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Resuscitation 58 (2003) 297–308

RESUSCITATION



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Cardiopulmonary resuscitation of adults in the hospital: A report of 14 720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation

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Received 16 May 2003; accepted 12 June 2003

Abstract

The National Registry of Cardiopulmonary Resuscitation (NRCPR) is an American Heart Association (AHA)-sponsored, prospective, multisite, observational study of in-hospital resuscitation. The NRCPR is currently the largest registry of its kind. The purpose of this article is to describe the NRCPR and to provide the first comprehensive, Utstein-based, standardized characterization of in-hospital resuscitation in the United States. All adult (≥ 18 years of age) and pediatric (< 18 years of age) patients, visitors, employees, and staff within a facility (including ambulatory care areas) who experience a resuscitation event are eligible for inclusion in the NRCPR database. Between January 1, 2000, and June 30, 2002, 14 720 cardiac arrests that met inclusion criteria occurred in adults at the 207 participating hospitals. An organized emergency team is available 24 h a day, 7 days a week in 86% of participating institutions. The three most common reasons for cardiac arrest in adults were (1) cardiac arrhythmia, (2) acute respiratory insufficiency, and (3) hypotension. Overall, 44% of adult in-hospital cardiac arrest victims had a return of spontaneous circulation (ROSC); 17% survived to hospital discharge. Despite the fact that a primary arrhythmia was one of the precipitating events in nearly one half of adult cardiac arrests, ventricular fibrillation (VF) was the initial pulseless rhythm in only 16% of in-hospital cardiac arrest victims. ROSC occurred in 58% of VF cases, yielding a survival-to-hospital discharge rate of 34% in this subset of patients. An automated external defibrillator was used to provide initial defibrillation in only 1.4% of patients whose initial cardiac arrest rhythm was VF. Neurological outcome in discharged survivors was generally good. Eighty-six percent of patients with Cerebral Performance Category-1 (CPC-1) at the time of hospital admission had a postarrest CPC-1 at the time of hospital discharge.

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Keywords: Cardiopulmonary resuscitation; Cardiac arrest; Emergency treatment; Defibrillation

Resumo

O Registo Nacional de Reanimação Cardio-pulmonar (NRCPR) é um estudo observacional de reanimação intrahospitalar multicêntrico, prospectivo, patrocinado pela American Heart Association (AHA). O NRCPR é actualmente o maior registo do seu tipo. O objectivo deste artigo é descrever o NRCPR e proporcionar a primeira caracterização abrangente, baseada no modelo Utstein, da reanimação intrahospitalar nos Estados Unidos. Todos os doentes, visitantes, empregados e pessoal de uma instituição (incluindo áreas de cuidados ambulatoriais), adultos (com idade igual ou superior a 18 anos) e pediátricos (idade inferior a 18 anos), que tenham sido alvo de reanimação foram elegíveis para inclusão na base de dados NRCPR. Entre 1 de Janeiro de 2000 e 30 de

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Julho de 2002 ocorreram 14720 paragens cardíacas, em adultos, de 207 hospitais participantes que cumpriram critérios de inclusão. Em 86% das instituições participantes está disponível uma equipe de emergência organizada 24 horas por dia, 7 dias por semana. As 3 razões mais frequentes para paragem cardíaca nos adultos foram: (1) arritmia cardíaca, (2), insuficiência respiratória aguda e (3) hipotensão. Globalmente, 44% dos adultos vítimas de paragem cardíaca intrahospitalar tiveram retorno da circulação espontânea (ROSC); 17% sobreviveram até alta hospitalar. Apesar do facto de uma arritmia primária ser um dos eventos precipitantes em cerca de metade das paragens cardíacas nos adultos, a fibrilhação ventricular (VF) foi o ritmo sem pulso inicial em apenas 16% das vítimas de paragem cardíaca intrahospitalar. Em 58% dos casos de VF ocorreu ROSC, resultando uma taxa de sobrevida até alta hospitalar de 34% neste subgrupo de doentes. Um desfibrilhador automático externo foi usado para administrar a desfibrilhação inicial em apenas 1,4% dos doentes em que o ritmo cardíaco inicial de paragem foi VF. O resultado neurológico nos sobreviventes com alta foi na generalidade bom. Oitenta e seis por cento dos doentes com Categoria de Performance Cerebral-1 (CPC-1) no momento da admissão hospitalar tiveram CPC-1 pós-paragem no momento da alta hospitalar.

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Palavras chave: Ressuscitação cardiopulmonar (CPR); Paragem cardíaca; Tratamento de Emergência; Desfibrilhação

Resumen

El Registro Nacional de Resucitación cardiopulmonar (NRCPR) es un estudio prospectivo, multi institucional, observacional apoyado por la Asociación Americana del Corazón (AHA). El NRCPR es actualmente el registro más grande de este tipo. El propósito de este artículo es describir el NRCPR y proporcionar la primera caracterización estandarizada, basada en el estilo Utstein, del paro cardíaco intra hospitalario en los Estados Unidos. Todos los pacientes, visitantes, empleados y personal de una instalación (incluyendo áreas de cuidados ambulatorios), adultos (≥ 18 años de edad) y niños (< 18 años) que experimentaron un evento de resucitación son elegibles para la inclusión en la base de datos de la NRCPR. Entre el 1 de Enero, 2000 y el 30 de Junio, 2002, en los 207 hospitales participantes, ocurrieron 14720 paros cardíacos en adultos que cumplieron los criterios de inclusión. En 86% de las instituciones participantes existe un equipo de emergencia organizado, disponible 24 horas al día, 7 días a la semana. Las 3 causas mas frecuentes de paro cardíaco en adultos fueron (1) arritmia cardíaca, (2) insuficiencia respiratoria aguda, y (3) hipotensión. Del total, 44% de los adultos víctimas de paro cardíaco presentaron retorno a circulación espontánea (ROSC); 17% sobrevivió al alta hospitalaria. A pesar del hecho que una arritmia primaria fue uno de los eventos precipitantes en casi la mitad de los paros cardíacos en adultos, fibrilación ventricular (VF) fue el ritmo inicial sin pulso en solo 16% de las víctimas de paro cardíaco en adultos. Ocurrió ROSC en 58% de los casos de VF, alcanzando una tasa de sobrevida al alta de 34% en este sub grupo de pacientes. Solo en el 1.4% de los pacientes en quienes el ritmo inicial era VF se usó un desfibrilador automático externo para proporcionar la desfibrilación inicial. El resultado neurológico en los pacientes dados de alta vivos fue bueno en general. 86% de los pacientes con Categoría de Desempeño Cerebral-1 (CPC-1) al momento de admisión tenía CPC-1 al momento del alta.

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Palabras clave: Reanimación cardiopulmonar; Paro cardíaco; Tratamiento de emergencia; Desfibrilación

1. Introduction

Several publications have reported the outcome of cardiopulmonary arrest in hospitalized patients over the past four decades. The majority of these reports are from single institutions, making generalization and meaningful comparisons difficult in the face of nonuniform data elements and definitions. To address this lack of standardization among patient, event, and outcome variables and to provide guidelines for the uniform reporting of hospital-based resuscitation events, in 1997 the International Liaison Committee on Resuscitation developed and published the Utstein style guidelines for reviewing, reporting, and conducting research on in-hospital resuscitation [1]. These guidelines represent an international consensus on the processes that hospitals should use to collect and review data on adult and pediatric in-hospital resuscitations. They also provide a template for capturing all events for which resuscitation might be indicated. This systematic approach is vital to permit valid comparisons among hospitals and to track

changes over time, both in single institutions and across the healthcare system as a whole [1–4].

American Heart Association (AHA) volunteers from the disciplines of cardiology, emergency medicine, pediatric and adult critical care medicine, nursing administration, and nursing education drafted a model for a registry of in-hospital cardiopulmonary resuscitation. This model, which was based on the in-hospital Utstein guidelines, was given to the AHA and has evolved into the National Registry of Cardiopulmonary Resuscitation (NRCPR). Following software development and preliminary beta testing, the registry was launched on January 1, 2000. The NRCPR allows participating hospitals to track the characteristics, treatment, and outcomes of persons who develop cardiac arrest in the hospital. The registry is based on the Utstein in-hospital template.

The purpose of this article is to describe the NRCPR and provide the first comprehensive, Utstein-based, standardized characterization of in-hospital resuscitation in the United States.

2. Methods

2.1. Data collection

The NRCPR is an AHA-sponsored, prospective, multisite, observational study of in-hospital resuscitation. Although the number of hospitals enrolled in the NRCPR changes, this analysis includes medical/surgical hospitals that provided at least 6 months of data from January 1, 2000, through June 30, 2002. Participating hospitals join the NRCPR voluntarily and are charged an annual fee for data support and report generation. Participants are asked to characterize facilities, staff, patients, and resuscitation services. Because the primary purpose of the NRCPR is quality improvement, participating hospitals are not required to obtain Institutional Review Board approval, although some have done so voluntarily, based on local custom. At each institution, specially trained research coordinators (usually a nurse or research technician) enter information about each cardiac arrest into a computer database. The information is abstracted from hospital medical records (including the patient's chart, cardiac arrest forms, and teletype records). The database contains precisely defined variables derived from the Utstein in-hospital guidelines. The six major categories of variables are (1) facility data (2) patient demographic data, (3) pre-event data, (4) event data, (5) outcome data, and (6) quality improvement data. Each patient is assigned a unique code, and no specific patient identifiers are transmitted to the central database repository. The data may be submitted on diskette or by encrypted transmission over the Internet.

A central data repository (Tri-Analytics, Inc, Forest Hill, MD) facilitates data management and provides sites with quarterly summaries of reports and comparisons of data from individual sites and groups. These reports provide hospitals with a comprehensive mechanism to meet the Joint Commission for the Accreditation of Healthcare Organization (JCAHO) requirements for hospital-based resuscitation review. The reports also provide continuous, standardized quality-improvement data to enhance resuscitation processes locally. On the macro level, registry data provide a rapidly growing information base that can be used to develop evidence-based guidelines for resuscitation practice.

The AHA oversees the entire process of data collection, analysis, and reporting through its staff and the Science Advisory Board. The latter is composed of AHA volunteers, some also serving on the Emergency Cardiovascular Care Committee or its Subcommittees.

2.2. Definitions of variables

One of the special features of the NRCPR is the provision of explicit definitions for every data element.

This feature not only allows interfacility comparison but also permits data from numerous facilities to be combined and evaluated periodically for trends in treatment and outcomes.

2.3. Case inclusion and exclusion criteria

All adult (≥ 18 years of age) and pediatric (< 18 years of age) patients, visitors, employees, and staff within a facility (including ambulatory care areas) who experience a resuscitation event are eligible for inclusion in the NRCPR database. A resuscitation event is defined as

- acute respiratory compromise that requires emergency assisted ventilation (either noninvasive or invasive) *or* acute respiratory compromise that requires emergency assisted ventilation leading to cardiopulmonary arrest that requires chest compressions and/or defibrillation, *or* cardiopulmonary arrest that requires chest compressions and/or defibrillation, *and*
- elicits an emergency resuscitation response by facility personnel, *and*
- a resuscitation record is completed for the event.

The following events are excluded from the database:

- events that begin outside the facility with treatment by nonhospital personnel, even if resuscitation is ongoing on arrival in the emergency department (ED) (i.e. out-of-hospital cardiac resuscitation events are excluded)
- resuscitation interventions for newborns in a delivery room
- resuscitation interventions for children in a neonatal intensive care unit (ICU)
- defibrillation of ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) only by an implantable cardioverter-defibrillator

2.4. Data collection categories

In hospitals, event data are entered under the heading of one of the three main event categories defined above in the inclusion criteria [1]. For the purposes of this article, the categories of *acute respiratory compromise leading to cardiopulmonary arrest* and *cardiopulmonary arrest* are combined into one category that comprises 'cardiac arrest.' Acute respiratory compromise and pediatric resuscitation events will be reported separately. This article focuses on cardiac arrest in adults.

2.5. Definition of end of event

The end of an event is defined as the return of spontaneous circulation (ROSC), including with the support of a pacemaker or cardiopulmonary bypass, lasting > 20 min *or* the termination of the resuscitation event with the patient declared dead due to being unresponsive to resuscitative efforts, a medical futility advance directive, or restrictions imposed by family members. The typical descriptor ‘spontaneous’ is included in the definition because this is the standard accepted terminology. We acknowledge that on occasion, return of circulation may be secondary to a technique such as cardiopulmonary bypass and that these cases technically do not have return of ‘spontaneous’ circulation. Any event that follows > 20 min of sustained ROSC is defined as a new event.

2.6. Statistical analysis

All statistical analyses were performed using a commercially available statistical package (Statistical Applications Software Version 8, SAS Institute, Cary, NC). Summary results are presented as the mean \pm standard deviation for variables that are distributed normally. Variables that are not distributed normally are presented as the median (lower quartile, upper quartile).

2.7. Data integrity

Data were checked for fidelity through a detailed periodic re-abstraction process. NRCPR participants were asked to submit event records voluntarily that corresponded to the events they entered into the database for the preceding quarter. Code numbers were assigned to each record and facility and patient identifiers were stripped out of the data to ensure confidentiality. A random sampling of the stripped

event records and the corresponding NRCPR data sheets were sent to clinicians on the NRCPR Scientific Advisory Board, who identified errors on the worksheet or indicated if a data element could not be confirmed by the event record. Mean error rates for all data were $2.4 \pm 2.7\%$. A web-based remediation program has been developed to continuously allow for improved data integrity for participating sites. Ongoing enrollment of new hospitals involves certification in which the accuracy of data abstraction is tested before data can be submitted to the central database.

3. Results

3.1. Hospital characteristics

A total of 207 (75 adult, 132 mixed adult and pediatric) hospitals submitted > 6 months of in-hospital adult cardiac arrest data during the data collection period of January 21, 2000, through June 30, 2002. Participating hospitals had a median of 260 total beds (46% had < 250 beds; 38%, from 250 to 499 beds; and 16%, > 500 total beds) and a median of 20 ICU beds, defined by the NRCPR as any unit, including critical care unit and stepdown, with hardwired bedside monitoring (59% had < 25 ICU beds; 36%, between 25 and 74 beds; and 5% > 75 beds). The median number of monitored non-ICU beds is 40 (29% have < 25 beds; 50%, from 25 to 74 beds; and 21% > 75 beds). Fig. 1 shows the distribution of NRCPR hospitals by bed size. Fig. 2 details the geographic distribution of participating hospitals.

An organized emergency team is available 24 h a day, 7 days a week in 86% of participating institutions. The team is dispatched by overhead page (38%), beeper (10%), or both (52%).

3.2. Patient characteristics

During the study period, among participating NRCPR hospitals, 14 720 adult patients experienced cardiac arrests that met the inclusion criteria. Most (92%) patients had only one cardiac arrest during hospitalization, 7% experienced 2 arrests, and 1% had ≥ 3 arrests. Patient characteristics are noted in Table 1.

3.3. Event and treatment characteristics

The average number of events per year per facility was 54.1 ± 41.5 ; however, the average number of index events, defined as the first cardiac arrest event overall per bed per year was 0.174 ± 0.087 . This rate ratio did not vary significantly by teaching (0.17) and non-teaching status (0.18). Hospitals with more than 500 adult beds had significantly fewer arrests per bed year

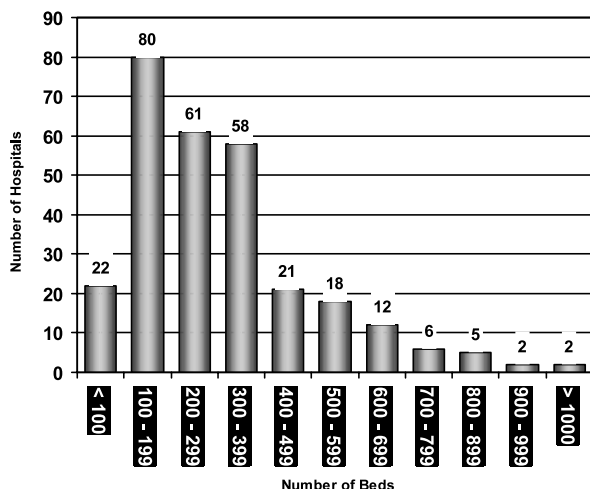


Fig. 1. Distribution of participating NRCPR hospitals by bed size.

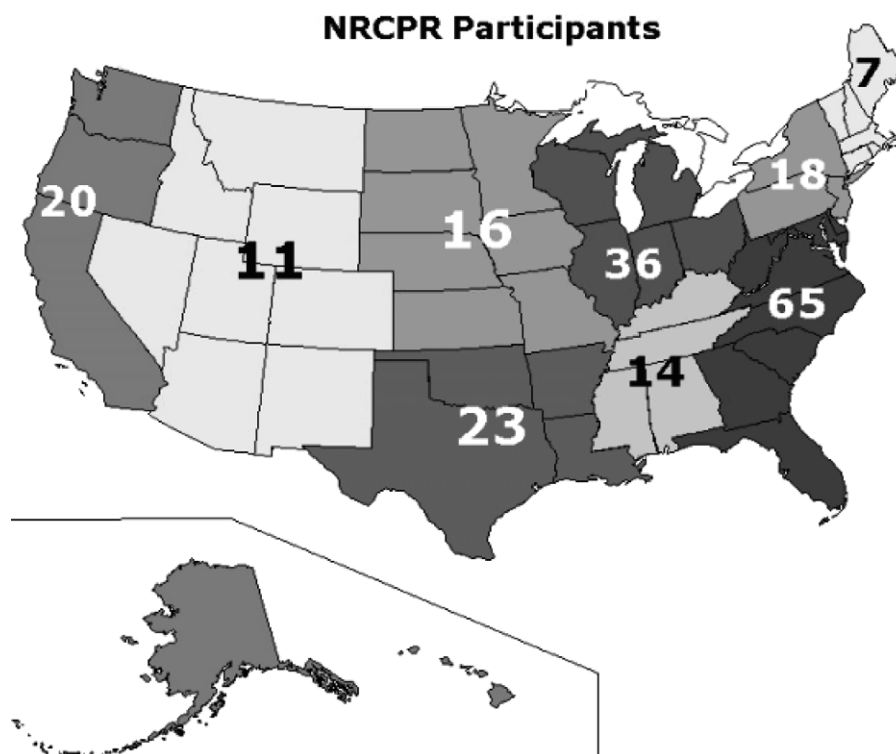


Fig. 2. Geographic distribution of NRCPR participating hospitals.

(0.17) than those with fewer than 500 adult beds (0.24) $P = 0.03$. Similarly, those with fewer than 250 beds had a significantly higher arrest rate than those adult hospitals with more than 250 beds (0.26 vs 0.19; $P = 0.01$) Only the 14 720 index cardiac arrest events are included in the analysis. Event characteristics are noted in Table 2. Treatments are noted in Table 3.

3.4. Outcomes

Overall survival for all patients and subgroups based on the initial pulseless rhythm is noted in Table 4. The characteristics of patients with an initial pulseless rhythm of VF or pulseless VT are noted in Table 5. The median self-reported time to first shock for VF/VT patients is < 1 min, with 75% reported as defibrillated within 3 min. When the first shock is delivered within 3 min, the survival rate is 38% (1037 of 2714) vs 21% (107 of 500) when delivery is reported as > 3 min ($P < 0.001$).

Neurological and functional outcomes are shown in Table 6. The average post-index event length of stay for patients who survived was 13.4 days compared with 1.5 days for those who died in the hospital. The average total length of stay for patients discharged alive was 17.9 days compared with 8.2 days for those who died in the hospital after surviving the initial resuscitation event.

4. Discussion

The NRCPR is currently the largest ongoing registry of in-hospital cardiopulmonary resuscitation. In its first 2 years, the number of cases in the registry dwarfed the number of cases previously reported by single institutions [2–35] and groups of hospitals [36]. The closest counterpart of the NRCPR was the British hospital Resuscitation study (BRESUS), reported in 1992, which registered 3765 patients in 12 metropolitan, provincial, teaching, and nonteaching hospitals across the United Kingdom [36]. Nearly one-quarter of the patients in that registry had cardiac arrest in the prehospital setting, which is likely to have had some influence on survival as well as hospital practice issues. The BRESUS registry tracked survival data for 1 year after discharge. The Brain Resuscitation Clinical Trials (BRCT), a series of three international, multicenter, prospective, randomized, controlled cerebral resuscitation studies, were conducted from 1979 through 1992 [37–41]. These trials enrolled 262, 515 and 1915 patients, respectively, but only 13–36% of these events occurred in the hospital. The BRCT studies contain detailed datasets of post-arrest management and long-term neurological follow-up, but they represent a select group of resuscitation patients who meet the eligibility criteria for participation. Although the NRCPR does not currently track survival past hospital discharge, the registry already

Table 1
Patient Characteristics

<i>N</i>	14 720
<i>Age (y)</i>	
Mean \pm S.D.	67.6 \pm 15.4
Median (25th, 75th)	70 (58, 79)
Range	18–111
<i>Sex</i>	57% M, 43% F
<i>Race/ethnicity</i>	
White	72%
Black	21%
Hispanic	5%
Other	2%
<i>Subject type</i>	
Inpatient	87%
ED	12%
Ambulatory/outpatient	0.8%
Visitor or employee	0.2%
<i>Illness category</i>	
Medical, cardiac	41%
Medical, noncardiac	39%
Surgical, noncardiac	10%
Surgical, cardiac	7%
Trauma	2%
Other	1%
<i>Pre-existing conditions</i>	
MI (this or prior admission)	36%
Respiratory insufficiency	35%
CHF (this or prior admission)	34%
Arrhythmia	29%
Renal insufficiency	29%
Diabetes mellitus	28%
Pneumonia/septicemia/other infection	26%
Hypotension/hypoperfusion	24%
Metabolic/electrolyte abnormality	18%
Baseline depression in CNS function	11%
Metastatic or hematologic malignancy	10%
None	6%
Hepatic insufficiency	6%
Acute CNS nonstroke event	4%
Acute stroke	4%
Major trauma	3%
Toxicological problem	2%
<i>Interventions in place before event</i>	
Vascular access	90%
ECG monitor	71%
Pulse oximeter	53%
Invasive airway	27%
Intravenous vaso-active agent	27%
Assisted or mechanical ventilation	24%
Intra-arterial catheter	8%
Intravenous antiarrhythmic medication	6%
Pulmonary artery catheter	5%
Pacemaker, internal	5%
Dialysis or extracorporeal filtration	3%
Chest tube	3%
Pacemaker, transcutaneous	2%
Intra-aortic balloon pump	1.6%
ICD	1.2%

CHF indicates congestive heart failure; CNS, central nervous system; and ICD, implantable cardioverter-defibrillator.

Table 2
Index event characteristics

<i>Event location</i>	
ICU	48%
Inpatient	32%
ED	11%
Diagnostic area	4%
Operating room	2%
PACU	0.5%
Outpatient	0.4%
Other	2.1%
<i>First pulseless rhythm</i>	
VF/VT	25%
PEA	30%
Asystole	36%
Unknown by documentation	9%
<i>Discovery status at time of event</i>	
Witnessed and/or monitored	86%
Witnessed and monitored	66%
Witnessed and not monitored	11%
Monitored and not witnessed	9%
Not witnessed or monitored	14%
<i>Immediate cause(s) of event (present within 1 h before arrest)</i>	
Arrhythmia	49%
Acute respiratory insufficiency or compromise	37%
Hypotension	32%
Acute myocardial infarction or ischemia	10%
Metabolic/electrolyte disturbance	10%
Acute pulmonary edema	3%
Acute pulmonary embolism	2%
Airway obstruction	2%
Toxicological problem	1%

includes data on > 14 000 adult, in-hospital cardiac arrests from > 200 US hospitals.

The primary purpose of the NRCPR is to provide a quality-improvement tool for hospitals that allows them to compare their performance against other institutions nationally and regionally. It allows participating hospitals to track their progress in improving resuscitation services over time. The NRCPR is also a vital resource for the AHA Emergency Cardiovascular Care Committee, allowing it to develop evidence-based resuscitation guidelines and to track the adoption and impact of these guidelines when new recommendations are made.

4.1. Hospital and emergency team characteristics

The NRCPR hospitals participating in this study do not represent a random sample of US hospitals, although the relationship between the characteristics of these hospitals and those of general US hospitals is known. Compared with the average US acute medical/surgical hospital, NRCPR hospitals have a larger mean number of beds (277 vs 152) [42]. A significantly greater proportion of NRCPR facilities have > 500 beds (15.7% vs 4.2%), and a smaller proportion have < 250 beds (46.5 vs 81.2%).

Table 3
Treatment characteristics and percentage of patients who received specific treatments

<i>Noninvasive airway(s)</i>	
Bag-valve-mask	67%
Mouth-to-barrier device	2.5%
Mouth-to-mouth	0.3%
<i>Invasive airway(s)</i>	
Endotracheal tube	85.9%
None	10.9%
Tracheostomy (present previously)	2.9%
Laryngeal mask airway	0.2%
Combitube	0.1%
<i>Documentation of invasive airway placement</i>	
Auscultation	48%
End-tidal carbon dioxide detection	35%
<i>Use of vasopressor during event</i>	
Epinephrine	86%
Dopamine	33%
Norepinephrine	8%
Dobutamine	4%
Vasopressin	3%
Phenylephrine	2%
<i>Nonpharmaceutical interventions</i>	
Pacemaker—transcutaneous	9%
Pacemaker—transvenous or epicardial	3%
Pericardiocentesis	2%
Open chest CPR	1%
Chest tube insertion	1%

Table 4
Overall survival rate for index events

<i>ROSC</i>	
Overall	44%
Asystole	35%
PEA	39%
VF	58%
Pulseless VT	63%
<i>Survival to hospital discharge</i>	
Overall	17%
Asystole	10%
PEA	10%
VF	34%
Pulseless VT	35%
<i>Of those who died</i>	
Declared DNAR after index event	63%
Life support withdrawn ^a	43%
Organ recovery	1.3%

^a Percentage of those declared DNAR after index event.

Although the majority of participating NRCPR institutions have an organized emergency team that responds to in-hospital cardiac arrests, 14% of hospitals do not have such a team. In addition, there is significant variation in the way in which the emergency teams are dispatched. Further investigation is needed to determine the impact of these system variables on survival.

Table 5
Treatment characteristics of VF or pulseless VT arrests

<i>N</i>	4071
<i>Defibrillation</i>	
Percentage of patients who received defibrillation	93%
<i>Total no. of shocks delivered during event and percentage of patients who received that number of shocks</i>	
1	31%
2	16%
3	16%
4–7	24%
8+	11%
Unknown	2%
<i>Time to first shock^a(min)</i>	
Mean ± S.D.	1.5 ± 3.1
Median (25th, 75th)	0 (0, 2)
Range	0–30
<i>Percentage of patients who received antiarrhythmics</i>	
At least 1 antiarrhythmic	63%
Lidocaine	49%
Amiodarone	28%
Procainamide	2%
Other	3%

^a Self-reported time to first shock as documented by the resuscitation record.

Table 6
Neurological and functional status of survivors

	Preadmission (%)	Postdischarge (%)
<i>Residence</i>		
Home	84	51.4
Other hospital	8	14
Rehabilitation center	0.6	10.8
Nursing facility	5.2	19.4
Other supervised residence	1	0.7
Hospice	0.2	2.0
Other	1.0	1.7
<i>Cerebral performance category</i>		
(1) Good cerebral performance	68	58.7
(2) Moderate cerebral disability	23.4	26.4
(3) Severe cerebral disability	6.7	11.2
(4) Coma or vegetative state	2	3.6
(5) Brain death	0	0
<i>Overall performance category</i>		
(1) Good performance	48.5	36.7
(2) Moderate disability	36.6	38.3
(3) Severe disability	13	21.4
(4) Coma or vegetative state	2	3.6
(5) Brain death	0	0

4.2. Patient characteristics

Persons who experienced cardiac arrest at NRCPR hospitals are typically male in-patients in their mid to late 60s who have been hospitalized for management of a cardiovascular or noncardiovascular medical problem. The ethnicity distribution reported is influenced by the

patient population mix of the participating hospitals and may not be applicable to all in-hospital cardiac arrests. The majority of cardiac arrests occur in-patients on medical services, with one third of events occurring on medical-cardiac services. This could have significant implications for decisions on staffing, training, and equipment placement. Despite sharing common demographic characteristics [43], there is a marked difference in patient characteristics of in-hospital and out-of-hospital cardiac arrest victims. Most in-hospital cardiac arrest victims have an intravenous line in place and are being monitored (cardiac, pulse oximeter, or both) at the time of the event. Approximately one third of these patients had an invasive airway in place at the time of cardiac arrest. These features are rarely present in the out-of-hospital cardiac arrest victim.

4.3. Event characteristics

Although half of in-hospital cardiac arrests occur in an ICU, many occur in in-patient wards. Unlike out-of-hospital cardiac arrest [43], however, an overwhelming majority (86%) of events are witnessed, monitored, or both. Even though out-of-hospital cardiac arrest patients brought to the ED with CPR in progress were excluded from this registry, the ED still accounted for 11% of all events. Diagnostic areas (e.g. radiology, CT scan, nuclear medicine) and the operating room were also important high-risk locations, contributing 4 and 2% of events, respectively. Although outpatient and nonpatient care hospital areas together accounted for <1% of all cardiac arrests; such areas pose a special challenge to hospitals since they may not be as readily accessible to hospital emergency teams as other areas. The JCAHO now requires a common standard of care for all hospital inpatient and contiguous outpatient units.

The three most common reasons for in-hospital cardiac arrest in adults are (1) cardiac arrhythmia; (2) acute respiratory insufficiency; and (3) hypotension. Although a primary arrhythmia is one of the precipitants in nearly half of adult cardiac arrests, only 25% of in-hospital cardiac arrest victims have VF or pulseless VT as the initial pulseless rhythm. This is quite surprising because VF is present in the majority of out-of-hospital cardiac arrests that occur with a continuous cardiac monitor in place [44]. Although the prevalence of VF diminishes rapidly over time [45], the fact that 86% of arrests were monitored or witnessed suggests that a delay in rhythm recognition does not explain the infrequent presence of VF/VT as the initial arrest rhythm. It may be more likely that the low incidence of VF/VT and the predominance of asystole and pulseless electrical activity (PEA) is because in-hospital cardiac arrest differs from out-of-hospital cardiac arrest in terms of mechanism and pathophysiol-

ogy. The frequency of asystole and PEA events may prompt hospitals to increase staff training and interventions focused on treatment of these rhythms. The presence of acute respiratory compromise and/or hypotension as a precipitating event in more than one third of arrests stresses the importance of prompt recognition and intervention by all in-hospital healthcare providers. Further emphasis on prearrest crisis intervention may have an impact on the progression to full arrest.

4.4. Treatment

Bag-mask ventilation was used during the resuscitation attempt in more than two thirds of patients. Eleven percent of patients never received an invasive airway during the resuscitation attempt. The American Society of Anesthesiology and the American College of Emergency Physician guidelines recommend confirmation of invasive airway placement by some objective means such as capnography or an esophageal detector device [46,47]. In the NRCPR population, only 35% of adult cardiac arrest patients had invasive airway placement documented as confirmed by any method of end-tidal carbon dioxide detection. This suggests that either documentation of this element needs improvement or hospitals need to implement use of end-tidal carbon dioxide detection technology more widely as part of their quality improvement process.

The AHA advanced cardiac life support guidelines state that either epinephrine (adrenaline) or vasopressin can be used as a first-line vasopressor after defibrillation attempts for adult victims of cardiac arrest associated with persistent VF. Interestingly, vasopressin accounted for only 3% of vasopressor use in NRCPR patients. This relatively slow adoption of new, alternative drug therapy may demonstrate the need for additional education of hospital staff about the availability and potential usefulness of vasopressin in certain arrest populations. Conversely, hospital staff may simply be more experienced and comfortable with use of epinephrine. The NRCPR dataset can be used potentially to track the change in vasopressor drug use over time and eventually correlate this with outcome in a large in-hospital population.

4.5. Survival

Over the past several decades there have been numerous advances in both the process and practice of resuscitation that have translated into improved outcomes in the prehospital setting [43,48–51]. Emergency medical services systems, following models developed by the AHA, have developed coordinated strategies to strengthen the community chain of survival for responding to cardiovascular emergencies [52]. Automated external defibrillators (AEDs) are now used by a variety

of first responders (police, firefighters, security officers, airline flight attendants, and trained laypersons) in many communities to provide early defibrillation while awaiting the arrival of paramedics [49–51,53–59].

In contrast, the process of in-hospital resuscitation has remained relatively unchanged, and survival from in-hospital cardiac arrest has appeared to remain stagnant for almost 40 years [2–35]. These results from the NRCPR seem to corroborate that little progress has been made, with only 17% of all adult cardiac arrest patients surviving to hospital discharge. It is not clear, however, whether the static survival rate represents lack of progress or the net effect of multiple offsetting events over time, including different variable definitions, different mixes of pulseless arrhythmias, different inpatient acuity levels, advances in patient monitoring and treatment, improved training of physicians and nurses in basic and advanced cardiac life support, more frequent use of the ‘Do Not Attempt Resuscitation (DNAR)’ designation, and formal procedures for terminating resuscitation and withdrawing life support.

Moreover, use of the term ‘overall survival’ to describe outcome may be misleading. The 35% survival rate from VF/VT that occurs in only 25% of arrests is diluted by the 10% survival rate for asystole and PEA that occurs in 66% of arrests. Future descriptions of in-hospital cardiac arrest outcome should be based on each of the initial arrest rhythms, not overall survival from all arrest rhythms combined.

Nearly two thirds of VF/VT arrest patients received at least one antiarrhythmic drug. Both the ARREST (Amiodarone in the Out-of-Hospital Resuscitation of Refractory Sustained Ventricular Tachyarrhythmia) [60] and ALIVE (Amiodarone vs Lidocaine in Pre-Hospital Refractory Ventricular Fibrillation Evaluation) [61] clinical trials of cardiac arrest in the prehospital setting demonstrate improved survival to hospital admission in shock-refractory VF patients who received amiodarone. The CALIBRE trial demonstrated that routine use of lidocaine for treatment of VF/VT arrests is no better than placebo [62]. The NRCPR data show that lidocaine is used almost twice as often as amiodarone in the treatment of in-hospital VF/VT arrest. Registry data can be used to track antiarrhythmic drug patterns over time and correlate them with survival for in-hospital cardiac arrest. The current NRCPR dataset is not powered to determine survival differences between these two antiarrhythmics.

Valenzuela et al. [49] reported a 74% rate of survival to hospital discharge from out-of-hospital cardiac arrest when on-site lay first responders provide defibrillation in < 3 min. Caffrey et al. [63] found an overall survival rate of 66% in victims of VF/VT arrests in the Chicago airport system. Data from witnessed VF arrest during cardiac rehabilitation [64–66,65] or induced in the

electrophysiology laboratory [67] report survival rates of > 90% and nearly 100%, respectively, with prompt defibrillation. On the basis of available data to date, the reported times to first shock in the NRCPR registry are inconsistent with the poor survival rate of only 38% when the first shock is delivered within 3 min. This may represent a problem with accurate documentation of timing of events during in-hospital resuscitation, or it may reflect the impact of acute comorbidities or other pathophysiological factors specific to this population.

Although survival is better for patients whose initial rhythm is VF/VT, the fact that outcome is improved when the first shock is delivered within 3 min suggests that there is an opportunity to improve provision of early defibrillation in the hospital. In the ICU, nurses typically initiate CPR for cardiac arrests and provide defibrillation and initial drug therapy following standing orders. Outside the ICU, nurses and other first responders perform CPR, but they typically must await the arrival of the emergency team physician to provide defibrillation. In-hospital use of AEDs by non-ICU nurses and other first responders trained in BLS was described in 1995 [68,69]. Seven years later, only 33% of NRCPR hospitals report some form of AED technology in any part of the facility. The current NRCPR dataset does not identify the specific type of AED (i.e. stand-alone vs shock-advisory conventional defibrillators), nor does it specify which areas of the hospital have an AED capability. The dataset also does not indicate whether a BLS-trained or an ACLS-trained responder used the AED. Further investigation is needed to determine the circumstances surrounding the use of automated defibrillation in hospitals.

Although asystole and PEA are often considered ‘fatal rhythms,’ these NRCPR data demonstrate that \approx 10% of patients with these rhythms survive with good neurological outcomes. Our results may represent an improvement that comes with increased use of monitoring and contrasts with prior work, including a meta-analytic review by Saklayen et al. [26] that revealed that 5.3 and 4.2% of patients with asystolic and PEA arrests, respectively, were discharged from the hospital alive. Our survival rates for PEA and asystole were also appreciably higher than the 7.2% survival rate for witnessed PEA and asystole recently reported by Brindley et al. [70].

4.6. Neurological and functional outcome

More than half of those who survived a pulseless index cardiac arrest event were discharged home. It is of concern that > 30% of survivors were discharged to either a rehabilitation center or a skilled nursing home when less than 6% had lived in such a facility before their arrest. Cerebral and occupational performance category information was not available for all patients;

however, it is reassuring that 86% of patients with a Cerebral Performance Category-1 (CPC-1) at the time of admission had a CPC-1 at discharge.

A large (63%) number of patients with ROSC after an in-hospital cardiac arrest are declared DNAR, and 44% of those have life support withdrawn, whereas only 8% are declared clinically brain dead. The aggressiveness with which an individual hospital withdraws care and withholds future resuscitation attempts has significant bearing on both individual and aggregate survival data and can have tremendous impact on clinical trials, with survival to hospital discharge as a primary end point.

The average hospital length of stay after an index event is nearly 2 weeks for survivors and <2 days for those who die in the hospital. Further investigation is needed to evaluate clinical factors and practice patterns that have an impact on these data.

4.7. Study limitations

The limitations of the NRCPR include (1) the fact that registry hospitals, although numerous, may not be representative of all US hospitals; (2) there is no on-site validation of data collection, although processes for data checking, data management certification, and data cleaning are ongoing; (3) there is no long-term follow-up after hospital discharge. In addition, although medication use is tracked, the NRCPR does not attempt to assess clinical appropriateness, dose, or sequence for each medication. These limitations are similar to those of other contemporary in-hospital registries, such as the National Registry of Myocardial Infarction (NRMI) [71,72].

5. Conclusions

The NRCPR is currently the largest multi-institutional, standardized database of in-hospital resuscitation events. It provides data on CPR process and outcome, allowing participants to evaluate their resuscitation performance critically in comparison with other institutions and to track secular trends over time. The registry provides important observational data that can be used by the AHA and other organizations to improve the base of evidence for future resuscitation guidelines and provide insight for areas of future resuscitation research.

Acknowledgements

The authors wish to thank the AHA, Dr Jerry Potts, Mr Michael C. Bell, and Mr Ted S. Borek, Jr., for their unwavering support in the development of the NRCPR; Tri-Analytics, Inc, especially Mr Scott Carey and Mr

Ted Bemb, for providing technical and statistical management of the registry and data; and all participating NRCPR hospitals for helping to improve the process and outcomes of resuscitation in the hospital.

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