Air Medical Journal 38 (2019) 115–124

Contents lists available at ScienceDirect

Air Medical Journal

journal homepage: http://www.airmedicaljournal.com/

Review Article

Helicopter Emergency Medical Services Literature 1972-2017: Characteristics and Trends

Stephen H. Thomas, MD, MPH [1,2,3*], Stephen W. Thomas, [4], Sarah A. Thomas, [5], Sameer Pathan, MD, PhD [3]

[1] *Weill Cornell Medical College, Doha, Qatar*
[2] *University of London, London, United Kingdom*
[3] *Department of Emergency Medicine, Hamad General Hospital, Doha, Qatar*
[4] *Corning Painted Post High School, Corning, NY*
[5] *American School of Doha, Doha, Qatar*

A B S T R A C T

Since its inception in the latter part of the 20th century, the rapid expansion of helicopter emergency medical services (HEMS) has been accompanied by remarkable growth in the relevant evidence base. There are many review articles describing lessons contained within the various arenas of HEMS literature, but there is little or no characterization of the numbers and types of publications comprising the HEMS-related evidence base. This study analyzed all indexed publications mentioning HEMS (with abstract included) in the United States National Library of Medicine's PubMed collection. The aims of the analysis were to provide quantitative, qualitative, and longitudinal trend information regarding the 1972 to 2017 evidence base relevant to HEMS.

The prehospital care evidence base includes many topics related to patient transport by air. As long ago as the 1920s, prescient commentators remarking on the first fixed wing medical flight (a 1915 French warplane transport of an injured Serbian) concluded that airplanes "will be used to bring back rapidly from the field ambulances the men suffering from severe head and abdominal injuries."[1] Within a few decades, the helicopter made its appearance in the air medical world.

Rotor wing medical units' World War II experience, which commenced in Burma (now Myanmar), was followed by rapid evolution in military and civilian settings.[2] By the 1970s, civilian helicopter emergency medical services (HEMS) were firmly established; the 2017 annual listing of the Association of Air Medical Services' Atlas & Database of Air Medical Services (www.adamsairmed.org) counted 1,049 HEMS aircraft operating in the United States alone.

As HEMS use proliferated, there was concomitant growth in its evidence base. An example is found in the execution of periodical reviews aiming to summarize just that small part of the evidence base comprising HEMS outcomes research. Such reviews have been forced by the burgeoning size of the body of HEMS research output, to become more restrictive even while covering narrower spans of time.[3-8] For example, a recent *Air Medical Journal* commentary was limited to assessing the literature of just 3 years (2014-2016); that review focused on just the outcomes-related HEMS studies and still required partitioning 2 full-length articles.[9,10]

The HEMS evidence base includes useful review articles assessing the state of the art within various subtopics of HEMS literature (eg, safety, triage, outcomes, and physiology). However, there are few data describing an overarching view of the evolving characteristics of the HEMS evidence base in its entirety. Collecting and organizing information on this big picture character of the HEMS evidence base is the purpose of this analysis.

A bird's-eye view of the HEMS evidence base allows 2 separate but equally useful forms of assessment. The first form is determination of the preponderance of various types of publications in the HEMS evidence base. As is the case with many acute care fields such as emergency medicine, much HEMS-related research falls into the category of case reports, case series, or observational cohort studies (OCSs). However, there are many other study types in the HEMS evidence base. The current review provides a picture of the many methodologies comprising the body of HEMS scientific inquiry.

The second form of assessment enabled by this study's high-level HEMS publication analysis is longitudinal assessment. Although it must be emphasized that the study's limitations include its inclusion

* Address for correspondence: Stephen H. Thomas, MD, MPH, Department of Emergency Medicine, Hamad General Hospital, Doha, Qatar
E-mail address: sthomasmd@gmail.com (S.H. Thomas).

1067-991X/$36.00

https://doi.org/10.1016/j.amj.2018.11.016

of only those PubMed publications with abstracts, the analysis benefits from a long-term view encompassing nearly a half century's science. In addition to the benefit of being able to claim a nearly complete view of the state of HEMS evidence, the longitudinal scope of the current project allows for temporal analysis for trends in the HEMS literature.

Therefore, the current study was executed to identify, count, and (to a limited extent) classify all HEMS literature found in the set of PubMed articles that included online abstracts. The current review's starting year was defined by the year of the earliest eligible study mentioning HEMS (a 1972 overview of California ambulance operations[11]); the analysis extended 46 years, through 2017.

Methods

Search Strategy and Generation of Study Set of HEMS Publications

The study's sole information source was the US National Library of Medicine (NLM) medical reference search engine (www.pubmed.gov). The search relevant to this review's subject matter was executed February 3, 2018 (ie, a month after the study's publication closure date of December 31, 2017).

The search terms were selected to maximize the chances of detecting HEMS-related publications. Terms were selected for full sensitivity to detect possibly relevant publications while accepting low specificity. The NLM index list for each selected search term was used as a reference point in order to prevent unnecessarily listing repetitive terms (eg, helicopter and helicopter aeromedical program). The final search terms were 1) helicopter, 2) rotor-wing, 3) rotorcraft, 4) HEMS, 5) air medical, 6) aeromedical, and 7) air transport.

The search for articles was restricted to NLM references for which a search term (or an index list term mapping to a search term) appeared in the either the publication title or its abstract. The study search methodology, limited to publications that had an abstract available on PubMed, used the following search string: (((helicopter or rotor-wing or rotorcraft or HEMS or air medical or aeromedical or air transport)) AND hasabstract[text] AND ("1900/01/01"[PDat]: "2017/12/31"[PDat])).

Selection of HEMS-relevant Publications for Study

This search string produced 54,462 results. All of the publications' titles and abstracts were reviewed by the study's senior author. Articles were selected for inclusion in this review if they had any relationship with HEMS, including military HEMS or search and rescue HEMS. Articles that were excluded were those publications with no HEMS relevance because of issues such as (but not limited to) the following:

1. The article had nothing to do with HEMS or aviation. Most excluded articles came under this umbrella as exampled by studies on "air transport of microbes" or "helicopter parenting."
2. The publication related to helicopters but not to HEMS or air medical aviation, as exampled by a publication addressing helicopter spraying of insecticides.
3. The article focused on air medical transport, but there was no mention of transport by HEMS. This set of excluded publications was populated primarily by articles discussing fixed wing transport (eg, intercontinental transports of the US Air Force Critical Care Aeromedical Transport Team).

If an article's title or abstract mentioned HEMS, even if only in brief, it was retained in the pool of publications subjected to classification for this analysis. There was no adjudication as to whether a publication's HEMS mention was sufficiently relevant or important for its inclusion in this review.

This process identified a total number (N) of 1,717 publications for inclusion in this overview. For this group, the methods proceeded with a 4-step categorization that classified each publication by journal category, publication year, subject matter, and article methodology. Classification methods are outlined next.

Publication Classification: Journal Categories

Journals in which studies appeared were categorized by subject area in order to allow for a practical assessment of the areas of literature in which HEMS-related work appeared. The multitude of encountered journals dictated a collapsing of journals into broad categories, with grouping of related journal arenas by either practitioner focus or subject area. This journal categorization, executed a priori, proceeded along precise steps in an aim to offset its subjectivity with reproducibility. All journals underwent the same classification process, with all journals placed into just 1 category using the following ordinal process.

1. The first step assigned a specific category (Air Transport & Aerospace Medicine) to the journals that specifically focused on HEMS or air transport. The 2 such journals encountered were *Air Medical Journal* (formerly *Journal of Air Medical Transport*) and *Aerospace Medicine and Human Performance* (formerly *Aviation, Space, and Environmental Medicine*).
2. The remaining journals were placed in a second journal category, Prehospital & Disaster Medicine, if they were defined by focus on disasters, mass casualty incidents, or general emergency medical services (EMS) or ground emergency medical services (GEMS).
3. Journals not yet classified defined a third journal category, Wilderness & Environmental medicine, if they discussed medicine in austere (eg, mountain or maritime) settings.
4. Next, multispecialty journals were classified according to the following ordinal progression:
    a. Journals dedicated to nursing science and practice formed a Nursing category.
    b. Any armed services journal was placed into a Military Medicine category.
    c. Medical or surgical journals focusing on infants or children comprised a Pediatrics category.
    d. Multidisciplinary resuscitation-oriented journals were grouped into an Interdisciplinary Acute Care category.
5. Journals that were not already categorized and that dealt with administrative and policy issues were grouped into a Health Administration & Economics category.
6. Engineering journals and those dedicated to extracorporeal membrane oxygenation defined a Biomedical Engineering & Extracorporeal Membrane Oxygenation category.
7. Next, for the remaining journals that focused on distinct and (relatively) narrow areas of medical practice, categories were defined for the following specialty areas (some of which included both medical and surgical fields): Anesthesia & Critical Care, Cardiology & Cardiovascular, Emergency Medicine, Neurology & Neurosurgery, and Trauma & Burns.
8. After these steps, the remaining journals were categorized into broad groups depending on their medical specialty area or basic science focus. The various surgical specialty journals that were not already categorized constituted a Surgery category. Journals intended for the global medical community (eg, countries' national medical journals and public health publications) were combined with those focused on internal medicine and its subspecialties to generate a Medicine & Public Health category.

Finally, journals that had not already been categorized, which included other medical specialties (eg, radiology) or basic sciences, defined the final category of Other Specialties & Basic Sciences.

Using the previously described method of steps in order, each journal encountered in this study was classified once (and only once) as defined by the first grouping (using the ordinal steps described earlier) into which that journal fell. As examples, the *Journal of Trauma Nursing* was categorized as Nursing (not Trauma), and the *Journal of Pediatric Surgery* was assigned to the category Pediatrics (not Surgery).

Publication Classification: Temporal Grouping

Articles were temporally classified by publication year. The publication year was set as that of an article's initial PubMed listing (including in the form of an electronic publication).

In order to analyze longitudinal trends of data too sparse for per-year analysis, study planning called for grouping of years into bins. The methodology called for first detecting which years were populated by publications eligible for this review and then dividing that time span into equal duration bins.

The time span of the study (1972-2017) covered 46 years, but there were 2 years (1973 and 1974) with no PubMed returns meeting study inclusion criteria. Therefore, there were 44 individual years included in this overview. Because this number was easily divisible by 4, the "bin width" for study years was set such as to define 11 quadrennial periods. The first quadrennial comprised the years 1972 as well as 1975 to 1977, and the remaining 10 quadrennials were all constituted by 4-year consecutive periods (eg, the 11th quadrennial consisted of the years 2014-2017).

Publication Classification: Subject Matter Grouping

During study planning, subject matter classification was quickly recognized as being of great importance and equally significant imprecision. In order to facilitate practical interpretation of this review's results, a number of a priori judgments were made regarding subject matter classification. These judgments are explained in this section.

First, given the breadth of HEMS publications' topics, it was not possible to classify every article for the purposes of this review. Depending on the narrowness of subject matter scope, it would have been easy to generate hundreds of subject matter categories. Therefore, the decision was made to not attempt to include all of this project's articles and topics in the subject classification process.

In determining the subjects on which to focus, study planning defined 5 discrete areas of high potential interest and with minimal cross-subject overlap (ie, a given publication would not likely have major emphasis in more than 1 of the defined subject area categories). The category application proceeded in ordinal fashion, such that an article meeting a higher-emphasis category was not also placed in a second category. Each article that was categorized was categorized into only 1 subject. The subject matter categories and their order of assignation were as follows:

1. Publications covering aircraft or pilot safety were placed in the Aviation Safety category.
2. After safety, prime importance was placed on outcomes and the associated disciplines of cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA). Studies with major results that included statistical testing of HEMS versus GEMS clinical outcome as well as publications calculating CBA or CEA constituted the Outcomes & CBA/CEA group.
3. The prime clinical imperatives of oxygenation, airway protection, and ventilation informed selection of Airway & Ventilation as a representative medical topic category. This category included multiple HEMS endotracheal intubation (ETI) studies as well as publications in associated arenas of airway management (eg, cricothyrotomy series) or post-ETI ventilation. It is noteworthy that studies with a major aim of airway investigation but for which major results included explicit reporting of HEMS-associated mortality or morbidity benefit were subject classified into the outcomes (not airway) category. Two examples are provided to illustrate the application process for subject area categorization. In 2004, Wang et al[12] examined ETI in traumatic brain injury cases in Pennsylvania. Four years later, Cudnik et al[13] assessed an ETI-survival relationship for possible association with transport distance. In neither case did the investigators set out to assess HEMS' association with trauma outcome, but in both of these "airway" studies, major findings included significant outcome improvement with HEMS versus GEMS; for the purposes of this project, both articles were classified with the Outcomes & CBA/CEA subject group.
4. Scientific inquiry into the things that make HEMS "different" from in-hospital or other out-of-hospital settings comprised the fourth category, In-cabin Care. Into this group were placed studies that were not previously categorized that addressed cabin care topics from disparate fields such as physics (eg, altitude and pressure issues and vibration-induced hemorrhage after thrombolysis), cabin space ergonomics (eg, performance of chest compressions), and in-flight functionality (eg, performance of ultrasound and bispectral index monitoring).
5. The previous categories having touched upon safety, efficacy, medical care, and the HEMS cabin care environment, the last (but not least) subject category—Flight Crew—garnered articles addressing aspects of the medical crew such as composition and training.

Articles that were purely of a review or editorial nature were not included in the subject classification process. However, if the publication included a review or editorial content in combination with new data (eg, case series with a review of the literature), it was eligible for subject classification.

Publication Classification: Methodology Categories

In order to determine whether publications were eligible for subject area classification, publication methodology was assessed using a grouping of methodologies as outlined in standard research texts.[14] As noted in these same texts,[14] the precise classification of study methodology is not always straightforward; depending on the strictness of the definition, a "case series" can be similar to a retrospective OCS assessing a single group. For reasons of practicality, a broad categorization approach was selected for this large-scale overview.

Given the relative paucity of prospective work in HEMS, the first step in methodology description entailed dichotomous coding of each publication as to whether it was prospective in design. Review articles and editorials were classified as "not prospective." After the assignment of a category representing prospective design, the remaining steps were all mutually exclusive; a study could be classified into only 1 of the following categories:

1. The first methodology category comprised single case reports. This category, Case & Incident Report, also included single incidents such as mass casualty incidents, even if more than 1 patient was involved.
2. The next category was created to include observational or descriptive analyses that were not prospective. Included methodologies in this Case Series & Retrospective Cohort were multiple case (or multiple incident) series and retrospective OCS designs.

3. The third methodologic category, comprising review articles on medical, administrative, or operational subjects, was Review & Program Practice Description. As suggested by the name, the category also included reviews of a given program's practices with respect to myriad subjects including (but not limited to) administration (eg, quality assurance methods) and clinical care (eg, the approach of a HEMS program to traumatic brain injury care).
4. The last nonprospective methodology category was Description of Study Design; this grouping comprised articles outlining specific protocols for in-progress or planned investigations.
5. The next categories were prospective in nature. Because of the importance of prospective analysis in any evidence base, the prospective grouping was split into multiple categories that departed from traditional study methodology classification (but which had relevance to an HEMS overview).

    a. The Prospective Evaluation: In-cabin Care category included methodologies that assessed care, equipment functionality, or related parameters in the in-cabin setting. The in-flight setting could have been actual or simulated (eg, audiology laboratory or hypobaric chamber).
    b. Clinical trials, including those in which the "intervention" was limited to phlebotomy of subjects (patients or crew) for biomarker assay, constituted the Prospective Clinical Trial & Biomarker category.
    c. The Survey category included surveys of either patients or others (eg, flight crew).
    d. The category of Computer Modeling nearly always involved logistics calculations for HEMS asset placement using geographic information software. Modeling studies with economic focus constituted a separate methodology category, Financial Analysis.
    e. Methodologies categorized as executing a Consensus-building Process used techniques such as Delphi to gather experts and generate guidelines or similar recommendations.

Statistical Analysis

For the study goals of outlining the nature of the HEMS literature, the methods were primarily descriptive. An association between major dependent variables (eg, proportions of a study methodology) and other independent categoric variables, such as time frame, was tested with the chi-square test or (if cell values dropped below 5) the Fisher exact test.

In order to assess reproducibility of the approaches to categorization of subject matter and publication methodology, a randomly sampled subset of 2.5% of the overall publications were categorized by a second investigator blinded to the categorizations assigned by the primary article reviewer. The study protocol called for the assessment of interrater agreement with respect to classification with calculation of a 2-rater, nonweighted kappa statistic.

Formal testing for trends (eg, whether publication proportions for a subject matter classification increased over time) was executed with the nonparametric trend test. If this trend testing identified a statistically significant time-related change in a response variable, scatterplots were used to illustrate the trends. When data were analyzed on a per-year basis (ie, when there were sufficient data points), trend lines were plotted using locally weighted scatterplot smoothing (with a standard bandwidth of .8).

Significance was set at $P < .05$. All statistical analysis and plotting were performed with Stata 15MP (StataCorp, College Station, TX).

Results

Journal Categories

The overall (N = 1717) group of articles appeared in 374 different journals. The breakdown by journal category is depicted in Figure 1. Cumulative article counts for each journal category are depicted in Table 1, which also shows the results of longitudinal analysis as to whether a journal category's proportion of publications changed over the study's 11 quadrennial time frames. For the 6 journal categories in which there was a significant longitudinal trend in proportional

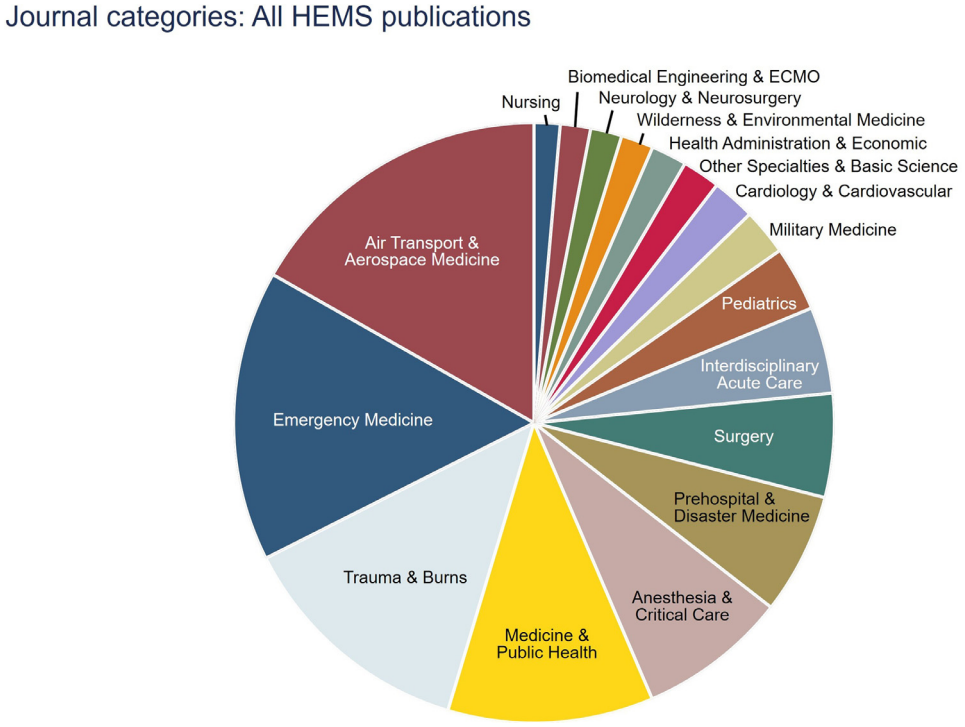

Figure 1. Journal categories in which HEMS literature appears. ECMO = extracorporeal membrane oxygenation.

Table 1
Journal Categories: Publication Number and Test for Trend in Proportion Over the Study Period

Journal Category	n	% of 1,717	*P* Value, Test for Trend Over 11 Quadrennial Periods
Air Transport & Aerospace Medicine	288	16.8	.84
Prehospital & Disaster Medicine	112	6.5	.01[a]
Wilderness & Environmental Medicine	30	1.7	.01[a]
Nursing	24	1.4	.52
Military Medicine	43	2.5	.02[a]
Pediatrics	60	3.5	1.00
Interdisciplinary Acute Care	80	4.7	.01[a]
Health Administration & Economics	33	1.9	.83
Biomedical Engineering & ECMO	28	1.6	.43
Emergency Medicine	269	15.7	.28
Trauma & Burns	222	12.9	.49
Anesthesia & Critical Care	138	8.0	.40
Cardiology & Cardiovascular	40	2.3	.06
Neurology & Neurosurgery	29	1.7	.09
Medicine & Public Health	190	11.1	.01[a]
Surgery (other than above)	96	5.6	.04[a]
Other Specialties & Basic Sciences	35	2.0	1.00
Total over 17 journal categories	1,717	100.0	

ECMO = extracorporeal membrane oxygenation.
[a] $P < .05$, indicating the proportion of a given journal category changed significantly over time.

representation, Figure 2 depicts the category's proportion of all articles in succeeding quadrennial time frames.

Publication Year and Subject Categories

Table 2 and Figure 3 depict annual counts for overall numbers of publications as well as for publications within the 5 selected subject categories (Aviation Safety, Outcomes & CBA/CEA, Airway & Ventilation, In-cabin Care, and Flight Crew). Publications in the selected 5 subject areas accounted for 32.4% of all 1,717 publications in the overall study set. Table 2 includes results of longitudinal analysis as to whether a subject category's proportion of publications changed over the study's 11 quadrennial time frames.

For the overall publication number and also for the numbers within each of the subject categories, the number of publications rose

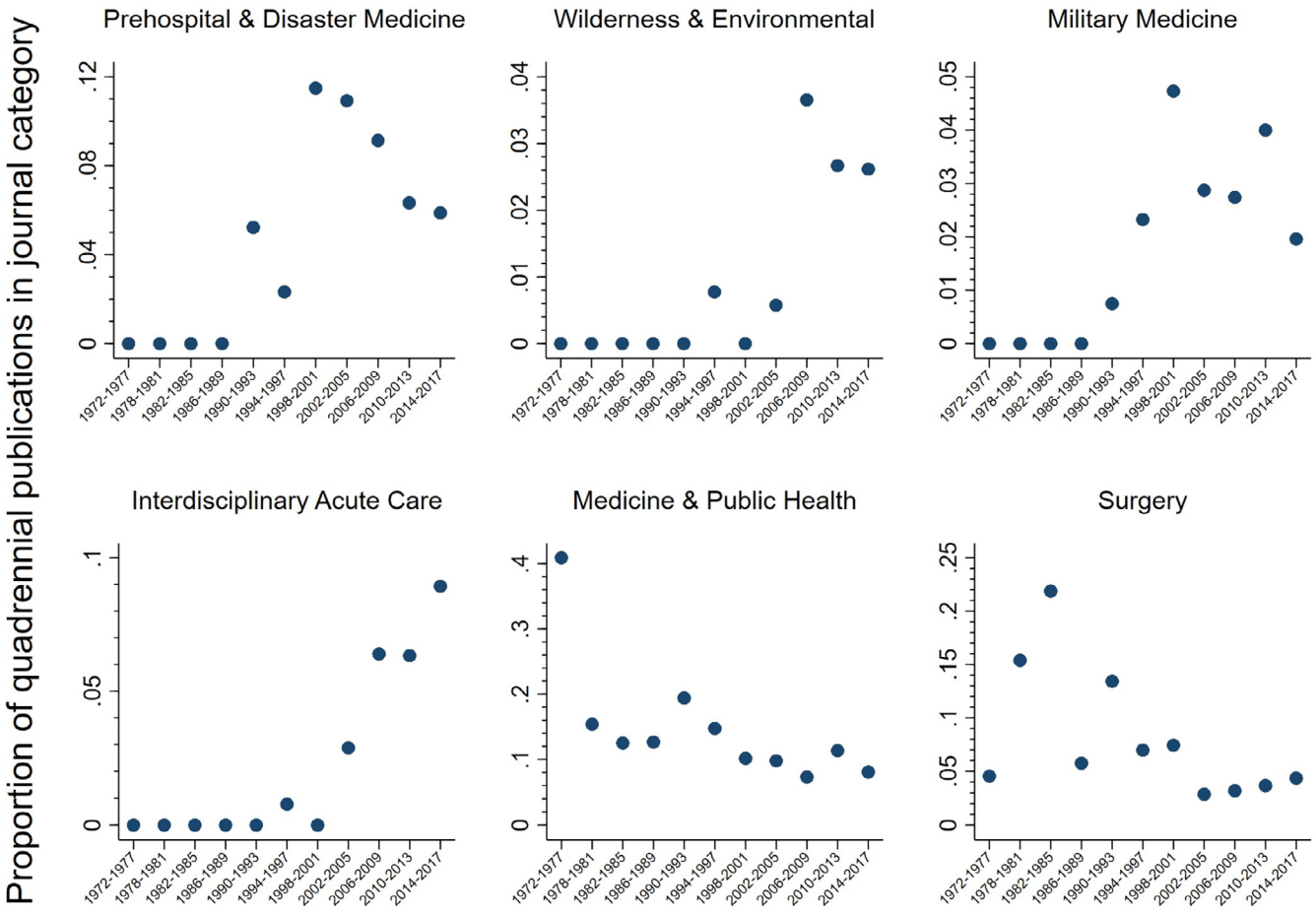

Figure 2. Journal categories with significant proportional trends over the study period.

Table 2
Selected Subject Categories: Publication Number and Test for Trend in Proportion Over Study Period

Subject Category	n	% of 1,717	*P* Value, Test for Trend Over 11 Quadrennial Periods
Aviation Safety	61	3.6	.02[a]
Outcomes & CBA/CEA	177	10.3	.19
Airway & Ventilation	122	7.1	.02[a]
In-cabin Care	128	7.5	.67
Flight Crew	69	4.0	.79
All other subjects	1160	67.6	
Total over 6 subject categories	1,717	100.0	

[a] $P < .05$, indicating the proportion of a given subject category changed significantly over time.

significantly over the study period ($P < .001$). For the 2 subject categories (Aviation Safety and Airway & Ventilation) in which there was a significant longitudinal trend in proportional representation, Figure 4 depicts the category's proportion of all publications in succeeding quadrennial time frames.

Methodology Categories

The first methodology analysis was evaluation of the dichotomization of publications as to whether they were prospective. Over the entire set of publications, 370 (21.5% of 1,717) were prospective. The proportion of prospective studies did not change ($P = .65$) over the study period's 11 quadrennia.

Methodology categories for the overall set of 1,717 publications are illustrated in Figure 5; in the figure, the 2 methodologies that were rarely seen (Description of Study Design and Consensus-building Process) were combined into an "Other" category. Table 3 depicts the overall numbers and proportions of each of the methodology categories; the table also shows the results of longitudinal analysis as to whether a methodology category's proportion of publications changed over the study's 11 quadrennial time frames. Because of the insufficient number in 2 rarely seen methodologies (Description of Study Design and Consensus-building Process), trend testing was not executed for these publication types.

For the 3 methodology categories in which there was a significant longitudinal trend in proportional representation, Figure 6 depicts the category's proportion of all articles in succeeding quadrennial time frames.

Interrater Agreement With Respect to Subject and Methodology Classification

With regard to interrater agreement, the 2 evaluators had 100% agreement on both the subject and methodology categories assigned to the 2.5% of publications randomly selected for cross-validation. Thus, there was no formal kappa statistic calculated.

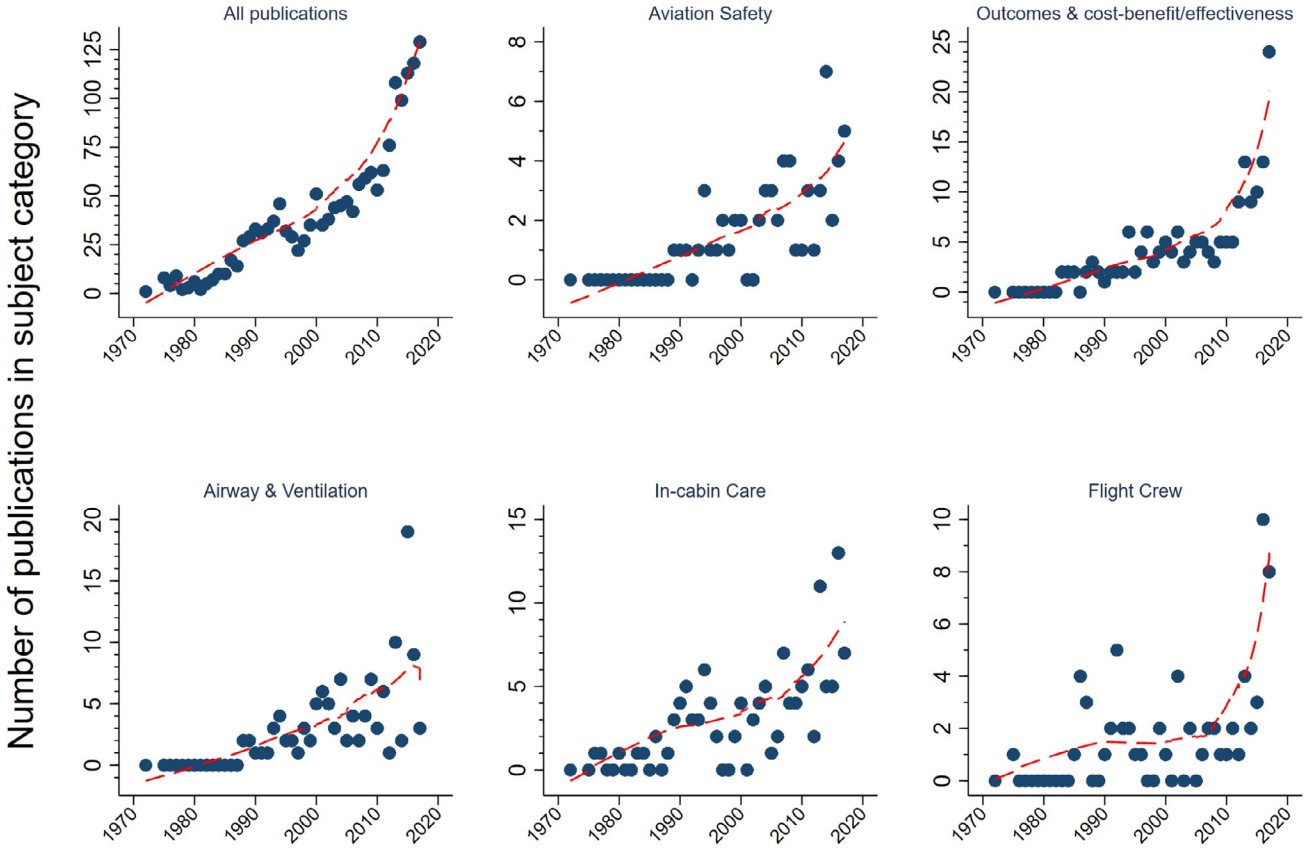

Figure 3. Publication number (n) by year for overall article set and for each of the 5 selected subjects.

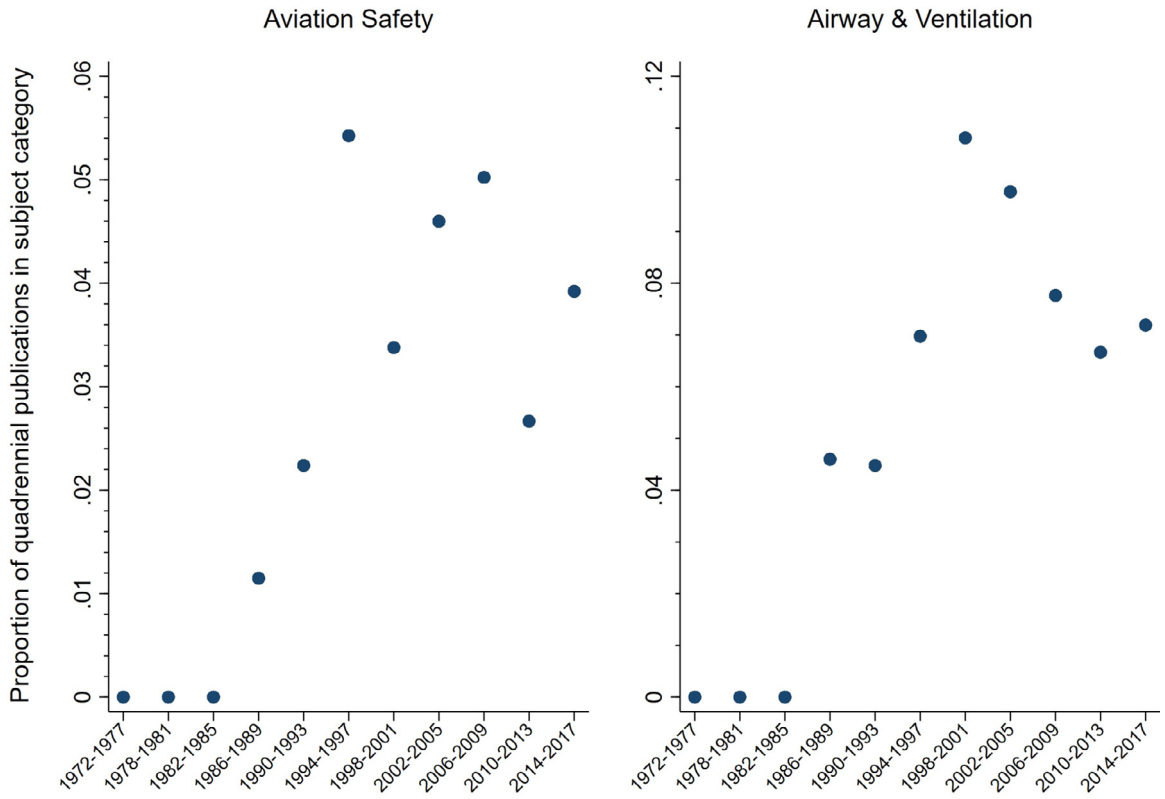

Figure 4. Subject categories with significant proportional trends over the study period.

Discussion

Although the myriad subjects related to helicopter patient transport have been discussed in numerous reviews, there are few data outlining the scope and character of the body of HEMS literature as a whole. Informative discussions have focused on dozens of individual topics. There are systematic reviews, for instance, summarizing the state of the HEMS evidence with regard to triage,[15] outcomes,[16] cost-benefit analysis,[17] and even endotracheal tube cuff pressures.[18] However, a bird's-eye view of the HEMS literature is not easily found. Given the sharp timing demarcation of HEMS' appearance on the health care scene, there is opportunity to embark on an overview of virtually the entire body of relevant evidence.

An overarching HEMS literature review offers potential benefits. First, given HEMS' extraordinary breadth of patient types, some will have interest in where (in terms of journal type or focus) the HEMS evidence base is found. Second, there is potential usefulness in knowing some of the major subject foci of the HEMS literature. Third, those involved in evaluating HEMS in general might find their discussions informed by analysis of the literature's various study methodologies. Finally, understanding of the body of HEMS-related publications may be further augmented by knowledge as to any temporal trends in publications' journal types, subject matter, or methodology.

With the caveat that substantial limitations restrict conclusions that can be drawn, this overview attempts to provide insight into where HEMS literature is found and what subjects and methodologies comprise the body of HEMS-related publications. Furthermore, the current analysis aims to investigate whether, and to what degree, the passage of nearly a half-century since HEMS' advent has seen changes in the number, location, focus, or methodology of the literature relevant to patient transport by helicopter.

As is often the case with literature assessments attempting a broad scope, there are limitations, some profound, that restrict both the number and weight of definitive conclusions. Before assessing the findings suggested by this overview, attention to those limitations is warranted.

First, and perhaps most importantly, this review does not actually encompass the entirety of the HEMS-relevant literature. Limitations include those engendered by selection of the single source for articles (PubMed) and the inclusion criteria requiring an online abstract for review. PubMed has been identified as 1 of the most effective and reliable tools for systematic reviews,[19,20] but the database is certainly not flawless.[21] A lack of using other databases or even hand searching (eg, via PubMed-identified publications' reference lists) contributes to the inevitability that the current overview is not comprehensive. However, there is little reason to believe that the inclusion of an extra database or hand searching would result in marked changes in either the number or the trends identified in this analysis.

A second limitation, far more important in terms of diminishing the lessons of this overview, is that it was not possible to develop a reproducible method for including only articles that had "real" HEMS relevance. If a publication title or abstract mentioned HEMS, the article was included in analysis, even if there were some basis for argument that the work did not have much to do with helicopter transport. The problem is simply that once a decision was made to draw a line demarcating "inclusion for relevance," the placement of that line would be subject to unavoidable controversy. On a related note, practicality and reliability issues meant there was no weighting of articles as to their degree of relevance to HEMS. For instance, even a seemingly straightforward decision to "discount" case reports and case series would be problematic in execution (eg, how much to downgrade) and also run against arguments that such methodologies often represent critically important contributions to medical science.[22]

The judgment to include all articles with HEMS mention avoided subjective publication exclusions, but erring on the side of inclusion

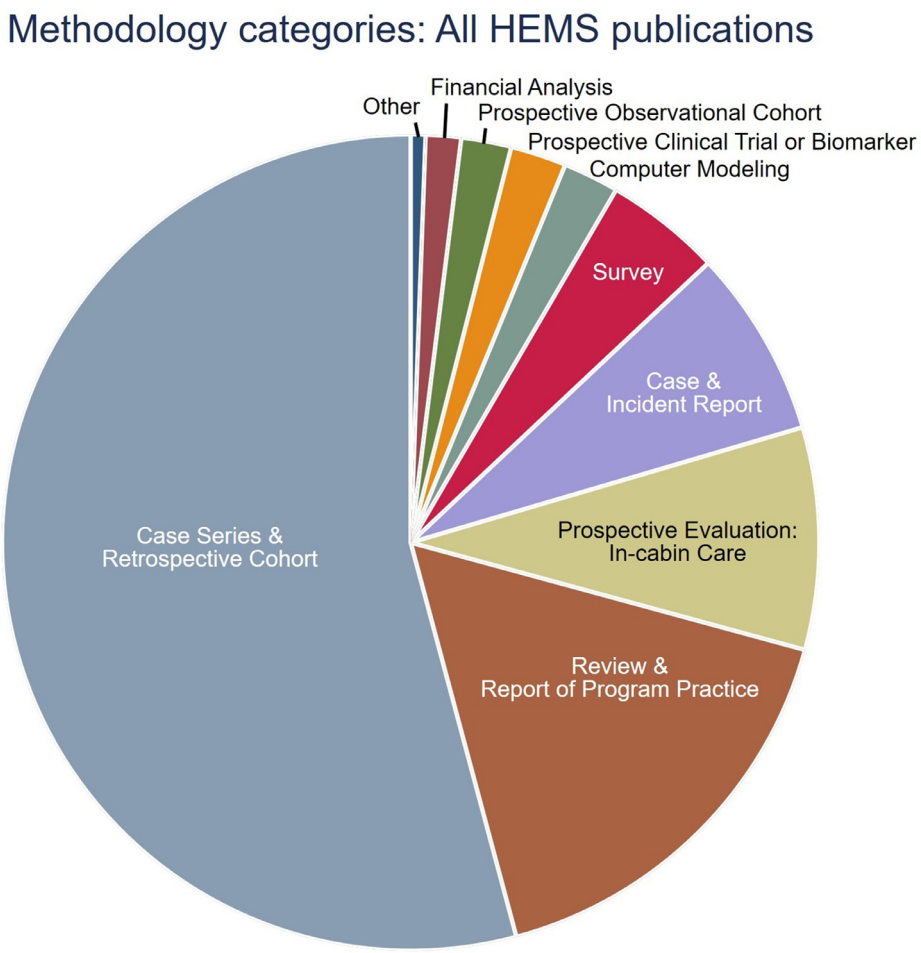

Figure 5. Methodology categories of HEMS literature.

created an analysis set that was so large as to be unwieldy for some purposes. With 374 different journals and hundreds of potential subject classifications, trade-offs had to be made in order to enable practical analysis. Perhaps most importantly, the restriction of each article to a single subject classification avoided the problem of overinflating the size of the evidence base, but this came at a cost of potentially underestimating a particular subject's representation. For instance, the emphasis on outcomes and cost-benefit/cost-effectiveness publications meant that articles that covered these topics but that also covered other topics (eg, ETI success rates as accounting for mortality benefit),[13] may have left those nonoutcomes topics underrepresented in this report.

The hierarchical assignation of subject arenas aimed to regularize the grouping approach and emphasize subject areas that were easily defined and minimally overlapping. The overlap issue was responsible for nonlisting of some important subjects. For example, triage was so often discussed as a component of an outcomes publication that defining a subject category for triage would have resulted in either

Table 3
Methodology Categories: Publication Number and Test for Trend in Proportion Over Study Period

Methodology Category	n	% of 1,717	*P* Value, Test for Trend Over 11 Quadrennial Periods
Nonprospective methodology	1,347	78.5	.65
Case & Incident Report	128	7.5	.06
Case Series & Retrospective Cohort	930	54.2	0.19
Review & Program Practice Description	285	16.6	.01[a]
Description of Study Design	4	0.2	Insufficient data to analyze trend
Prospective methodology	370	21.5	.65
Prospective Evaluation: In-cabin Care	151	8.8	.17
Prospective Clinical Trial & Biomarker	38	2.2	.03[a]
Prospective Observational Cohort	34	2.0	.01[a]
Survey	79	4.6	.98
Computer Modeling	38	2.2	.13
Consensus-building Process	6	0.3	Insufficient data to analyze trend
Financial Analysis	24	1.4	0.22
Total	1,717	100.0	

[a] $P < .05$, indicating the proportion of a given subject category changed significantly over time.

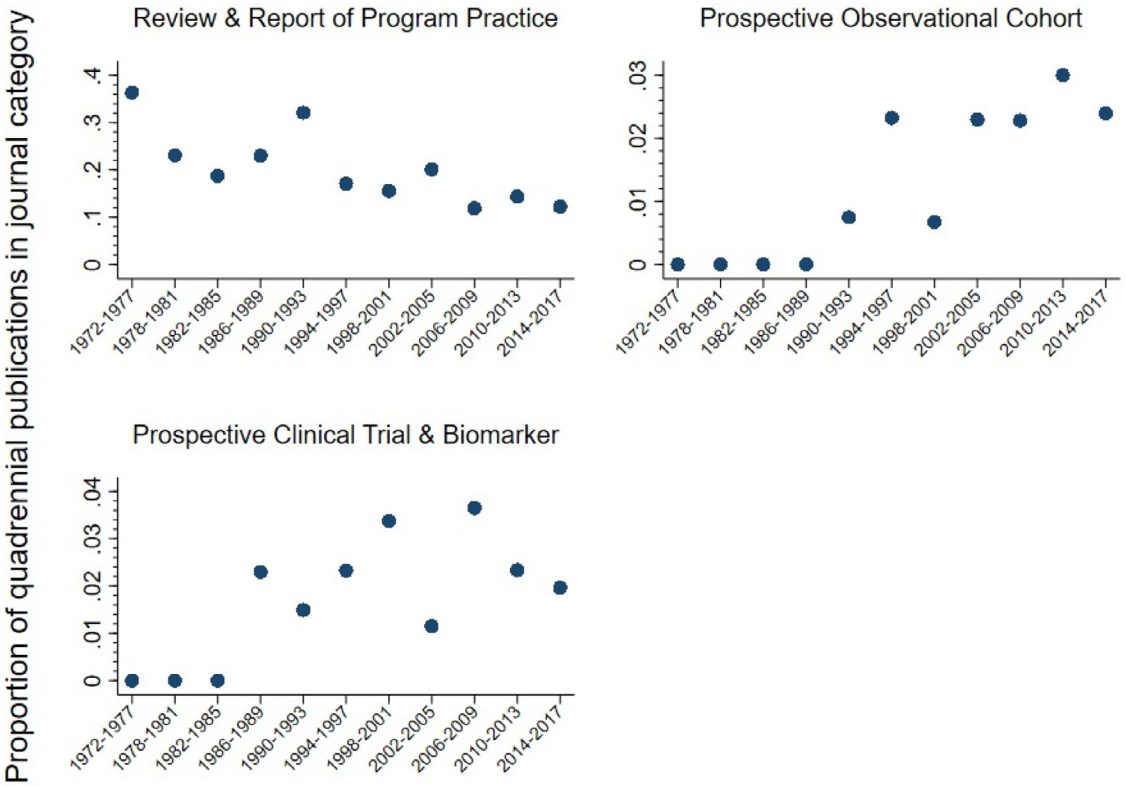

Figure 6. Methodology categories with significant proportional trends over the study period.

significant underrepresentation (of triage because the outcomes category takes precedence) or required a double category listing. The double category listing would risk the previously noted problem of inflating the apparent size of the HEMS evidence base; it would also engender subjective judgment as to how much triage discussion in an outcomes article would need to be present to also classify that article as a triage publication.

Although the definition of the overview's subject foci had subjective elements, the 100% interrater agreement suggested that the application of the categorization rule was straightforward. Similar conclusions could be drawn regarding the categorization of the publications' methodologies.

The analysis methodology was limited by its simple descriptive reporting and nonparametric testing for publication trends over time. No nonlinear modeling was executed (eg, to see if publications for a given subject rose and then fell). There was no attempt to generate estimates of time's "effect size" (eg, over each increment in the quadrennial period) on the various publication parameters.

Despite its acknowledged limitations, the current effort identified some results that could be of import and interest. First, there is a potentially surprising breadth of journal categories in which HEMS makes an appearance. Figure 1 includes some expected findings; the publications count was highest for air medicine–focused publications (*Air Medical Journal*'s 228 articles easily topped the count listings). However, the figure also shows contributions of noteworthy heterogeneity across many disciplines. For those wishing to keep up with what is happening in HEMS, it is clearly not sufficient to restrict focus to journals covering air medicine, prehospital care, or trauma and emergency medicine.

The burgeoning interest in HEMS over the previous decades is further illustrated in the Figure 2 depiction of the marked proportional rise in HEMS articles in journals covering the various "non-HEMS" out-of-hospital and acute care fields. The figure shows that as HEMS publications' proportions from broad-spectrum medical and surgical journals decrease, there has been an accompanying rise in proportional HEMS publication numbers in various focused journals such as those covering wilderness or military medicine.

Figure 3 depicts an exponentially increasing number of publications mentioning HEMS over the past decades. This increase may be reasonably interpreted as reflecting the broadening application of helicopter transport. Greater article numbers are also indicative of an increased attention to building the evidence base surrounding HEMS. Although the publication counts for all 5 of the areas of subject focus increased (ie, following the overall trend of increasing publication numbers), the subject areas of greater proportional increase (ie, safety and airway management) are of particular interest. Aviation safety has long been the most important consideration in HEMS,[23] and airway stabilization is both an imperative and a challenge in acute care.[24] Thus, there is reason to applaud findings that these 2 subjects accounted for a disproportionate share of the rising HEMS publication counts over time. Those contributing to the HEMS evidence base seem to be concentrating on vital areas of scientific inquiry.

As would be expected when examining a broad base of clinical publications, case reports and case series constituted the majority of the published articles. The fallacy of presuming these methodologies to be noncontributory to an evidence base has already been highlighted.[22] Furthermore, the generally lower-quality perception of retrospective analyses is matched by acknowledgment that most medical practice in emergency medicine is in fact based on this "lower-quality" evidence.[25]

In fact, in this review's HEMS publication set, more than 1 in 5 articles had a prospective methodology. With the (repeated) caveat that all of the articles were not necessarily "100% HEMS" in focus, this proportion should probably still be viewed as favorable. Furthermore, even as review articles and similar publication methodologies decreased in proportional representation over the study period, prospective cohort studies and clinical trials rose disproportionately. Not only is the HEMS literature growing, but it is growing with a

particularly higher rate with regard to the types of methodologies that tend to be of higher quality. Overall, the HEMS evidence base is not too dissimilar in its constitution from the evidence base used by national organizations (eg, American College of Emergency Physicians) to support clinical guidelines.[25]

The collection of publications, available from the corresponding author, will also be posted in Microsoft Excel format on the Critical Care Transport Collaborative Outcomes Research Effort website (www.cctcore.org). It is hoped that the resource may be useful to those wishing to further explore the information as a secondary aid to their own pursuits.

Conclusions

In conclusion, the current analysis attempted to paint a broad picture of the body of existing PubMed HEMS literature. Despite limitations that restrict definitive conclusions, this overview's article count, journal category, subject matter, and methodology results provide findings of potential interest to the HEMS community. Analyzed over nearly a half-century's time span, growth in the HEMS-related literature's size, quality, and interdisciplinary spread reflects a firmly established, substantive integration of helicopter transport into health care. In addition to focusing on particular subject-related components of the literature (eg, whether publications in 1 subject are more likely to be prospective), future research may include more specific parsing of publications (such as into various methodologies).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.amj.2018.11.016.

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