ORIGINAL RESEARCH

National Institutes of Health–Funded Cardiac Arrest Research: A 10-Year Trend Analysis

Ryan A. Coute, BS; Ashish R. Panchal, MD, PhD; Timothy J. Mader, MD; Robert W. Neumar, MD, PhD

Background—Cardiac arrest (CA) is a leading cause of death in the United States, claiming over 450 000 lives annually. Improving survival depends on the ability to conduct CA research and on the translation and implementation of research findings into practice. Our objective was to provide a descriptive analysis of annual National Institutes of Health (NIH) funding for CA research over the past decade.

Method and Results—A search within NIH RePORTER for the years 2007 to 2016 was performed using the terms: "cardiac arrest" or "cardiopulmonary resuscitation" or "heart arrest" or "circulatory arrest" or "pulseless electrical activity" or "ventricular fibrillation" or "resuscitation." Grants were reviewed and categorized as CA research (yes/no) using predefined criteria. The annual NIH funding for CA research, number of individual grants, and principal investigators were tabulated. The total NIH investment in CA research for 2015 was calculated and compared to those for other leading causes of death within the United States. Interrater reliability among 3 independent reviewers for fiscal year 2015 was assessed using Fleiss κ. The search yielded 2763 NIH-funded grants, of which 745 (27.0%) were classified as CA research (κ=0.86 [95%CI 0.80-0.93]). Total inflation-adjusted NIH funding for CA research was $35.4 million in 2007, peaked at $76.7 million in 2010, and has decreased to $28.5 million in 2016. Per annual death, NIH invests ≈$2200 for stroke, ≈$2100 for heart disease, and ≈$91 for CA.

Conclusions—This analysis demonstrates that the annual NIH investment in CA research is low relative to other leading causes of death in the United States and has declined over the past decade. **(*J Am Heart Assoc*. 2017;6:e005239. DOI: 10.1161/JAHA.116.005239.)**

Key Words: cardiac arrest • National Institutes of Health • research funding

Cardiac arrest (CA) is the third leading cause of death in the United States,[1,2] claiming the lives of over 450 000 individuals annually.[3-5] The estimated survival rates of those treated for in-hospital CA and out-of-hospital CA with any initial rhythm are ≈24% and 11%, respectively.[3] In order to improve outcomes for this lethal condition and to decrease its burden on society, funding for CA research and translation of findings into clinical practice is critical.[2,6] Yet, the number of CA randomized controlled trials, a marker of research and innovation in the field, is low with fewer than 5 published yearly throughout the world over the past 2 decades.[7]

Unlike other diseases (eg, stroke and heart failure), CA research rarely receives external funding from pharmaceutical or cardiovascular device manufacturers and instead relies heavily on funding from governmental agencies such as the National Institutes of Health (NIH).[6] The NIH research portfolio, which provides support details for more than 250 disease areas and is updated annually, includes no data specific to CA funding.[2] Therefore, data on the NIH investment in CA research and number of funded CA principal investigators are largely unknown.

In an effort to fill this knowledge gap, we performed a simple descriptive analysis of NIH-funded CA research over the past decade. The overall goals were to understand the trend in CA research funding over time and to compare the NIH investment in CA research to that of other leading causes of death in the United States.

Methods

NIH Funding for CA Research

A search within the NIH Research Portfolio Online Reporting Tools Expenditures and Results (NIH RePORTER) database[8]

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Clinical Perspective

What Is New?

- We performed a descriptive analysis of NIH-funded cardiac arrest research over the past decade.
- The results demonstrate the annual NIH investment in cardiac arrest research is low relative to other leading causes of death in the United States, and has declined over the past decade.

What Are the Clinical Implications?

- These results should help inform the debate regarding optimal funding for cardiac arrest research in the United States.

for the years 2007 to 2016 was performed using the following search term string: "cardiac arrest" or "cardiopulmonary resuscitation" or "heart arrest" or "circulatory arrest" or "pulseless electrical activity" or "ventricular fibrillation" or "resuscitation." All grants from non-NIH funding sources including the US Food and Drug Administration, US Department of Veterans Affairs, and the Agency for Health Care Research and Quality were excluded from the analysis. Grants were individually reviewed and categorized as CA research (yes/no) using predefined inclusion/exclusion criteria.

Grants were classified as CA research if they met any of the following criteria: (1) studies designed to improve the treatment/outcomes of prehospital or in-hospital CA; (2) use of a CA model; (3) use of a global ischemic brain injury model; (4) study of the mechanism of ventricular fibrillation, pulseless ventricular tachycardia, pulseless electrical activity, or asystole; (5) study of the mechanism of therapeutic hypothermia for CA; or (6) funding for resuscitation centers or group collaborations that list CA research as a specific aim.

Grants were classified as not CA research according to the following guidelines: (1) study of channelopathies or arrhythmia research other than ventricular fibrillation, pulseless ventricular tachycardia, pulseless electrical activity, or asystole; (2) cardioplegia research; (3) implantable cardioverter defibrillator research; (4) trauma unless traumatic arrest is specifically mentioned; or (5) not CA research.

The data were directly exported from the NIH RePORTER search to a Microsoft Excel file. The data available included the grant title, contact principal investigator, investigator affiliation, award amount, funding agency (ie, National Heart, Lung, and Blood Institute, National Institute of Neurological Diseases and Stroke, etc), award type (ie, newly funded, competing renewal, and noncompeting renewal grants), and funding mechanism. As a measure of the CA research pipeline, the number of individual trainee grants was also tabulated and defined as K awards (K01, K08, K22, K23, and K99), F awards (F30, F31, and F32), and R awards (R00). The data used in this analysis include publicly available grant information from NIH RePORTER and thus did not require approval by the University of Michigan Institutional Review Board.

NIH Research Investment for Leading Causes of Death

Data for the top 10 leading causes of death in the United States were obtained from the *National Center for Health Statistics 2015 Health Report*.[9] The annual NIH Categorical Spending Report is available online and is titled, *Estimates of Funding for Various Research, Conditions, and Disease Categories*.[10] NIH research funding data for the leading causes of death were obtained from the *Estimates of Funding for Various Research, Conditions, and Disease Categories* for funding year 2015.[10] Estimates for the number of deaths due to CA (both in-hospital and out-of-hospital CA) were extrapolated from the *AHA Heart Disease and Stroke Statistics—2015 Update*.[11] From this information, the NIH research investment, expressed as dollars per annual death, was calculated for each disease.

Primary Data Analysis

The data were analyzed descriptively. The primary outcome measure was inflation-adjusted annual funding of CA research in millions of dollars. Inflation adjustment was performed for funding years 2007 through 2015 using the consumer price index inflation calculator provided by the US Bureau of Labor Statistics.[12] Secondary outcome measures included number of individual principal investigators funded per year (defined as contact principal investigator), total number of funded grants per year, and the NIH investment in CA research (defined as dollars per annual death) compared to other leading causes of death. For funding year 2015, we estimated interrater reliability among 3 independent reviewers using Fleiss κ for multiple raters using the MAGREE macro in SAS (SAS 14.1, 2015; SAS, Cary, NC). The MAGREE macro is based on methods developed by Fleiss et al.[13]

Results

The NIH RePORTER database search yielded a total of 2845 grants, 82 of which were excluded due to a non-NIH funding source. Of the remaining 2763 NIH-funded grants, 745 (27.0%) met study inclusion criteria and were classified as CA research (Figure 1). Of the total search result, 73% of NIH grants were excluded from the evaluation. Fleiss κ for interrater reliability was 0.86 (95%CI 0.80–0.93), indicating good inter-rater agreement.

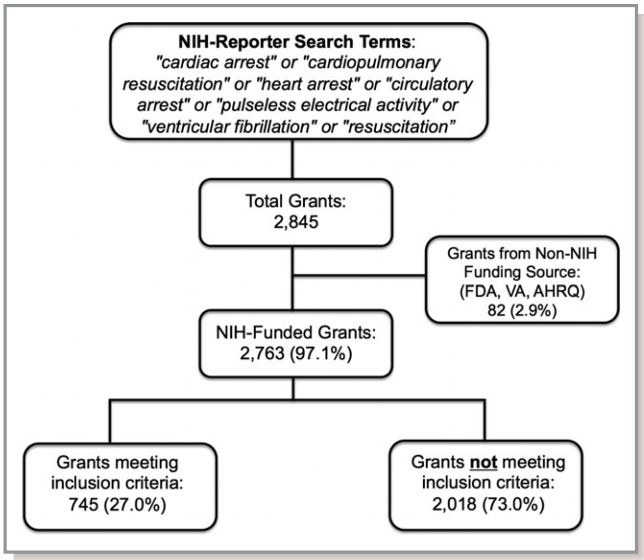

Figure 1. Flow diagram of grants extracted from the National Institutes of Health RePORTER database.

The total CA funding in the index year of 2007 was \$30.5 million (inflation-adjusted \$35.4 million), and declined to \$28.5 million in 2016 (Figure 2). Maximum annual funding during the study period occurred in 2010 (\$69.7 million; inflation-adjusted \$76.7 million), with \$42.9 million supporting the Resuscitation Outcomes Consortium (ROC) Data Coordinating Center. Of particular note, a decrease of over \$12 million was observed from 2015 to 2016, 80% of which can be attributed to the cessation of ROC funding. A nearly 10-fold increase in pediatric CA research was observed from 2007 (\$0.95 million; inflation-adjusted \$1.1 million) to 2016 (\$9.6 million).

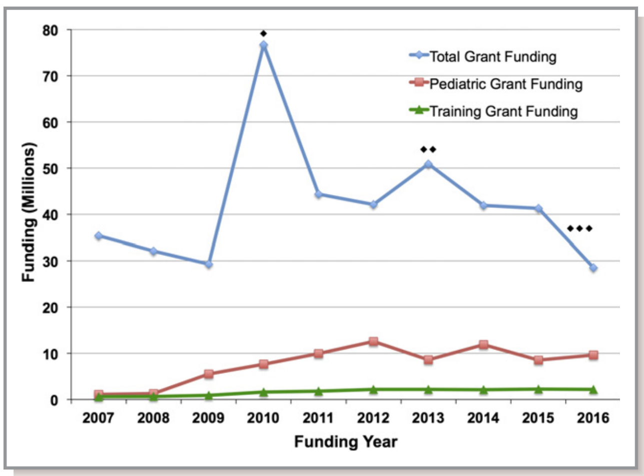

Figure 2. National Institutes of Health annual funding of cardiac arrest research. ♦ \$42.9 million ROC Data Coordinating Center, which supported both trauma and cardiac arrest studies. Proportion that specifically supported cardiac arrest studies is not reported in the RePORTER database. ♦♦ \$21.9 million ROC data coordinating center, which supported both trauma and cardiac arrest studies. Proportion that specifically supported cardiac arrest studies is not reported in the RePORTER database. ♦♦♦ Cessation of ROC funding accounts for ≈80% of the decrease in 2016 funding. Individual training grants defined as K awards (K01, K08, K22, K23, and K99), F awards (F30, F31, and F32) and R awards (R00). Data for funding years 2007 through 2015 are adjusted for inflation. ROC indicates Resuscitation Outcomes Consortium.

The NIH investment in CA research for the 2015 funding year (\$40.8 million) represents ≈0.19% of the total NIH research grant funding for 2015 (\$21.2 billion),[14] while stroke and heart disease represent 1.4% and 5.9%, respectively. As illustrated in Figure 3, the NIH investment per annual death equates to ≈\$2200 for stroke, ≈\$2100 for heart disease, and ≈\$91 for CA.

Table presents data on the number of total grants funded, CA principal investigators, newly funded grants, and trainee grants by year. From 2007 to 2016, an increase was observed in the number of pediatric CA grants (from 5 to 17) and individual trainee CA grants (from 5 to 15). Little to no growth was observed in the number of funded investigators (from 54 to 60), newly funded grants (from 12 to 17), and overall grants funded (from 70 to 65).

Discussion

In this evaluation, when adjusted for inflation, the total NIH funding for CA research in 2016 was nearly 7 million dollars less than a decade previous in 2007. Although CA is the third leading cause of death in the United States,[1] annual NIH funding for research to improve outcomes is relatively low. There were influxes of funding at different times in the decade in support of the ROC with a large decrease in funding in fiscal year 2016 when ROC funding was discontinued. In 2015 the annual NIH investment in CA research was \$91 per annual US CA death.

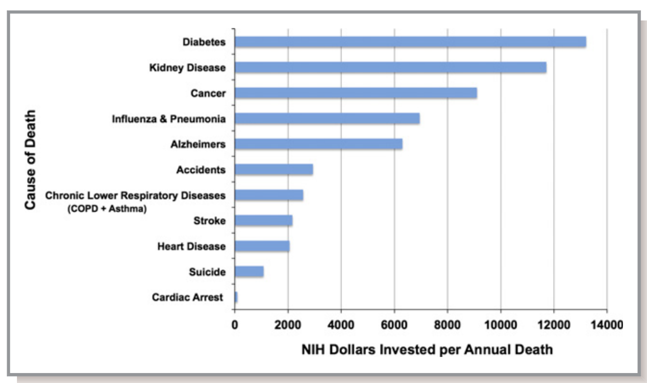

Figure 3. National Institutes of Health investment in 2015 for leading causes of death. Data for leading causes of death obtained from *National Center for Health Statistics 2015 Health Report*, Table 19.[9] Data for National Institutes of Health research funding obtained from the NIH portfolio on Research, Condition, and Disease Category for 2015.[10]

Table. Funded Grants and Associated Types and Descriptions Summarized From 2007 to 2016

Grants		Funding Year									
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	Total, n	70	64	67	79	86	82	72	79	81	65
	Pediatric specific, n (%)	5 (7.1)	5 (7.8)	9 (13.4)	10 (12.7)	13 (15.1)	16 (19.5)	14 (19.4)	17 (21.5)	16 (19.8)	17 (26.2)
Funded Investigators*, n		54	58	53	68	77	74	62	72	75	60
Funding Institute, n (%)	NHLBI	37 (52.9)	37 (57.8)	35 (52.2)	44 (55.7)	46 (53.5)	47 (57.3)	39 (54.2)	45 (57.0)	46 (56.8)	33 (50.7)
	NINDS	21 (30.0)	15 (23.4)	21 (31.3)	24 (30.4)	23 (26.7)	22 (26.8)	21 (29.2)	22 (27.8)	24 (29.6)	25 (38.5)
	Other	12 (17.1)	12 (18.8)	11 (16.4)	11 (13.9)	17 (19.8)	13 (15.9)	12 (16.7)	12 (15.2)	11 (13.6)	7 (10.8)
Research setting, n (%)	University	65 (92.9)	60 (93.8)	64 (95.5)	75 (94.9)	83 (96.5)	76 (92.7)	70 (97.2)	74 (93.7)	78 (96.3)	64 (98.5)
	Industry	5 (7.1)	4 (6.3)	3 (4.5)	4 (5.1)	3 (3.5)	6 (7.3)	2 (2.8)	5 (6.3)	3 (3.7)	1 (1.5)
Grant type, n (%)	Newly funded grants	12 (17.1)	13 (20.3)	14 (20.9)	15 (19.0)	16 (18.6)	11 (13.4)	11 (15.3)	16 (20.3)	16 (19.8)	17 (26.2)
	Continuing	58 (82.9)	51 (79.7)	53 (79.1)	64 (81.0)	70 (81.4)	71 (86.6)	61 (84.7)	63 (79.7)	65 (80.2)	48 (73.8)
Individual trainee grants†, n (%)		5 (7.1)	6 (9.4)	7 (10.4)	13 (16.5)	15 (17.4)	17 (20.7)	16 (22.2)	15 (19.0)	16 (19.8)	15 (23.1)
Study model, n (%)	Human subjects	29 (41.4)	24 (37.5)	20 (29.9)	34 (43.0)	36 (41.9)	39 (47.6)	35 (48.6)	37 (46.8)	39 (48.1)	32 (49.2)
	Nonhuman subjects	41 (58.6)	40 (62.5)	47 (70.1)	45 (57.0)	50 (58.1)	43 (52.4)	37 (51.4)	42 (53.2)	42 (51.9)	33 (50.8)

NHLBI indicates National Heart, Lung, and Blood Institute; NINDS, National Institute of Neurological Disorders and Stroke.
*Includes only contact principal investigator.
†Includes K awards (K01, K08, K22, K23, K99), F awards (F30, F31, F32), and R award (R00).

The results of this analysis are consistent with previous assessments of NIH funding for CA research. Ornato et al reviewed CA grants funded by the NIH National Heart, Lung, and Blood Institute between 1985 and 2009. During this time period, they noted 257 funded grants in NIH RePORTER through a primary keyword search of "heart arrest and resuscitation."[6] They reported a large disparity from other cardiovascular diseases in the number of funded projects per 10 000 annual deaths, with myocardial infarction having 439 grants, stroke with 294 grants, heart failure with 349 grants, and CA with only 8 funded grants.[6] More recently, an estimate of total CA research funding was made as part of the Institute of Medicine report using NIH RePORTER. With the search terms "cardiac arrest" and "resuscitation science," NIH grants were identified with an estimated total funding in 2013 of $107.7 million.[2] In both of these studies the calculated amount of funding was likely overestimated.[2,6] These evaluations used nonspecific search terms (ie, resuscitation) identifying both CA grants and those not studying CA. In the current analysis, when strict inclusion and exclusion criteria were used requiring inspection of the individual grant descriptions, only 27% of all grants identified by initial search terms were CA grants. These grants account for the overall funding of 28.5 million dollars for CA in 2016.

Our analysis indicates that NIH CA research funding is low per annual death compared with other leading causes of death (Figure 3). CA funding as calculated in this evaluation was $91 per death in 2015. This is significantly lower than other leading causes of death (Figure 3). For example, the investments in diabetes mellitus, kidney disease, and cancer are ≈$13 000, $12 000, and $9000 per annual death, respectively. Another time-sensitive condition, stroke, has an investment of $2200 per annual death. Using total NIH funding for 2016, assuming no change in the incidence of CA, we expect the NIH investment in CA research to further drop to $63 per death.

It is important to note that the number of individual training grants increased from 5 (7% of all grants) in 2007 to 15 (23% of all grants) in 2016. Although this suggests a growing pipeline of early career investigators, it has yet to translate into an increased number of funded principal investigators or funded grants. Another area where a steady increase in funding was noted was grants related to CA in pediatrics. The number of funded grants that had a pediatric focus increased steadily over the last decade from 5 (7% of all grants) in 2007 to 17 (26% of all grants) in 2016 (Table).

Limitations

Our study does not answer important questions about the cause of relatively low and declining funding for CA research. Importantly, our results do not include numbers of grant applications submitted and funding rates. Unfortunately, these data are not publically available and are not released by the NIH. The lack of growth in number of principal investigators funded by NIH to perform CA research does suggest an inadequate pool of investigators focused on this disease. Furthermore, we also did not evaluate funding from other federal sources, foundations, or industry. We focused on NIH funding because NIH is the primary governmental funder of biomedical research in the United States. However, there is no evidence that funding of CA research from other sources is different for CA compared to other diseases.

NIH funding per annual death may not be the best metric for CA research funding because it is the final common pathway of death and overlaps with many other disease states. However, a similar argument could be made about the overlap between other leading causes of death such as diabetes mellitus and heart disease or chronic respiratory disease and pneumonia, all of which are reported independently by Centers for Disease Control and Prevention as causes of death. An alternative approach would be to compare funding per disability-adjusted life year. However, to our knowledge, a reliable estimate of the annual disability-adjusted life years lost due to CA in the United States is currently not available.

Additional limitations include the fact that data were extracted from the NIH RePORTER software and depend on the accurate reporting of the grants funded per fiscal year by the NIH. Data associated with the burden of disease and the funding associated with each of the leading causes of death are from the Centers for Disease Control and Prevention and NIH research portfolios and depend on accuracy of these reports. The funding for the ROC supported both trauma and CA research trials. NIH RePORTER does not provide details to delineate funding specific to CA for ROC grants. With this in mind, the final estimates of total annual funding may be overestimated. The inclusion criteria used in this evaluation were liberal to enable capture of all research associated with CA. Included in our criteria were global ischemia models and asphyxia models of CA. We limited our evaluation of interrater reliability to a single funding year. Although we utilized 3 reviewers in this evaluation, and the interrater reliability demonstrated good reliability, extraction errors in data collection are possible.

Conclusion

NIH's mission is to seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce illness and disability. This analysis demonstrates that the annual NIH investment in CA research is low relative to other leading causes of death in the United States and has declined over the past decade. Although these results do not elucidate the cause of this apparent funding disparity, they should inform the debate regarding optimal funding for CA research in the United States.

Author Contributions

Coute designed the study, analyzed the data, and co-wrote the manuscript. Panchal and Mader analyzed the data and co-wrote the manuscript. Neumar participated in study design, data analysis, and manuscript writing. All authors have read and approved of the manuscript.

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