



Twenty Years After the EMS Research Agenda: Trends in Emergency Medical Services Publications and Research Funding

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Study objective: Since its publication in 2001, the National EMS Research Agenda has brought attention to a relative paucity of emergency medical services (EMS)-specific research and has called for an increase in funding and infrastructure to support EMS research. We investigated the trends in EMS-specific publications and National Institutes of Health (NIH)-funded research grants in the 20 years since this landmark publication.

Methods: We performed a structured PubMed search of English-language citations from 2001 to 2020 to identify publications with populations, settings, or topics related to EMS care, education, or operations. Publications in trade journals and studies not involving humans were excluded. We also queried NIH Research Portfolio Online Reporting Tools Expenditures and Results (RePORTER) using a similar structured search. Titles, keywords, and abstracts were reviewed. Descriptive statistics were calculated, and nonlinear trends were described using segmented regression models.

Results: A total of 183,307 references met the search criteria in PubMed, and 4,281 grants were identified in NIH RePORTER. After removing duplicates, 152,408 titles were screened, with 17,314 (11.5%) included. EMS-related publications increased from 419 in 2001 to 1,788 in 2020, a 327% increase, compared with a 197% increase in total PubMed publications. There was a statistically significant nonlinear (J-shaped) increase in EMS publications after 2007. There were 1,166 funded EMS-related NIH grants, with a 469% increase from 2001 to 2020 compared with an 18% increase in overall NIH awards.

Conclusion: Although total publications have doubled in the United States over the past 20 years, EMS-specific research has more than tripled and the number of funded EMS research grants has increased nearly 5-fold. Future evaluation should examine the quality of this research and its application to clinical practice. [Ann Emerg Med. 2023;82:94-100.]

Please see page 95 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Published in 2001, the National EMS Research Agenda brought attention to a relative paucity of emergency medical services (EMS)-specific research and called for an increase in funding and infrastructure to support EMS research.¹ The EMS Research Agenda highlighted several salient barriers to EMS research, including a lack of skilled researchers, poor translation of EMS research into clinical practice, deficient linkages of EMS data to patient-centered outcomes, process challenges with informed consent, and inadequate research funding. Further complicating the issue is an increasing number of case reports and case series of variable quality, compared with studies with more rigorous methodology.² However, despite these challenges, EMS research is essential for advancing the field and

improving the health and safety of our communities and our patients.

Importance

High-quality EMS research has driven significant improvements in patient outcomes for a variety of conditions, including out-of-hospital cardiac arrest (OHCA), stroke, and trauma.³ Additionally, specific EMS interventions have seen substantial advancement in recent years, including improvements in out-of-hospital airway management and seizure care.^{4,5} However, although several high-profile studies have garnered much attention, the overall breadth and scope of current research in EMS remain unclear.⁶ Furthermore, although the EMS Research Agenda highlighted the need for increased funding, there have been few attempts to quantify the overall investment in EMS research.

Editor's Capsule Summary*What is already known on this topic*

EMS research can drive improvements in patient care but was less well matured and funded in the first decades after development.

What question this study addressed

What is the volume and support for EMS research between 2002 and 2020?

What this study adds to our knowledge

Using a scoping review, the authors noted EMS-related publications doubled over the past 20 years. NIH support increased with five-fold in grants awarded and six-fold in distributed funding.

How this is relevant to clinical practice

EMS care has an increasing evidence base and more federal competitive funding.

Goals of This Investigation

We aimed to investigate the quantitative trends in EMS-related research publications and federal funding over the 20 years since the publication of the EMS Research Agenda.

MATERIALS AND METHODS**Study Design and Setting**

We conducted a 2-part evaluation of EMS research output: (1) a bibliometric evaluation of biomedical literature indexed in PubMed from 2001 to 2020 to identify publications that were EMS-related and (2) a similar structured search of funded grants from the National Institutes of Health (NIH) Research Portfolio Online Reporting Tools Expenditures and Results (RePORTER) database to identify EMS-related NIH funding. We defined an EMS-related study as a study in which the population, setting, or topic involved EMS care, education, or operations, including studies on topics ranging from clinical care to the EMS workforce. An overall search for all PubMed citations was also performed for each year of the study period.

Search Strategy

Following a similar approach to a scoping review, we developed a structured search of National Library of Medicine Medical Subject Heading terms in coordination with a medical librarian (M.B.B.), including search terms relevant to EMS

medicine (Appendix E1, available at <http://www.annemergmed.com>). The literature search was performed in June 2021 with a publication date range of January 1, 2001, to December 31, 2020. We limited the search to publications in English and excluded citations with a publication date outside the period of interest (eg, those with an electronic publication date of 2020 but final publication date of 2021 were excluded) and publications not in a peer-reviewed journal (eg, known EMS trade journal or without documented journal name). Studies not involving human subjects were also excluded during citation screening. Duplicate records were removed, and data were entered into a systematic review platform (Covidence) for screening.

We used a similar search strategy for NIH RePORTER (Appendix E2, available at <http://www.annemergmed.com>), searching in fiscal years 2001 to 2020 for grants from any funding mechanism and any agency, institute, or center. We searched project titles, terms, and abstracts for the same keywords used in the previously described PubMed search strategy. Multiyear grants were included for each year in which they had funding. Between 2007 and 2018, there was a mean increase of 74 per year (95% CI 67 to 81), and the mean increase was 199 per year (95% CI 148 to 250) after 2018 (Table E1, available at <http://www.annemergmed.com>).

Screening and Categorization

The title and abstract of each citation were screened to determine whether they met the inclusion criteria of being EMS-related. Three research assistants (E.C., S.M., H.J.S.) underwent a 2-hour training session facilitated by EMS researchers (S.A.G., R.E.C.) and a research librarian (M.B.B.) on coding methodology. The first 100 citations were contemporaneously reviewed in duplicate to ensure proficiency. The three research assistants and two EMS researcher investigators reviewed all the relevant titles and abstracts, with approximately 20% of citations screened in duplicate. Data abstracted included journal, EMS-related, human subjects, and English language. Citations were excluded during screening if the study did not involve humans (eg, a basic science, laboratory study, or animal study) or if the setting was solely the emergency department and did not explicitly involve EMS care. NIH grant records were reviewed by one investigator (R.E.C.) using similar criteria.

Included citations from 2001, 2010, and 2020 were then extracted for second-level screening and categorization of topic area and publication type. Categories were

determined a priori. Two investigators with content expertise in the profession of EMS (S.A.G., R.E.C.) reviewed the titles and abstracts to assign each to one or more categories from the following: airway, case study, disaster, education, geriatrics, mobile integrated health, OHCA, opioids, pediatrics, position statement, review (including systematic reviews and meta-analyses), sepsis, cardiac (including ST-segment elevation myocardial infarction and acute coronary syndrome, excluding OHCA), stroke, trauma, workforce, and workforce health and safety.

Analysis

For abstracts that underwent duplicate screening, we calculated interrater reliability using Gwet's agreement coefficient 1 (AC1), using the Landis and Koch⁷ guidelines for interpretation of the κ and AC1 values (eg, 0.81 to 1.00 indicated nearly perfect agreement). We calculated descriptive statistics to describe the change in EMS-related publications, unique journals in which EMS-related publications were published, and EMS-related NIH grant funding. To quantify change over time, we calculated the percentage change from 2001 to 2020. There was clear evidence of a nonmonotonic and nonlinear trend; thus, we further calculated the increase or decrease (ie, slope) and inflection points in trends using segmented regression. We used joinpoint regression with weighted least-squares regression models, following recommendations for quantifying trends.⁸ Based on guidelines for the minimum observations per joinpoint,

we allowed for up to 2 inflection points using a Monte Carlo permutation method with Bonferroni adjustment to determine whether there was a statistically significant change in slope at the $P < .05$ level.⁹ Using the breakpoints identified, we fit regression models for each segment. The slope, 95% confidence interval (CI), and standardized coefficient were calculated and reported for each segment.

RESULTS

A total of 183,307 references met the search criteria. After removing 30,899 duplicate records, 152,408 titles were screened. Of these, 2,752 were excluded for various reasons (Figure 1). A final total of 17,513 (11.5%) articles were included for analysis. Of the original sample, 23.3% underwent duplicate screening, with a conflict rate of 5.3% and Gwet's AC1 of 0.90, indicating nearly perfect interrater agreement.

The number of journals publishing EMS-related content also increased significantly from 130 in 2001 to 513 in 2020, a 295% increase (Table 1 and Figure 2A). EMS-related publications increased significantly from 419 publications in 2001 to 1,788 publications in 2020, a 327% increase (Figure 2B). Total PubMed citations also increased significantly during the study period from 547,572 to 1,627,353, a 197% increase (Figure 2C). There was a statistically significant nonlinear (J-shaped) increase in EMS publications after 2007 (Figure 2B, D). Before 2007, there was a mean increase of 14 per year (95% CI, 0.4 to 29). Between 2007 and 2018, there was a mean

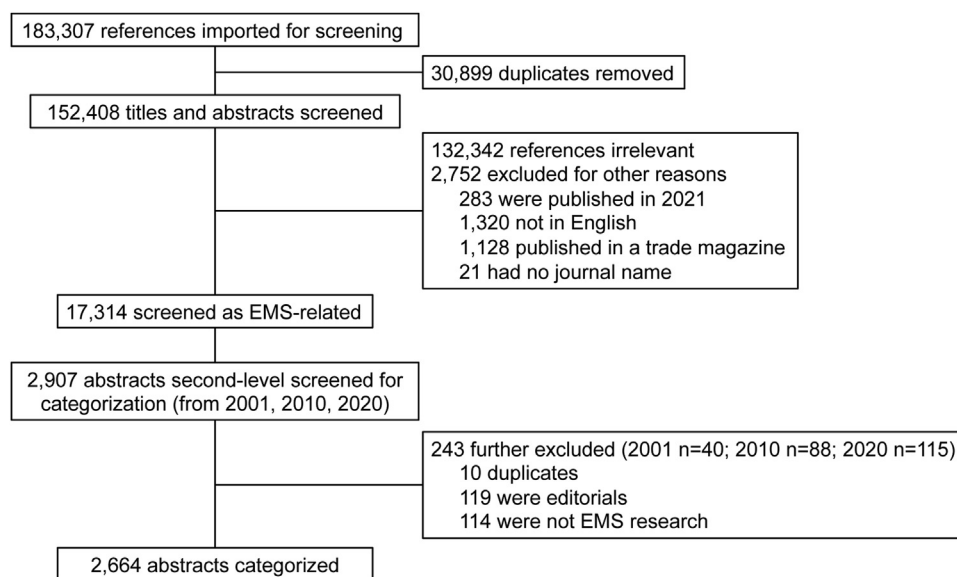


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart.

Table 1. Total EMS-related publications, unique journals, and NIH funding per year.

Year	Total PubMed Publications	EMS-Related Publications	Journals Publishing EMS Literature	Total NIH Awards	EMS-Related NIH Awards	EMS-Related Total Costs
2001	547,572	419	130	12,577	16	\$4,235,594
2002	565,384	500	167	13,151	19	\$13,307,990
2003	594,544	480	157	14,296	26	\$18,888,828
2004	639,712	425	161	14,048	55	\$37,913,794
2005	700,232	489	148	13,373	60	\$47,234,047
2006	749,825	534	180	12,519	59	\$61,240,516
2007	786,603	536	187	13,808	72	\$71,034,803
2008	837,038	609	237	13,276	60	\$64,299,405
2009	877,472	697	231	12,387	68	\$74,103,180
2010	941,953	700	254	12,852	71	\$115,319,014
2011	1,020,176	789	270	11,911	59	\$40,797,539
2012	1,089,349	917	327	12,301	63	\$41,818,338
2013	1,149,622	962	316	11,199	53	\$24,151,116
2014	1,205,233	1,059	351	12,577	55	\$32,682,181
2015	1,257,277	1,086	388	12,616	56	\$27,560,102
2016	1,284,265	1,268	415	13,668	57	\$17,094,995
2017	1,302,387	1,271	417	13,542	67	\$23,085,039
2018	1,344,825	1,348	434	14,779	76	\$23,432,256
2019	1,406,266	1,437	456	14,788	83	\$26,143,255
2020	1,627,353	1,788	513	14,859	91	\$32,200,249
Increase (%)	197	327	295	18	469	660

increase of 74 per year (95% CI 67 to 81), and the mean increase was 199 per year (95% CI 148 to 250) after 2018.

Abstracts from 2000, 2010, and 2020 were categorized on the basis of second-level screening (Table 2). Although total airway studies increased from 2001 to 2020, the relative number of studies decreased substantially (from 32, 8.4% of total, to 85, 5.1% of total). Decreases were also seen for the categories of disaster (56 [14.8%] to 68 [4.1%]) and cardiac (26 [6.9%] to 76 [4.5%]). Increases were seen in the categories of mobile integrated health, OHCA, opioids, sepsis, stroke, and workforce health and safety. Case reports and reviews also increased. There were other, less substantial changes in the categories of education, geriatrics, pediatrics, trauma, and position statements.

A total of 264,527 grants were identified in NIH RePORTER during the study period. Our search yielded 4,281 results, of which 1,166 (0.44%) were EMS-related, with a 469% increase from 16 in 2001 to 91 in 2020 (Table 1). There was a 660% increase in total EMS-related awards from \$4,235,594 in 2001 to \$32,300,249 in 2020, and overall NIH funding for all topics and mechanisms increased from \$14.9 million in 2001 to \$29.3 million in 2020, an increase of 96%. In 2010, total EMS-related awards were the highest at \$115,319,014 across 71 grants

(0.55% of total awards). Overall grant funding for EMS-related research increased significantly from 2001 to 2006 (slope, 10; 95% CI, 8 to 11), decreased between 2006 and 2015 (slope, -2; 95% CI, -4 to -1), and then increased significantly from 2015 to 2020 (slope, 8; 95% CI, 5 to 10).

LIMITATIONS

Our investigation has several limitations. Despite a broad search strategy, it is certainly possible that some studies were missed. Furthermore, our search strategy was limited to PubMed, English-language, and human studies, which excluded certain important contributions to EMS research. Our team of research assistants was trained by EMS professionals and researchers, and interrater reliability was nearly perfect; however, it is likely that some studies were inadvertently excluded or miscoded. The more thorough second-level screening did reveal additional studies meeting the exclusion criteria that were not identified on initial screening. Although this may have resulted in an overestimate of the absolute number of studies per year, we do not believe this had any impact on our primary analysis of research trends. Because of the volume of the literature, we chose to categorize only a subset of publications. Although NIH is an

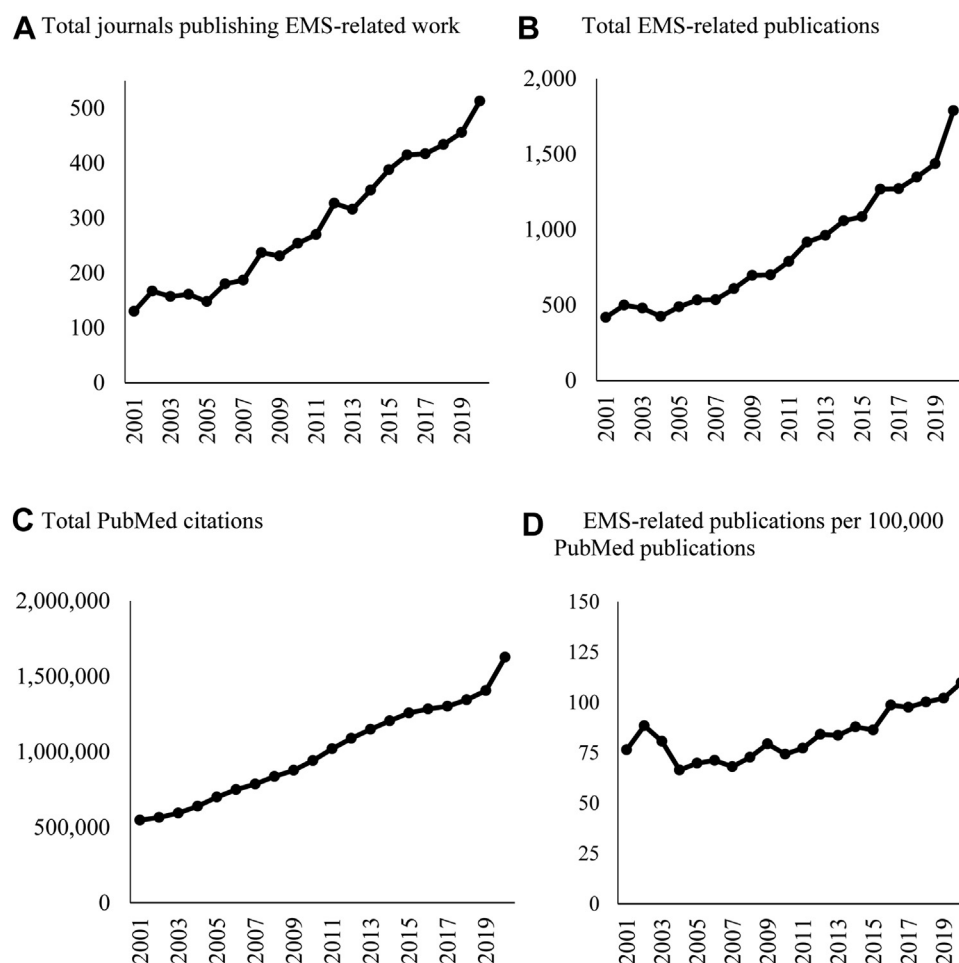


Figure 2. Year-over-year volume of EMS-related publications and journals that published EMS-related work compared with total PubMed publications. A, Total journals publishing EMS-related work during each year of the study period. B, Total EMS-related publications during each year of the study period. C, Total PubMed citations during each year of the study period. D, The relative number of EMS-related publications per 100,000 PubMed citations for each year of the study period.

important funder of EMS research, and NIH funding is likely representative of evolving trends in EMS funding, we did not evaluate other funding sources and, as such, may have missed other important sources of EMS funding. Finally, our study design did not allow us to comment on research quality or clinical impact, which are important areas for future investigation.

DISCUSSION

High-quality research is essential to progress in the field of EMS, as highlighted by the EMS Research Agenda, now more than 2 decades old.¹ Although multiple authorities have called for improved EMS research both before and since the publication of the EMS Research Agenda, this seminal document marked an important time point in EMS history. Our analysis of the research published in the following 2 decades

demonstrates significant growth in the breadth of EMS research. Importantly, although overall research publications increased in a nearly linear fashion during the study period, EMS-related research increased exponentially, highlighting the rapid pace of investigation in the field. Additionally, although a decrease in funding between 2011 and 2016 might be explained by the loss of funding of several large, well-funded EMS collaborations, overall funding for EMS research has increased significantly by >600% since 2001, disproportionate to the 96% increase in overall NIH awards.¹⁰

In a sample of 3 time points (2001, 2010, and 2020), we found changes in several key topics of EMS publications. It should be noted that when considering proportional changes in specific content areas, an increase in one area will necessarily reflect a proportional decrease in other areas. However, these proportional changes may serve as indicators of the shifting interests of EMS research and

Table 2. Categorization of abstracts on the basis of second-level screening for selected publication years.

Category*	Overall (n=2,664)		2001 (n=379)		2010 (n=612)		2020 (n=1,673)	
	N	%	n	%	n	%	n	%
Airway	177	6.6	32	8.4	60	9.8	85	5.1
Cardiac	153	5.7	26	6.9	51	8.3	76	4.5
Case study	46	1.7	3	0.8	19	3.1	24	1.4
Disaster	189	7.1	56	14.8	65	10.6	68	4.1
Education	137	5.1	20	5.3	37	6.1	80	4.8
Geriatrics	33	1.2	2	0.5	11	1.8	20	1.2
MIH	21	0.8	3	0.8	0	0	18	1.1
OHCA	497	18.7	60	15.8	137	22.4	300	17.9
Opioids	50	1.9	1	0.3	4	0.7	45	2.7
Pediatrics	171	6.4	28	7.4	28	4.6	115	6.9
Position statement	20	0.8	3	0.8	7	1.1	10	0.6
Review	79	3	2	0.5	17	2.8	60	3.6
Sepsis	28	1.1	0	0	2	0.3	26	1.6
Stroke	114	4.3	5	1.3	19	3.1	90	5.4
Trauma	404	15.2	54	14.3	85	13.9	265	15.8
Workforce	93	3.5	14	3.7	28	4.6	51	3.1
Workforce health and safety	225	8.5	14	3.7	39	6.4	172	10.3

MIH, mobile integrated health care.

*Some publications may have been included in multiple categories. Categories were not mutually exclusive and, thus, may sum to greater than 100%.

the medical field at large. Although the absolute numbers of publications focusing on airway, cardiac, and OHCA increased, the relative percentages of publications in these key content areas decreased in recent years. We further note the relative increases in stroke, sepsis, and opioids. Although it is encouraging to see research growth in previously neglected areas, such as workforce health and safety, studies on OHCA and trauma remained in the top 3 categories at all evaluated time points. Furthermore, this study did not specifically address study quality, and future research should evaluate both research quality and methodology. Future work might also consider current trends in EMS publication quality. Finally, although calls for additional pediatric EMS research continue, growth in pediatric research remains proportionally stable compared with that in other categories over the study period, highlighting the continued need to focus research efforts in this area.^{11,12}

In conclusion, although total publications have doubled over the past 20 years, EMS-specific research has nearly tripled. Furthermore, funding for EMS research, as indicated by NIH funding, has also increased significantly over this period almost 5-fold in grants awarded and over 6-fold in funding. Future evaluation should examine the quality of this published research and its application to clinical practice.

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Author contributions: SAG and REC conceived the study. MBB developed the search strategy. SAG, REC, and MAH supervised the data collection. Data collection was performed by EC, SM, HJS, SAG, and REC. Secondary screening and categorization were performed by SAG and REC. REC performed the search and data collection for NIH RePORTER. Data analysis was performed by REC with additional analytic support from CAC. SAG drafted the manuscript, and all authors contributed substantially to its revision. SAG takes responsibility for the paper as a whole.

All authors attest to meeting the four [ICMJE.org](https://www.annemergmed.com) authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement 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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IMAGES IN EMERGENCY MEDICINE

(continued from p. 82)

DIAGNOSIS:

Benign subcutaneous emphysema. Because of concern for early necrotizing fasciitis, an exploratory fasciotomy was performed, which revealed normal subcutaneous tissue, with good bleeding and no evidence of infection or necrosis. The fascia and underlying muscle appeared normal. A rapid-frozen section showed no signs of necrotizing fasciitis. Follow-up radiographs demonstrated resolving subcutaneous emphysema.

Subcutaneous emphysema affecting an extremity is very rarely benign and must be investigated further to exclude life- and limb-threatening causes such as necrotizing fasciitis and gas gangrene. A traumatic break in the skin plus lack of infectious, historical, physical, and laboratory findings suggest benign subcutaneous emphysema.¹ It is theorized that the wound acts as a 1-way valve, pulling air in with movement.¹⁻⁴ Conservative management, with observation and prophylactic antibiotics, is the recommended treatment option.¹⁻³ Astute recognition of benign subcutaneous emphysema can help obviate unnecessary surgery.

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