with high survival rates [27]. The impact of the lack of senior support at these low frequency, high stakes scenarios may weaken its effectiveness and is an area deserving of future research.

Our study has several significant weaknesses. Firstly, and most significantly, it is a survey that was only completed by a single individual at each hospital. While we made every effort to ensure that the survey was only completed by one person per hospital and that the person completing the form would be able to do so correctly, we were unable to verify this due to anonymous nature of the survey.

Our response rate of 35% is a significant limitation to the generalisability of our findings. As the survey was anonymous, we were unable to assess the variation in location, resources and affiliation between responders and non-responders. It is unclear whether there was any significant difference between hospitals who responded and those that did not, although a lower proportion of small hospitals completed surveys, which limits our results further. Smaller hospitals may have fewer resources, more limited physician availability, and a lower number of RRT events when compared to larger hospitals and factors such as these may affect their approach to the RRT structure and availability.

The study included only Medicare-participating hospitals in New York, Pennsylvania, Rhode Island, Vermont, and New Jersey and our findings cannot necessarily be extrapolated to the practice of hospitals across the country or internationally. Variation in RRT and cardiac arrest team composition, as well as activation criteria, has been demonstrated in small studies in a number of other countries, suggesting that such variation is not a unique finding, an area of future study for our group [28-30].

When assessing the evidence concerning the clinical impact of RRTs, it is important to remember that the RRT is only part of the inpatient chain of rescue. For the best outcome and ideal RRT, multiple factors must be met: the team must be called early, whether by EWS or other track and trigger score; the patient must be diagnosed correctly and managed promptly by experienced clinicians; and the team must work smoothly and communicate well.

Conclusion:

RRTs have become almost ubiquitous across the USA, despite the uncertainty of their impact. As the largest study to date, we have demonstrated considerable heterogeneity among RRTs and cardiac arrest teams, a factor that likely contributes to the mixed results seen in studies. Increased use of EWS, optimizing team dynamics and ensuring that trainee team leaders are adequately supported may improve RRT function and patient safety. Individual factors that influence the effectiveness of the RRT deserve further study.

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Data Sharing Statement: Data will not be published publically. Please contact Oscar Mitchell at oscar.mitchell@nyumc.org if access to the original data is required.

Author Contributions: OM, LE, VM designed the study. OM, CM, JH and VM collected and analysed the data. OM, CM, JH, LE and VM wrote the manuscript and agree to its submission for publication.

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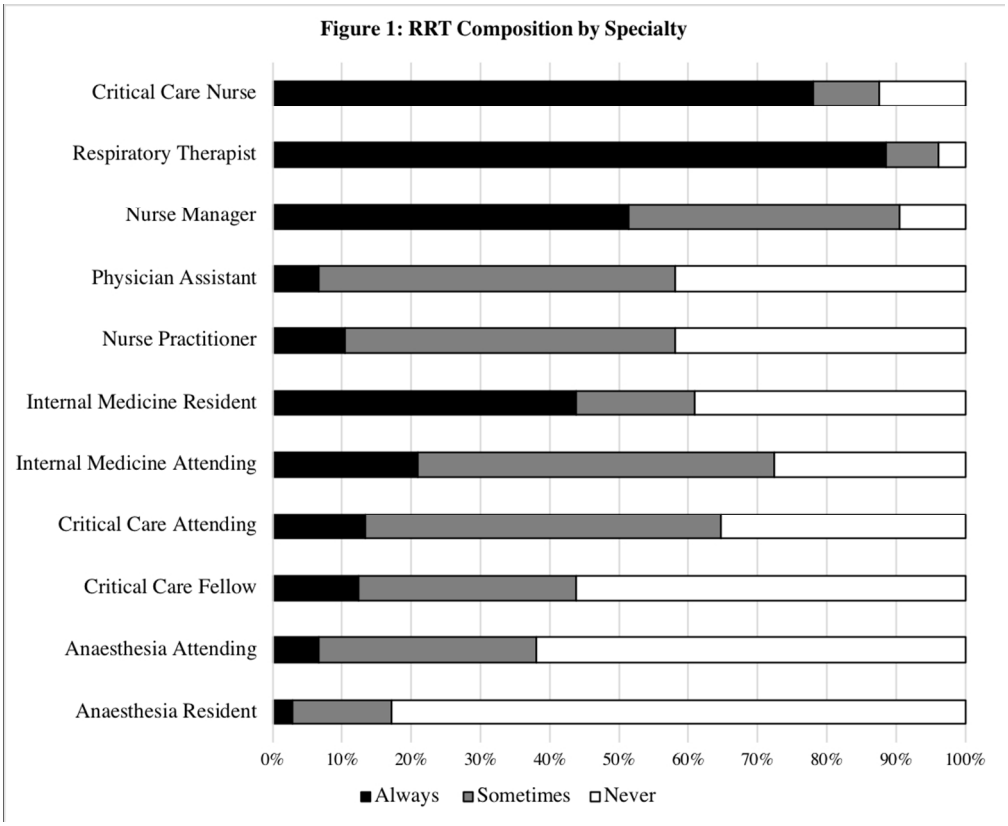

Figure 1: Composition of RRTs by specialty.

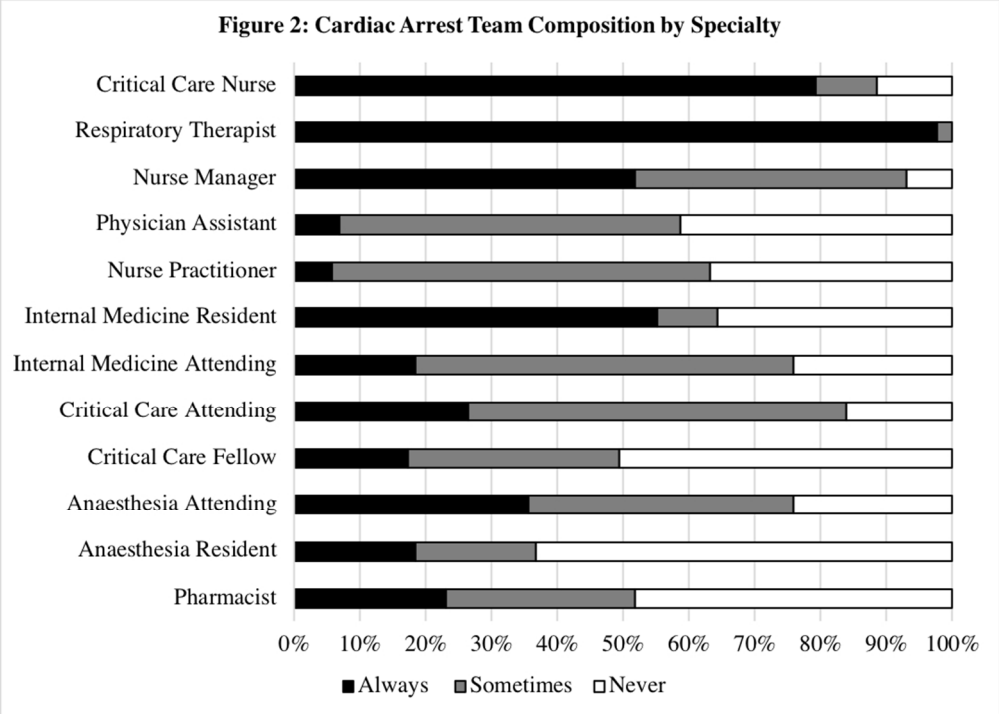

Figure 2: Composition of cardiac arrest teams by speciality.

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Conflicts of Interest: None

Abstract

Objectives:

To characterise the variation in composition, leadership, and activation criteria of rapid response and cardiac arrest teams in five northeastern states of the United States of America.

Design:

Cross-sectional study consisting of a voluntary 46-question survey of acute care hospitals in northeastern USA.

Setting:
Acute care hospitals in New York, New Jersey, Rhode Island, Vermont, and Pennsylvania.

Participants:
Surveys were completed by any member of the RRT with a working knowledge of the team structure. Participants were all Medicare-participating acute care hospitals, including teaching and community hospitals as well as hospitals from rural, urban and suburban areas.

Results:

Out of 378 hospitals, contacts were identified for 303, and 107 surveys were completed. All but two hospitals had an RRT, 70% of which changed members daily. The most common activation criteria were clinical concern (95%), single vital sign abnormalities (77%), and Early Warning Score (59%). 81% of hospitals had a dedicated cardiac arrest team.

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Conclusions:

As the largest study to date in the USA, we have demonstrated wide heterogeneity, rapid team turnover, and a lack of senior supervision of RRT and cardiac arrest teams. These factors likely contribute to the mixed results seen in studies of RRTs.

Strengths and Limitations of the Study:

- This is the largest study of its kind and the only study of RRT and cardiac arrest team composition in the USA
- Gives an understanding of the characterisation of RRT and cardiac arrest team structure and function
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The use of Rapid Response Teams (RRTs) is now well established throughout the United States of America (USA), Europe, Australia and Canada, in part due to their inclusion in the Institute for Healthcare Improvement (IHI) 5 Million Lives Campaign. [1] Although no criteria have been formally defined, the IHI defines an RRT as "a team of clinicians who bring critical care expertise to the bedside." In practice the composition of each RRT likely varies by hospital, based on local resources and requirements. Once activated, the goal of the RRT is to rescue sick or deteriorating patients to prevent further decompensation and to facilitate appropriate and timely treatment, as well as rapid and appropriate escalation of care. Each RRT may be a multidisciplinary team with representatives from internal medicine, critical care and nursing, as well as other allied healthcare professionals. [2-4]

Evidence behind RRTs is far from robust, with some studies showing reductions in rates of unexpected hospital deaths and out of intensive care unit (ICU) cardiac arrest after the establishment of an RRT [5-11] and others failing to demonstrate significant improvement. [2 12 13] The effectiveness of an RRT might be intrinsically linked to its composition, as provider expertise possibly influences the ability to promptly stabilise, resuscitate and triage a deteriorating patient. Most of the published literature, however, is focused on the impact on patient outcomes after implementation of an RRT in a single hospital or healthcare system, with little attention to RRT and cardiac arrest team composition. To our knowledge, there has been only one such study in the USA, which described substantial heterogeneity between 33 hospitals in a south-eastern state. [4]

We hypothesised that there would be wide variation in team structure, leadership and activation criteria of RRT and cardiac arrest teams. We sought to survey acute care hospitals in five northeastern states: New York; Pennsylvania; Rhode Island; Vermont; and New Jersey in order to establish the current practice with regards to RRT and cardiac arrest team members, availability and activation criteria.

Methods:

Survey Design:

The study was reviewed and approved by the New York University School of Medicine's Office of Science and Research Institutional Review Board (i17-01584). A 46-question survey was created by the investigators (Appendix 1). The survey collected baseline hospital characteristics, which were limited to hospital size, ICU beds and presence of an Accreditation Council for Graduate Medical Education (ACGME) training program to avoid loss of anonymity. Characteristics of the RRT included methods of RRT activation, including the use of Early Warning Scores (EWS), single vital sign abnormalities and clinical concern. Additionally, information on RRT and cardiac arrest team leadership and individual team makeup was also collected, with the RRT leader being defined as the member of the team who usually leads the RRT.

Survey Distribution:

The study was conducted over a 3-month period from January to March 2018. Acute care hospitals in New York, Pennsylvania, Rhode Island, Vermont, and New Jersey were identified

from the publicly available Medicare database (data.medicare.gov). If contact details were not already known to team members or available online, hospitals were contacted by telephone by study team members in order to identify a contact person involved in RRTs and cardiac arrests. Study team members contacted hospital personnel in a systematic fashion: initially contacting the nursing administration department; then the hospitalist or Medicine division; then Chief Residents of the Internal Medicine program (if available); and finally the Chief Nursing Officer of the hospital. Once an appropriate contact was identified, an anonymous survey email was sent via the Health Insurance Portability and Accountability Act of 1996 (HIPAA) compliant REDCap web application. After two weeks, a reminder email was sent if the survey had not been completed.

To minimise the risk of duplicate surveys being completed, each survey contained a unique link, and only one valid link was sent to each hospital at a time. All survey questions had to be completed in order to submit the survey.

Statistical comparisons of categorical variables were performed using the Chi squared test. Data analysis was completed using the Statistical Package for the Social Sciences (SPSS) version 23.

Patient Involvement:

Patients were not involved in this research project.

Results:

Characteristics of the Study Hospitals:

Three hundred and seventy-eight acute care hospitals were identified from the Medicare database and RRT contacts were identified for 303 of these (80%) using the methods above. One hundred and seven surveys were completed, the majority from New York and Pennsylvania, a response rate of 35%. As all questions were mandatory, there were no missing data.

Out of the hospitals that responded, 59 (55%) reported a university affiliation. All but two hospitals had an ICU (Table 1). Seventy-two hospitals (67%) had a training program approved by the ACGME in Internal Medicine, Anaesthesia, or Critical Care.

Characteristics of Participating Hospitals			
		n	**Percentage**
University Affiliation	Yes	59	55%
	No	48	45%
Financial Structure	Private	54	50%
	Public	53	50%
Inpatient Beds	0-500	72	67%
	>500	35	33%
ICU Beds	0	2	2%
	1-20	50	47%
	21-50	31	29%
	>50	24	22%
ACGME Training Program Present	Internal Medicine Residency	69	64%
	Anaesthesia Residency	39	36%
	Critical Care Fellowship	51	48%

Table 1: Characteristics of participating hospitals. ICU: Intensive Care Unit, ACGME: Accreditation Council for Graduate Medical Education.

RRT Activation Criteria and Availability:

Of the 107 hospitals, 105 had an RRT. One of the two hospitals without an ICU also did not have an RRT. One hundred and four of the 105 RRTs were available 24 hours a day. RRTs were dispatched by overhead call in 75 hospitals (71%), pager in 71 hospitals (68%) and by phone in 24 hospitals (23%). Over half of the RRTs were called out with more than one modality, the most common of which was a combination of pager and overhead call in 49 hospitals (47%).

RRT Characteristics			
		n	Percentage
24h RRT		104	99%
RRT Calling Criteria	Clinical Concern	100	95%
	Vital sign	81	77%
	EWS	62	59%
RRT Called Over	Overhead	75	71%
	Pager	71	68%
	Phone	24	23%
	Pager and Overhead	49	47%
RRT Team Members Change	Daily	73	70%
	Weekly	15	14%
	Monthly	4	4%
	Rarely	13	12%

Table 2: RRT characteristics, including availability of RRT, activation criteria, mechanism of dispatch, and variation in individual team members. RRT: Rapid Response Team.

Membership Turnover:

Turnover of the RRT was high, with team members changing daily in 70%. The majority of hospitals had multiple activation criteria for RRTs, the most common of which were clinical concern (95%), vital sign abnormalities (77%), and EWS (59%) (Table 2). Less common activation criteria included family member concern (2%), alcohol withdrawal scores (1%), falls (1%), and lack of intravenous access (1%). Neither the size of the hospital nor the size of the ICU was significantly associated with the use of EWS as activation criteria.

RRT Composition:

RRT composition varied widely with most hospitals having representatives from multiple disciplines including physicians, nursing management, respiratory therapy and pharmacy. Respiratory therapists, critical care nurses, physicians and nurse managers were the most common healthcare professionals to always attend RRTs (89%, 78%, 64%, and 51% respectively) (Figure 1). Sixty-seven hospitals (64%) always had a physician present in the RRT. Attending physicians were always part of the RRT in 40 hospitals (38%), occasionally present in 56 (53%), and never present in 9 (9%). Critical care physicians, whether attending or fellow, always attended RRT activations in 20% of hospitals and never attended in 25%. The size of the hospital was not associated with having consistent presence of attending physicians or critical care physicians as part of their RRT (p=0.89 and p=0.30 respectively). The presence of an ACGME training program was not significantly associated with consistent attending presence at RRTs (p=0.49).

RRT Leadership:

RRTs were led by an attending physician in 31%, a trainee physician in 41%, a nurse in 12%, and a nurse practitioner or physician assistant (PA) in 10%. The remaining 6% were led by any physician present at the RRT (5%), or an emergency department physician (1%), (Table 3). In 35 out of the 69 hospitals with an ACGME internal medicine residency (51%), RRTs were led by internal medicine residents, in six of these hospitals (17%) internal medicine attending physicians also always made up part of the RRT, presumably in a supervisory role.

Team Leader by Specialty					
		Rapid Response		Cardiac Arrest	
		n	Percentage	n	Percentage
Internal Medicine	NP/PA	11	10%	5	6%
	Resident	35	33%	33	38%
	Attending	22	21%	18	21%
Critical Care	Fellow	5	5%	6	7%
	Attending	10	10%	17	20%
	Nurse	13	12%	2	2%
Anaesthesia	Resident	0	0%	0	0%
	Attending	0	0%	0	0%
Other	Family Medicine Resident	3	3%	1	1%
	ED Physician	1	1%	1	1%
	Variable Providers	5	5%	4	5%

Table 3: Individual who was reported to usually lead the RRT and cardiac arrest team by specialty and training level. NP: Nurse Practitioner, PA: Physician Assistant, ED: Emergency Department.

Cardiac Arrest Teams:

Eighty seven hospitals hospitals (81%) had a dedicated cardiac arrest team. The most common method to call a cardiac arrest team was overhead (91%), followed by pager (68%) and phone (9%). Sixty percent of hospitals used both overhead call and pager. As with RRTs, membership of cardiac arrest teams varied widely (Figure 2). Senior physicians were slightly more likely to lead cardiac arrests (40% of cardiac arrest teams compared to 31% of RRTs) with critical care attendings leading 20% of cardiac arrest teams compared to 10% of RRTs and nurses leading only 2% of cardiac arrests (Table 3).

Discussion:

Rapid Response Teams aim to provide rapid deployment of skilled healthcare professionals to the bedside of a critically unwell patient in order to simultaneously assess, triage, and intervene to prevent further deterioration. For such an intervention to be effective, patients must be identified early in their clinical course, correctly diagnosed and expeditiously treated. While there has been broad adoption of the RRT model, there is no clear guideline-based "best practices" statement regarding team structure, dynamics or activation criteria, which may contribute to the variability in the effectiveness reported by single-centre studies of RRTs. Factors that have been associated with top performing cardiac arrest teams include team design, team composition, communication and leadership during cardiac arrest and training of the cardiac arrest team. [14]

We here report the results of the largest study in the USA, demonstrating substantial inter-hospital variations in the activation, constitution and functioning of RRT and cardiac arrest teams. To our knowledge it is also the first study to have described the structure of cardiac arrest teams.

The choice of activation criteria is paramount to the success of the team. Ideally, such criteria allow for accurate and early identification of patients while avoiding excessive false alarms. We found that the most commonly used activation criteria were clinical concern and single vital sign abnormalities. Early warning scores, which are calculated from routinely collected vital signs, are extensively studied and have been shown to outperform single vital sign abnormalities in

predicting adverse clinical outcomes. [15] Introduction of EWS has been associated with reduction in cardiac arrest rates and inpatient mortality. [16-22] Despite the evidence supporting the use of EWS to reduce adverse clinical outcomes, we found that they were only used in 59% of centres in this survey. Broader adoption of EWS as a trigger for activating RRTs might help in standardising the way deteriorating patients are identified early in their trajectory.

Almost all RRTs were available around the clock, however team membership varied considerably and RRT members changed daily in the vast majority. The effect of frequent team turnover in RRTs has not been studied, but one-off teams are known to perform particularly poorly and the beneficial effects of increasing team familiarity are well described in fields outside of medicine and improved cardiac arrest team communication has been associated with top-performing cardiac arrest teams. [14 23 24] Given this, maintaining a consistent RRT with familiar members may improve team dynamics. Individual hospital requirements and resources will certainly impact on their ability to support such a team. An RRT huddle at the beginning of each shift, describing individual roles and responsibilities, may help to preserve team dynamics and efficient communication despite this turnover. [25]

One of the appealing features of RRTs is the rapid delivery of skilled healthcare practitioners and critical care expertise to the bedside, in essence a projection of ICU level of care to the medical floors. In practice, we found that lack of consistent attending physician presence was commonplace, even in hospitals where RRTs were led by resident physicians with only one to three years of postgraduate experience. Although some studies have suggested that the addition of an senior critical care physician to the RRT does not improve mortality, [26 27] the inclusion

of an attending critical care physician ensures attending supervision of the RRT or cardiac arrest, improves documentation, and is associated with high survival rates [28]. We expected that smaller hospitals would be more stretched for resources and as such less likely have senior physicians at RRTs, but we did not find any association between the size of hospital, number of ICU beds, or presence of an ACGME training program and the consistent presence of senior physicians. The impact of the lack of senior support at these low frequency, high stakes scenarios may weaken RRT effectiveness and is an area deserving of future research.

Our study has several weaknesses. Firstly and most importantly, it is a survey that was only completed by a single individual at each hospital. While we made every effort to ensure that the survey was only completed by one person per hospital and that the person completing the form would be able to do so correctly, we were unable to verify this due to anonymous nature of the survey.

Our response rate of 35% is a substantial limitation to the generalisability of our findings. As the survey was anonymous, we were unable to assess the variation in location, resources and affiliation between responders and non-responders. It is unclear whether there was any difference between hospitals who responded and those that did not, although a lower proportion of small hospitals completed surveys, which limits our results further. Smaller hospitals may have fewer resources, more limited physician availability, and a lower number of RRT events when compared to larger hospitals and factors such as these may affect their approach to the RRT structure and availability.

The study included only Medicare-participating hospitals in New York, Pennsylvania, Rhode Island, Vermont, and New Jersey and our findings cannot necessarily be extrapolated to the practice of hospitals across the country or internationally. Variation in RRT and cardiac arrest team composition, as well as activation criteria, has been demonstrated in small studies in a number of other countries, suggesting that such variation is not a unique finding, an area of future study for our group [29-31].

When assessing the evidence concerning the clinical impact of RRTs, it is important to remember that the RRT is only part of the inpatient chain of rescue. For the best outcome and ideal RRT, multiple factors must be met: the team must be called early, whether by EWS or other track and trigger score; the patient must be diagnosed correctly and managed promptly by experienced clinicians; and the team must work smoothly and communicate well.

Conclusion:

RRTs have become almost ubiquitous across the USA, despite the uncertainty of their impact. As the largest study to date, we have demonstrated considerable heterogeneity among RRTs and cardiac arrest teams, a factor that likely contributes to the mixed results seen in studies. Increased use of EWS, optimising team dynamics and ensuring that trainee team leaders are adequately supported may improve RRT function and patient safety. Individual factors that influence the effectiveness of the RRT, including the importance of leadership, member turnover, and team structure on RRT and cardiac arrest team outcome. The creation of consensus guidelines regarding RRT and cardiac arrest team membership could serve to standardise RRT and cardiac arrest team structure and function across the country.

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Data Sharing Statement: Data will not be published publicly. Please contact Oscar Mitchell at oscar.mitchell@nyumc.org if access to the original data is required.

Author Contributions:

OM, LE, VM designed the study. OM, CM, JH and VM collected and analysed the data. OM, CM, JH, LE and VM wrote the manuscript and agree to its submission for publication.

All authors were involved in the writing of the manuscript and have drafted, reviewed and approved the current version. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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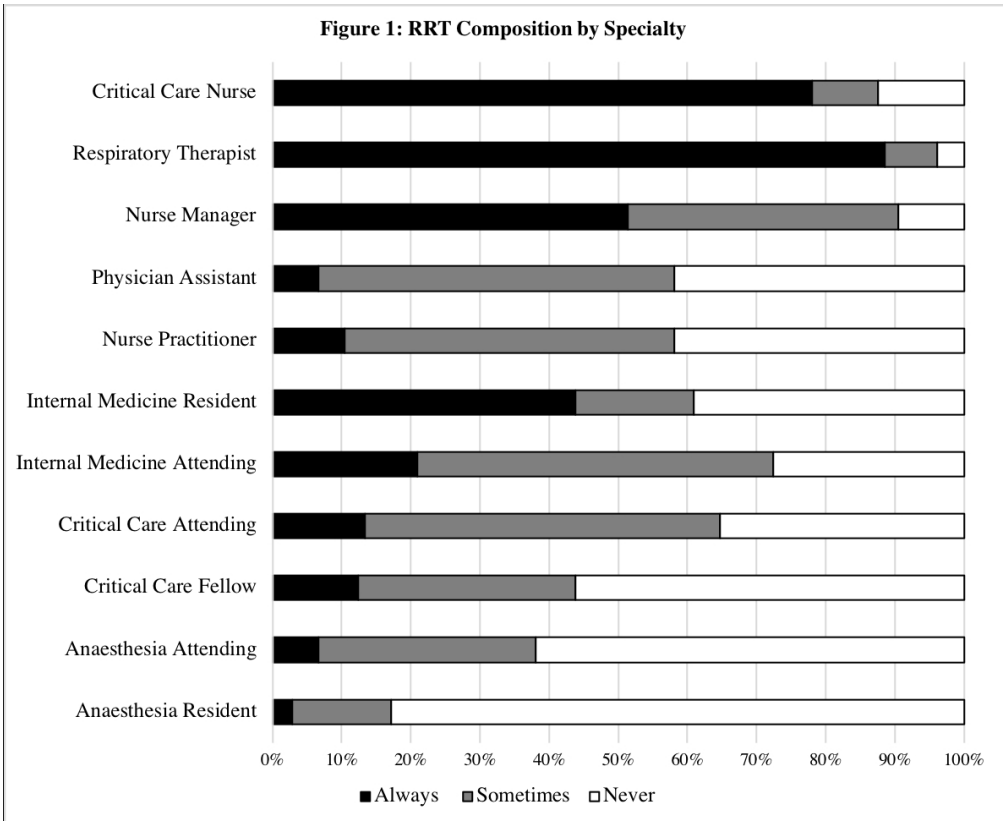
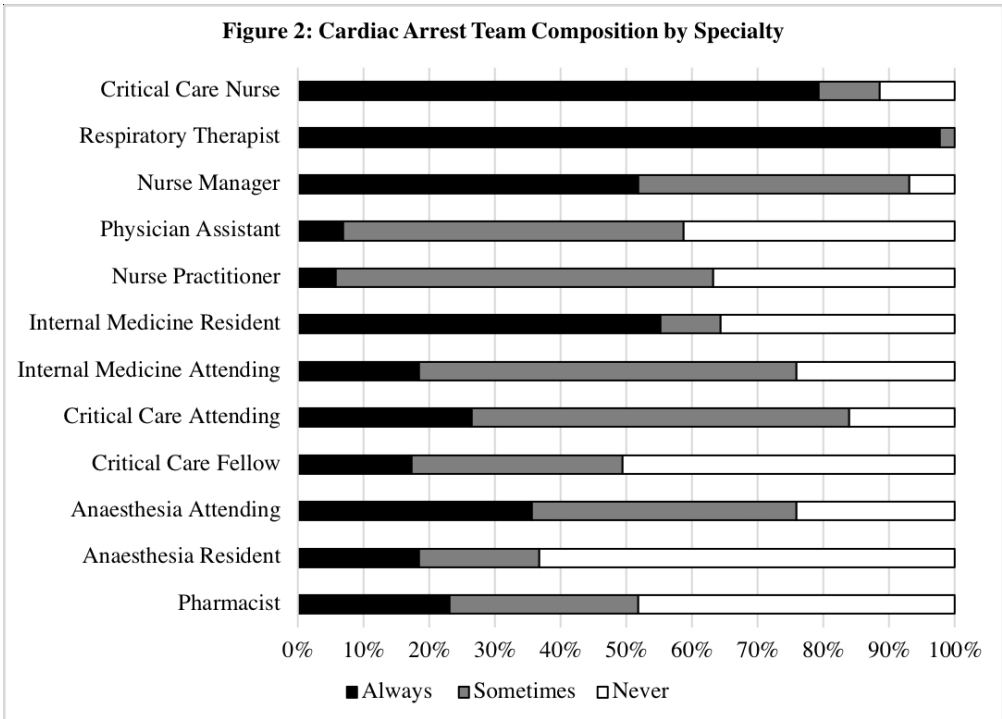
Legends to Figures:

Figure 1: Composition of RRTs by specialty.

Figure 2: Composition of cardiac arrest teams by speciality.





1. Hospital affiliation (select one):	University affiliated Non-university affiliated
2. State:	
3. Financial structure (select one)	Private Public Veteran's Affairs
4. Number of inpatient beds	0-100 100-500 >500
5. Number of ICU beds in your hospital	0 1-20 21-50 >50
6. ACGME Internal Medicine Residency Program	Yes/No
7. ACGME Critical Care Fellowship Program	Yes/No
8. ACGME Anaesthesiology Residency Program	Yes/No
9. Does your hospital have a rapid response team (RRT)?	Yes/No
10. Is your RRT available 24 hours a day?	Yes/No
11. How are RRTs called at your hospital?	Pager Overhead call Phone Other
12. If other, how are RRTs called at your hospital?	

13. Who is usually responsible for leading RRTs?

- NP/PA
- Internal medicine resident
- Internal medicine attending
- Critical care fellow
- Critical care attending
- Critical care nursing
- Anaesthesia resident
- Anaesthesia attending
- Other

14. If other, who is usually responsible for leading RRTs at your hospital?

15. What parameters can result in a RRT being called?

- Early warning score (NEWS, MEWS etc)
- Single vital sign abnormality (eg HR, RR etc)
- Clinical concern
- Other

16. If other, what parameters can results in an RRT being called at your hospital?

17. Members of the RRT usually change:

- Daily
- Weekly
- Monthly
- Rarely

18-29. Who is present at RRT's?

Always, Sometimes, Never

Nurse Practitioner
Physician Assistant
Internal Medicine Resident
Internal Medicine Attending
Anaesthesia Resident
Anaesthesia Attending

Critical Care Fellow
Critical Care Attending
Critical Care Nurse
Nurse Manager
Respiratory Therapist
Pharmacist

30. Does your hospital have a cardiac arrest team?

31. How are cardiac arrests called at your hospital? Pager
Overhead call
Phone
Other

32. If other, how are cardiac arrests called at your hospital?

33. Who is usually responsible for leading cardiac arrests? NP/PA
Internal medicine resident
Internal medicine attending
Critical care fellow
Critical care attending
Critical care nursing
Anaesthesia resident
Anaesthesia attending
Other

34. If other, who is responsible for leading cardiac arrests at your hospital?

35-46. Who is present at cardiac arrests? Always, Sometimes, Never

Nurse Practitioner
Physician Assistant
Internal Medicine Resident
Internal Medicine Attending

Anaesthesia Resident
Anaesthesia Attending
Critical Care Fellow
Critical Care Attending
Critical Care Nurse
Nurse Manager
Respiratory Therapist
Pharmacist

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract X p.1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found X p.2-3
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported X p. 4-5
Objectives	3	State specific objectives, including any prespecified hypotheses X p.5
Methods		
Study design	4	Present key elements of study design early in the paper X p.5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection X p.5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants X p.5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable X p.5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group X All data was derived from the surveys
Bias	9	Describe any efforts to address potential sources of bias X p.6
Study size	10	Explain how the study size was arrived at X p.7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why NA
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding p.6
		(*b*) Describe any methods used to examine subgroups and interactions NA
		(*c*) Explain how missing data were addressed p.7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy NA
		(*e*) Describe any sensitivity analyses NA

Results		
Participants	13*	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed X p.7
		(b) Give reasons for non-participation at each stage NA
		(c) Consider use of a flow diagram NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders X Table 1 on page 8
		(b) Indicate number of participants with missing data for each variable of interest NA
Outcome data	15*	Report numbers of outcome events or summary measures X Tables 2 and 3 and pages 7-13
Main results	16	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included NA
		(*b*) Report category boundaries when continuous variables were categorized NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses NA
Discussion		
Key results	18	Summarise key results with reference to study objectives p.14-16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias p.15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence p.15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results p.16
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based NA

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Characterising Variation in Composition and Activation Criteria of Rapid Response and Cardiac Arrest Teams: A Survey of Medicare Participating Hospitals in Five American States

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Characterising Variation in Composition and Activation Criteria of Rapid Response and Cardiac Arrest Teams:

A Survey of Medicare Participating Hospitals in Five American States

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Conflicts of Interest: None

Abstract

Objectives:

To characterise the variation in composition, leadership, and activation criteria of rapid response and cardiac arrest teams in five northeastern states of the United States of America.

Design:

Cross-sectional study consisting of a voluntary 46-question survey of acute care hospitals in northeastern USA.

Setting:

Acute care hospitals in New York, New Jersey, Rhode Island, Vermont, and Pennsylvania.

Participants:

Surveys were completed by any member of the RRT with a working knowledge of team composition and function. Participants were all Medicare-participating acute care hospitals, including teaching and community hospitals as well as hospitals from rural, urban and suburban areas.

Results:

Out of 378 hospitals, contacts were identified for 303, and 107 surveys were completed. All but two hospitals had an RRT, 70% of which changed members daily. The most common activation criteria were clinical concern (95%), single vital sign abnormalities (77%), and Early Warning Score (59%). 81% of hospitals had a dedicated cardiac arrest team.

RRT composition varied widely, with respiratory therapists, critical care nurses, physicians and nurse managers being the most likely to attend (89%, 78%, 64%, and 51% respectively). Consistent presence of critical care physicians was uncommon and both cardiac arrest teams and teams were frequently led by trainee physicians, often without senior supervision.

Conclusions:

As the largest study to date in the USA, we have demonstrated wide heterogeneity, rapid team turnover, and a lack of senior supervision of RRT and cardiac arrest teams. These factors likely contribute to the mixed results seen in studies of RRTs.

Strengths and Limitations of the Study:

- Survey based design of the study and 35% response rate limits the generalisability of our findings.
- Design of survey allowed for detailed description of CAT and RRT composition and function in participating hospitals.
- Only represents Medicare participating hospitals in five states.

Funding Statement:

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Conflicts of Interest:

None of the authors have any conflicts of interest to declare.

Keywords: Critical care; resuscitation; rapid response team

Abbreviations: RRT: rapid response team; USA: United States of America; IHI: Institute for Healthcare Improvement; ICU: Intensive Care Unit; ACGME: Accreditation Council for Graduate Medical Education; HIPAA: Health Insurance Portability and Accountability Act of 1996

Introduction:

The use of Rapid Response Teams (RRTs) is now well established throughout the United States of America (USA), Europe, Australia and Canada, in part due to their inclusion in the Institute for Healthcare Improvement (IHI) 5 Million Lives Campaign. [1] Although no criteria have been formally defined, the IHI defines an RRT as "a team of clinicians who bring critical care expertise to the bedside." In practice the composition of each RRT likely varies by hospital, based on local resources and requirements. Once activated, the goal of the RRT is to rescue sick or deteriorating patients to prevent further decompensation and to facilitate appropriate and timely treatment, as well as rapid and appropriate escalation of care. Each RRT may be a multidisciplinary team with representatives from internal medicine, critical care and nursing, as well as other allied healthcare professionals. [2-4]

Evidence behind RRTs is far from robust, with some studies showing reductions in rates of unexpected hospital deaths and out of intensive care unit (ICU) cardiac arrest after

the establishment of an RRT [5-11] and others failing to demonstrate significant improvement. [2 12 13] The effectiveness of an RRT might be intrinsically linked to its composition, as provider expertise possibly influences the ability to promptly stabilise, resuscitate and triage a deteriorating patient. Most of the published literature, however, is focused on the impact on patient outcomes after implementation of an RRT in a single hospital or healthcare system, with little attention to RRT and cardiac arrest team composition. To our knowledge, there have been only two such studies in the USA, one which described substantial heterogeneity between 33 hospitals in a south-eastern state, and another that showed variation in CAT composition. [4 14]

We hypothesised that there would be wide variation in the leadership, activation criteria, and the composition of RRT and cardiac arrest teams. We sought to survey acute care hospitals in five northeastern states: New York; Pennsylvania; Rhode Island; Vermont; and New Jersey in order to establish the current practice with regards to RRT and cardiac arrest team members, availability and activation criteria.

Methods:

Survey Design:

The study was reviewed and approved by the New York University School of Medicine's Office of Science and Research Institutional Review Board (i17-01584). A 46-question survey was created by the investigators (Appendix 1). The survey collected baseline hospital characteristics, which were limited to hospital size, ICU beds and presence of an Accreditation Council for Graduate Medical Education (ACGME) training program to avoid loss of anonymity. Characteristics of the RRT included methods of RRT activation, including the use of Early Warning Scores (EWS), single vital sign abnormalities and clinical concern. Additionally, information on RRT and cardiac arrest team leadership and individual team composition was also collected, with the RRT leader being defined as the member of the team who usually leads the RRT.

Survey Distribution:

The study was conducted over a 3-month period from January to March 2018. Acute care hospitals in New York, Pennsylvania, Rhode Island, Vermont, and New Jersey were identified from the publicly available Medicare database (data.medicare.gov). If contact details were not already known to team members or available online, hospitals were contacted by telephone by study team members in order to identify a contact person involved in RRTs and cardiac arrests. Study team members contacted hospital personnel in a systematic fashion: initially contacting the nursing administration department; then the hospitalist or Medicine division; then Chief Residents of the Internal Medicine program (if available); and finally the Chief Nursing Officer of the hospital. Once an appropriate contact was identified, an anonymous survey email was sent via the Health Insurance Portability and Accountability Act of 1996 (HIPAA) compliant REDCap web application. After two weeks, a reminder email was sent if the survey had not been completed.

To minimise the risk of duplicate surveys being completed, each survey contained a unique link, and only one valid link was sent to each hospital at a time. All survey questions had to be completed in order to submit the survey.

Statistical comparisons of categorical variables were performed using the Chi squared test. Data analysis was completed using the Statistical Package for the Social Sciences (SPSS) version 25.

Patient Involvement:

Neither patients, nor the general public were involved in this research project.

Results:

Characteristics of the Study Hospitals:

Three hundred and seventy-eight acute care hospitals were identified from the Medicare database and RRT contacts were identified for 303 of these (80%) using the methods above. One hundred and seven surveys were completed, the majority from New York and Pennsylvania, a response rate of 35%. As all questions were mandatory, there were no missing data.

Out of the hospitals that responded, 59 (55%) reported a university affiliation. All but two hospitals had an ICU (Table 1). Seventy-two hospitals (67%) had a training program approved by the ACGME in Internal Medicine, Anaesthesia, or Critical Care.

Characteristics of Participating Hospitals

		n	Percentage
University Affiliation	Yes	59	55%
	No	48	45%
Financial Structure	Private	54	50%
	Public	53	50%
Inpatient Beds	0-500	72	67%
	>500	35	33%
ICU Beds	0	2	2%
	1-20	50	47%
	21-50	31	29%
	>50	24	22%
ACGME Training Program Present	Internal Medicine Residency	69	64%
	Anaesthesia Residency	39	36%
	Critical Care Fellowship	51	48%

Table 1: Characteristics of participating hospitals. ICU: Intensive Care Unit, ACGME: Accreditation Council for Graduate Medical Education.

RRT Activation Criteria and Availability:

Of the 107 hospitals, 105 had an RRT. One of the two hospitals without an ICU also did not have an RRT. One hundred and four of the 105 RRTs were available 24 hours a

day. RRTs were dispatched by overhead call in 75 hospitals (71%), pager in 71 hospitals (68%) and by phone in 24 hospitals (23%). Over half of the RRTs were called out with more than one modality, the most common of which was a combination of pager and overhead call in 49 hospitals (47%).

RRT Characteristics

		n	Percentage
24h RRT		104	99%
RRT Calling Criteria	Clinical Concern	100	95%
	Vital sign	81	77%
	EWS	62	59%
RRT Called Over	Overhead	75	71%
	Pager	71	68%
	Phone	24	23%
	Pager and Overhead	49	47%
RRT Team Members Change	Daily	73	70%
	Weekly	15	14%
	Monthly	4	4%
	Rarely	13	12%

Table 2: RRT characteristics, including availability of RRT, activation criteria, mechanism of dispatch, and variation in individual team members. RRT: Rapid Response Team.

Membership Turnover:

Turnover of the RRT was high, with team members changing daily in 70%. The majority of hospitals had multiple activation criteria for RRTs, the most common of which were clinical concern (95%), vital sign abnormalities (77%), and EWS (59%) (Table 2). Less common activation criteria included family member concern (2%), alcohol withdrawal scores (1%), falls (1%), and lack of intravenous access (1%). Neither the size of the hospital nor the size of the ICU was significantly associated with the use of EWS as activation criteria (p=0.48 and p=0.33 respectively).

RRT Composition:

RRT composition varied widely with most hospitals having representatives from multiple disciplines including physicians, nursing management, respiratory therapy and pharmacy. Respiratory therapists, critical care nurses, physicians and nurse managers were the most common healthcare professionals to always attend RRTs (89%, 78%, 64%, and 51% respectively) (Figure 1). Sixty-seven hospitals (64%) always had a physician present in the RRT. Attending physicians were always part of the RRT in 40 hospitals (38%), occasionally present in 56 (53%), and never present in 9 (9%). Critical care physicians, whether attending or fellow, always attended RRT activations in 20% of hospitals and never attended in 25%. The size of the hospital was not associated with having consistent presence of attending physicians or critical care physicians as part of their RRT (p=0.89 and p=0.30 respectively). The presence of an ACGME training program was not significantly associated with consistent attending presence at RRTs (p=0.50).

RRT Leadership:

RRTs were led by an attending physician in 30%, a trainee physician in 41%, a nurse in 12%, and a nurse practitioner or physician assistant (PA) in 10%. The remaining 6%

were led by any physician present at the RRT (5%), or an emergency department physician (1%), (Table 3). In 35 out of the 69 hospitals with an ACGME internal medicine residency (51%), RRTs were led by internal medicine residents, in six of these hospitals (17%) internal medicine attending physicians also always made up part of the RRT, presumably in a supervisory role.

Team Leader by Specialty

		Rapid Response		Cardiac Arrest	
		n	Percentage	n	Percentage
Internal Medicine	NP/PA	11	10%	5	6%
	Resident	35	33%	33	38%
	Attending	22	21%	18	21%
Critical Care	Fellow	5	5%	6	7%
	Attending	10	10%	17	20%
	Nurse	13	12%	2	2%
Anaesthesia	Resident	0	0%	0	0%
	Attending	0	0%	0	0%

	Family Medicine Resident	3	3%	1	1%
Other	ED Physician	1	1%	1	1%
	Variable Providers	5	5%	4	5%

Table 3: Individual who was reported to usually lead the RRT and cardiac arrest team by specialty and training level. NP: Nurse Practitioner, PA: Physician Assistant, ED: Emergency Department.

Cardiac Arrest Teams:

Eighty seven hospitals hospitals (81%) had a dedicated cardiac arrest team. The most common method to call a cardiac arrest team was overhead (91%), followed by pager (68%) and phone (9%). Sixty percent of hospitals used both overhead call and pager. As with RRTs, membership of cardiac arrest teams varied widely (Figure 2). Senior physicians were slightly more likely to lead cardiac arrests (40% of cardiac arrest teams compared to 31% of RRTs) with critical care attendings leading 20% of cardiac arrest

teams compared to 10% of RRTs and nurses leading only 2% of cardiac arrests (Table 3).

Discussion:

Rapid Response Teams aim to provide rapid deployment of skilled healthcare professionals to the bedside of a critically unwell patient in order to simultaneously assess, triage, and intervene to prevent further deterioration. For such an intervention to be effective, patients must be identified early in their clinical course, correctly diagnosed and expeditiously treated. While there has been broad adoption of the RRT model, there is no clear guideline-based “best practices” statement regarding team composition, dynamics or activation criteria, which may contribute to the variability in the effectiveness reported by single-centre studies of RRTs. Factors that have been associated with top performing cardiac arrest teams include team design, team composition, communication and leadership during cardiac arrest and training of the cardiac arrest team. [15]

We here report the results of the largest study in the USA, demonstrating substantial inter-hospital variations in the activation, constitution and functioning of RRT and cardiac arrest teams.

The choice of activation criteria is paramount to the success of the team. Ideally, such criteria allow for accurate and early identification of patients while avoiding excessive false alarms. We found that the most commonly used activation criteria were clinical concern and single vital sign abnormalities. EWS, which are calculated from routinely collected vital signs, are extensively studied and have been shown to outperform single vital sign abnormalities in predicting adverse clinical outcomes. [16] Introduction of EWS has been associated with reduction in cardiac arrest rates and inpatient mortality. [17-23] Despite the evidence supporting the use of EWS to reduce adverse clinical outcomes, we found that they were only used in 59% of centres in this survey. Broader adoption of EWS as a trigger for activating RRTs might help in standardising the way deteriorating patients are identified early in their trajectory.

Almost all RRTs were available around the clock, however team membership varied considerably and RRT members changed daily in the vast majority. The effect of frequent team turnover in RRTs has not been studied, but one-off teams are known to perform particularly poorly and the beneficial effects of increasing team familiarity are well described in fields outside of medicine and improved cardiac arrest team communication has been associated with top-performing cardiac arrest teams. [15 24 25] Given this, maintaining a consistent RRT with familiar members may improve team dynamics. Individual hospital requirements and resources will certainly impact on their ability to support such a team. An RRT huddle at the beginning of each shift, describing individual roles and responsibilities, may help to preserve team dynamics and efficient communication despite this turnover. [26]

One of the appealing features of RRTs is the rapid delivery of skilled healthcare practitioners and critical care expertise to the bedside, in essence a projection of ICU level of care to the medical floors. In practice, we found that lack of consistent attending

physician presence was commonplace, even in hospitals where RRTs were led by resident physicians with only one to three years of postgraduate experience. Although some studies have suggested that the addition of an senior critical care physician to the RRT does not improve mortality, [27 28] the inclusion of an attending critical care physician ensures attending supervision of the RRT or cardiac arrest, improves documentation, and is associated with high survival rates [29]. We expected that smaller hospitals would be more stretched for resources and as such less likely have senior physicians at RRTs, but we did not find any association between the size of hospital, number of ICU beds, or presence of an ACGME training program and the consistent presence of senior physicians. The impact of the lack of senior support at these low frequency, high stakes scenarios may weaken RRT effectiveness and is an area deserving of future research.

Our study has several weaknesses. Firstly and most importantly, it is a survey that was only completed by a single individual at each hospital. While we made every effort to ensure that the survey was only completed by one person per hospital and that the

person completing the form would be able to do so correctly, we were unable to verify this due to anonymous nature of the survey.

Our response rate of 35% is a substantial limitation to the generalisability of our findings. As the survey was anonymous, we were unable to assess the variation in location, resources and affiliation between responders and non-responders. It is unclear whether there was any difference between hospitals who responded and those that did not, although a lower proportion of small hospitals completed surveys, which limits our results further. Smaller hospitals may have fewer resources, more limited physician availability, and a lower number of RRT events when compared to larger hospitals and factors such as these may affect their approach to the RRT composition and availability.

The study included only Medicare-participating hospitals in New York, Pennsylvania, Rhode Island, Vermont, and New Jersey and our findings cannot necessarily be extrapolated to the practice of hospitals across the country or internationally. Variation in RRT and cardiac arrest team composition, as well as activation criteria, has been

demonstrated in small studies in a number of other countries, suggesting that such variation is not a unique finding, an area of future study for our group [30-32].

When assessing the evidence concerning the clinical impact of RRTs, it is important to remember that the RRT is only part of the inpatient chain of rescue. For the best outcome and ideal RRT, multiple factors must be met: the team must be called early, whether by EWS or other track and trigger score; the patient must be diagnosed correctly and managed promptly by experienced clinicians; and the team must work smoothly and communicate well.

Conclusion:

RRTs have become almost ubiquitous across the USA, despite the uncertainty of their impact. As the largest study to date, we have demonstrated considerable heterogeneity among RRTs and cardiac arrest teams, a factor that likely contributes to the mixed results seen in studies. Increased use of EWS, optimising team dynamics and ensuring that trainee team leaders are adequately supported may improve RRT function and

patient safety. Individual factors that influence the effectiveness of the RRT, including the importance of leadership, member turnover, and team composition on RRT and cardiac arrest team outcome. The creation of consensus guidelines regarding RRT and cardiac arrest team membership could serve to standardise RRT and cardiac arrest team composition and function across the country.

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Data Sharing Statement: Data will not be published publicly. Please contact Oscar Mitchell at oscar.mitchell@nyumc.org if access to the original data is required.

Author Contributions:

OM, LE, VM designed the study. OM, CM, JH and VM collected and analysed the data. OM, CM, JH, LE and VM wrote the manuscript and agree to its submission for publication.

All authors were involved in the writing of the manuscript and have drafted, reviewed and approved the current version. All authors agree to be accountable for all aspects of the work in

ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Legends to Figures:

Figure 1: Composition of RRTs by specialty.

Figure 2: Composition of cardiac arrest teams by speciality.

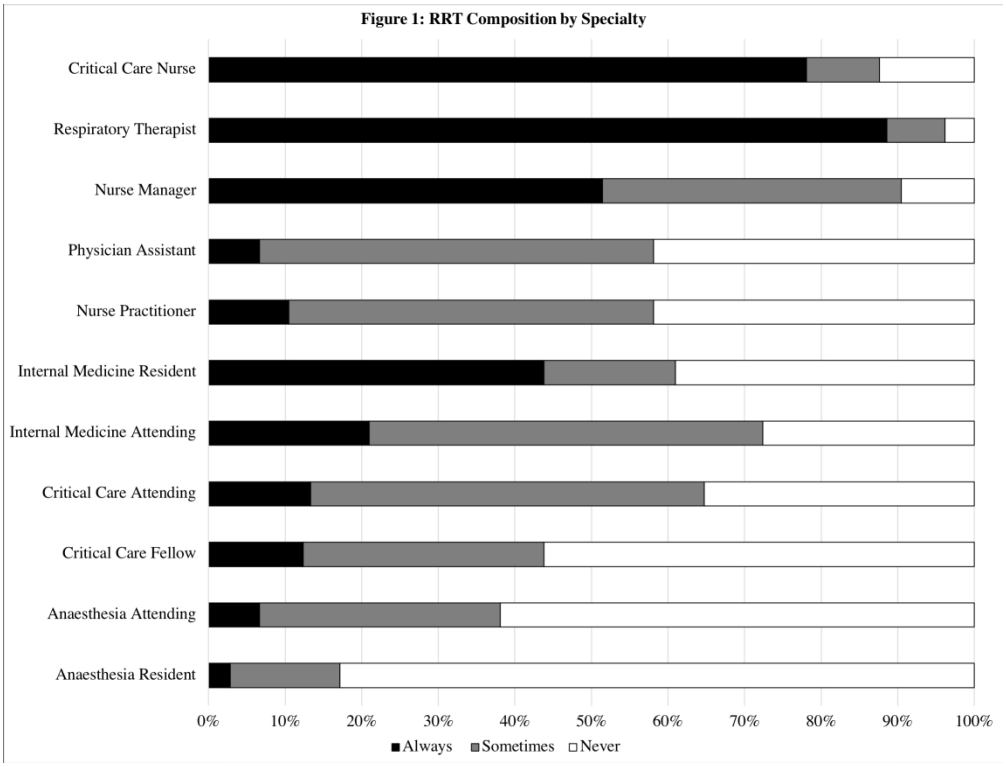

Figure 1: Composition of RRTs by specialty.

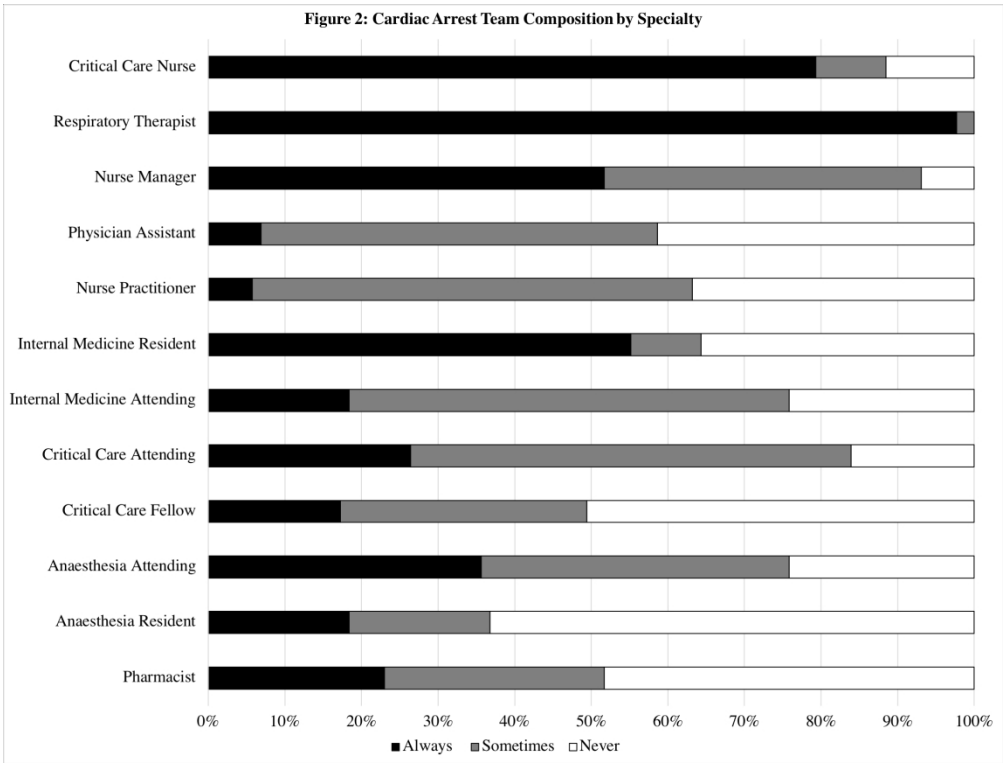

Figure 2: Composition of cardiac arrest teams by speciality.

1. Hospital affiliation (select one):	University affiliated Non-university affiliated
2. State:	
3. Financial structure (select one)	Private Public Veteran's Affairs
4. Number of inpatient beds	0-100 100-500 >500
5. Number of ICU beds in your hospital	0 1-20 21-50 >50
6. ACGME Internal Medicine Residency Program	Yes/No
7. ACGME Critical Care Fellowship Program	Yes/No
8. ACGME Anaesthesiology Residency Program	Yes/No
9. Does your hospital have a rapid response team (RRT)?	Yes/No
10. Is your RRT available 24 hours a day?	Yes/No
11. How are RRTs called at your hospital?	Pager Overhead call Phone Other
12. If other, how are RRTs called at your hospital?	

13. Who is usually responsible for leading RRTs?	NP/PA Internal medicine resident Internal medicine attending Critical care fellow Critical care attending Critical care nursing Anaesthesia resident Anaesthesia attending Other

14. If other, who is usually responsible for leading RRTs at your hospital?

15. What parameters can result in a RRT being called?	Early warning score (NEWS, MEWS etc) Single vital sign abnormality (eg HR, RR etc) Clinical concern Other

16. If other, what parameters can results in an RRT being called at your hospital?

17. Members of the RRT usually change:	Daily Weekly Monthly Rarely

18-29. Who is present at RRT's?	Always, Sometimes, Never

Nurse Practitioner
Physician Assistant
Internal Medicine Resident
Internal Medicine Attending
Anaesthesia Resident
Anaesthesia Attending

Critical Care Fellow
Critical Care Attending
Critical Care Nurse
Nurse Manager
Respiratory Therapist
Pharmacist

30. Does your hospital have a cardiac arrest team?

31. How are cardiac arrests called at your hospital? Pager
Overhead call
Phone
Other

32. If other, how are cardiac arrests called at your hospital?

33. Who is usually responsible for leading cardiac arrests? NP/PA
Internal medicine resident
Internal medicine attending
Critical care fellow
Critical care attending
Critical care nursing
Anaesthesia resident
Anaesthesia attending
Other

34. If other, who is responsible for leading cardiac arrests at your hospital?

35-46. Who is present at cardiac arrests? Always, Sometimes, Never

Nurse Practitioner
Physician Assistant
Internal Medicine Resident
Internal Medicine Attending

Anaesthesia Resident

Anaesthesia Attending

Critical Care Fellow

Critical Care Attending

Critical Care Nurse

Nurse Manager

Respiratory Therapist

Pharmacist

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract X p.1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found X p.2-3
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported X p. 4-5
Objectives	3	State specific objectives, including any prespecified hypotheses X p.5
Methods		
Study design	4	Present key elements of study design early in the paper X p.5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection X p.5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants X p.5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable X p.5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group X All data was derived from the surveys
Bias	9	Describe any efforts to address potential sources of bias X p.6
Study size	10	Explain how the study size was arrived at X p.7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why NA
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding p.6
		(*b*) Describe any methods used to examine subgroups and interactions NA
		(*c*) Explain how missing data were addressed p.7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy NA
		(*e*) Describe any sensitivity analyses NA

Results		
Participants	13*	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed X p.7
		(b) Give reasons for non-participation at each stage NA
		(c) Consider use of a flow diagram NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders X Table 1 on page 8
		(b) Indicate number of participants with missing data for each variable of interest NA
Outcome data	15*	Report numbers of outcome events or summary measures X Tables 2 and 3 and pages 7-13
Main results	16	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included NA
		(*b*) Report category boundaries when continuous variables were categorized NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses NA
Discussion		
Key results	18	Summarise key results with reference to study objectives p.14-16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias p.15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence p.15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results p.16
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based NA

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.