Scholarly Productivity of United States Academic Cardiothoracic Anesthesiologists: Influence of Fellowship Accreditation and Transesophageal Echocardiographic Credentials on h-Index and Other Citation Bibliometrics

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Objective: **The h-index allows the evaluation of scholarly output in academics, but this bibliometric statistic has not been applied extensively to measure productivity in anesthesiology. The authors tested the hypothesis that the h-index is dependent on academic rank, American College of Graduate Medical Education (ACGME) accreditation of the training program, and National Board of Echocardiography credentials in perioperative transesophageal echocardiography (TEE) in United States academic cardiothoracic anesthesiologists.**

Design: **Observational.**

Setting: **Internet analysis.**

Participants: **United States academic cardiothoracic anesthesiologists.**

Interventions: **None.**

Measurements and Main Results: **Faculty members from 30 randomly selected fellowship programs with or without accreditation were identified using the Society of Cardiovascular Anesthesiologists web site. The status of each faculty member's credentials in perioperative TEE was defined using the "verify certification" function on the National Board of Echocardiography web site. Publications, citations, citations/publication, and the h-index for each faculty member were obtained using Scopus. Two hundred fifty-nine cardiothoracic anesthesiologists (204 men and 55 women) were identified (8 instructors [3%], 123 assistant professors [48%], 56 associate professors [22%], 63 professors [24%], and 9 chairpersons [3%]). The average cardiothoracic anesthesiologist had an h-index of 6 ± 7 with 28 ± 46 publications, 499 ± 988 total citations, and 13 ± 18 citations per publication. The h-index increased significantly ($p < 0.05$) among ranks (instructors [1 ± 1], assistant professors [3 ± 3], associate professors [7 ± 5], professors [12 ± 8], and chairpersons [18 ± 13]). Significant differences in the number of publications and total citations also were observed among ranks. Differences in the h-index among ranks were observed regardless of program accreditation status or transesophageal echocardiographic credentials. Faculty members working in American College of Graduate Medical Education–accredited programs had more publications and citations and higher h-indices than their counterparts in programs that were not accredited. Except for program directors, the scholarly output of academic cardiothoracic anesthesiologists with or without transesophageal echocardiographic credentials was similar within each academic rank.**

Conclusions: **The results show that the h-index increases progressively with academic rank and is dependent on fellowship program accreditation status but not transesophageal echocardiographic credentials in United States academic cardiothoracic anesthesiologists.**

KEY WORDS: bibliometrics, cardiothoracic anesthesia, h-index, performance measures, scholarship

THE H-INDEX is a bibliometric statistic that allows the evaluation of scholarly output in academics.[1] The h-index is defined as the number (h) of a faculty member's publications that have been cited at least h times in the peer-reviewed literature.[2] For example, if a faculty member has published 10 papers, 5 of which have been cited 5 or more times, this individual's h-index is 5; the remaining 5 publications that do not have more than 5 citations are not included. Similarly, another investigator with a total of 20 articles, 12 of which are cited at least 12 times, has an h-index of 12. Thus, the h-index has been suggested as a measure of the relative quality of a faculty member's collective body of work because less important publications probably are not cited as often.[2] The h-index for any scientific author may be calculated online using the Scopus, the Institute for Scientific Information Web of Science, and Google Scholar databases.[3] Several previous studies used h-index to quantify scholarly output in a variety of biologic and health sciences,[4-12] but h-index has not been studied extensively in anesthesiology. To the authors' knowledge, only a single study in which the h-index and other citation metrics were examined in anesthesiologists has been reported in the peer-reviewed literature.[10] The authors conducted a bibliometric analysis of academic cardiothoracic anesthesiologists who participate in fellowship training programs in the United States. The hypothesis that the h-index is dependent on academic rank, American College of Graduate Medical Education (ACGME) accreditation of the training program, and National Board of Echocardiography (NBE) credentials in perioperative transesophageal echocardiography (TEE) was tested.

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Table 1. Adult Cardiothoracic Anesthesiology Fellowship Program Demographics

	n	Faculty per Program	TEE Diplomates	TEE Testamurs	Total TEE Credentials	No TEE Credentials
All	30	9 ± 4	3 ± 3	2 ± 2	5 ± 4	4 ± 3
Accredited	15	10 ± 4	5 ± 3	2 ± 1	7 ± 4	3 ± 4
Not Accredited	15	8 ± 3*	2 ± 2*	2 ± 2	3 ± 3*	4 ± 2

NOTE. Data are mean ± standard deviation.
Abbreviation: TEE, transesophageal echocardiography.
*Significantly ($p < 0.05$) different from accredited.

METHODS

All data were collected in January 2011. Thirty programs were selected using a random number generator (Microsoft Excel; Microsoft, Redmond, WA) from United States adult cardiothoracic anesthesiology fellowship programs with or without ACGME (www.acgme.org) accreditation (n = 15 in each group) listed on the Society of Cardiovascular Anesthesiologists (SCA) web site (www.scahq.org). The academic rank (ie, instructor, assistant professor, associate professor, professor, or chairperson) of each faculty member in each program was defined using the corresponding departmental web site. The director of each fellowship program was identified using the SCA web site. The status of each faculty member's credentials (ie, testamur, diplomate, recertified, or none) in perioperative TEE was defined using the "verify certification" function on the NBE web site (www.echoboards.org). A NBE testamur in perioperative TEE successfully has passed a written test, whereas a diplomate also has documented extensive clinical experience in performing, reading, and reporting comprehensive transesophageal echocardiographic examinations. The number of publications, total citations, citations per publication, and h-index for each faculty member were obtained using the Scopus database (www.scopus.com). Self-citations were excluded using the available software option in "Author Results" because such citations may falsely elevate h-index.[13,14] The number of publications was verified using the PubMed database (www.ncbi.nlm.nih.gov) to minimize potential inaccuracy in raw h-index values. Affiliation history and primary research interests in the health sciences were used to distinguish investigators with similar names.

Data among groups were compared using analysis of variance followed by application of the Tukey-Kramer multiple comparison test (faculty rank) or Aspin-Welch unequal variance test (program demographics, accreditation status, and TEE credentials) using NCSS 2001 software (NCSS, Kaysville, UT). The null hypothesis was rejected when $p < 0.05$. Data are presented as the mean ± standard deviation.

RESULTS

A total of 259 (204 men and 55 women) cardiothoracic anesthesiologists were identified from the SCA web site (8 instructors [3%], 123 assistant professors [48%], 56 associate professors [22%], 63 professors [24%], and 9 chairpersons [3%]). Thirty of these faculty members served as program directors (9 assistant professors [30%], 8 associate professors [27%], and 13 professors [43%]). The demographics of cardiothoracic anesthesia fellowship programs whose members underwent bibliometric analysis are summarized in Table 1. The average training program had 9 ± 4 faculty members. ACGME-accredited programs had a larger number of faculty members, more of whom were NBE diplomates in perioperative TEE than their counterparts in programs that were not accredited. The average academic cardiothoracic anesthesiologist had an h-index of 6 ± 7 with 28 ± 46 publications, 499 ± 988 total citations, and 13 ± 18 citations per publication (Table 2). The h-index increased significantly ($p < 0.05$) among successive academic ranks (instructors [1 ± 1], assistant professors [3 ± 3], associate professors [7 ± 5], professors [12 ± 8], and chairpersons [18 ± 13]). Significant differences in the number of publications and total citations also were observed among ranks. Program directors had an average h-index of 7 ± 7 with 29 ± 33 publications, 531 ± 802 total citations, and 13 ± 12 citations per publication. These data were similar to those of associate professors. Differences in the h-index among faculty ranks were observed regardless of program accreditation status (Table 3) or transesophageal echocardiographic credentials (Table 4). Faculty members working in ACGME-accredited programs had evidence of more extensive scholarly output (more publications and citations and higher h-indices) than their colleagues in programs that were not accredited (Table 3). For example, professors working in accredited programs had more publications (68 ± 49), more total citations (1,292 ± 1,071), and higher h-indices (14 ± 8) than those in programs that were not accredited (40 ± 43, 497 ± 600, and 8 ± 5, respectively; $p < 0.05$ for each). The scholarly output of

Table 2. Overall Bibliometric Analysis of Cardiothoracic Anesthesiologists

	n	Total Pubs	Total Cites	Cites-Pub	h-Index
Total	259	28 ± 46	499 ± 988	13 ± 18	6 ± 7
Chairs	9	120 ± 80	2,925 ± 2874	20 ± 11	18 ± 13
Program directors	30	29 ± 33*†	531 ± 802*†	13 ± 12	7 ± 7*†
Professors	63	59 ± 48*	1,040 ± 1,013*	17 ± 11	12 ± 8*
Associate professors	56	30 ± 50*†	422 ± 654*†	14 ± 13	7 ± 5*†
Assistant professors	123	7 ± 11*†‡	117 ± 267*†‡	11 ± 22	3 ± 3*†‡
Instructors	8	2 ± 3*†‡	26 ± 68*†‡	4 ± 8	1 ± 1*†‡

NOTE. Data are mean ± standard deviation.
Abbreviations: Pubs, publications; Cites, citations.
*Significantly ($p < 0.05$) different from chairs.
†Significantly ($p < 0.05$) different from professors.
‡Significantly ($p < 0.05$) different from associate professors.

Table 3. Bibliometric Comparison of Cardiothoracic Anesthesiologists Based on Program Accreditation

	+ Accredited					− Accredited				
	n	Total Pubs	Total Cites	Cites-Pub	h-Index	n	Total Pubs	Total Cites	Cites-Pub	h-Index
Total	151	37 ± 53	694 ± 1,199	16 ± 20	8 ± 8	108	17 ± 30*	234 ± 487*	10 ± 13*	4 ± 4*
Chairs	4	154 ± 104	4,627 ± 3,660	27 ± 11	26 ± 15	5	92 ± 51	1,563 ± 1,121	15 ± 8	11 ± 6
Program directors	15	37 ± 40	770 ± 1,043	15 ± 16	9 ± 7	15	20 ± 24	293 ± 350	12 ± 7	6 ± 6
Professors	43	68 ± 49	1,292 ± 1,071	19 ± 12	14 ± 8	20	40 ± 43*	497 ± 600*	12 ± 7*	8 ± 5*
Associate professors	31	39 ± 66	572 ± 834	16 ± 14	8 ± 6	25	19 ± 13	236 ± 217	13 ± 12	5 ± 3*
Assistant professors	69	11 ± 13	176 ± 335	14 ± 26	3 ± 3	54	3 ± 5*	43 ± 98*	9 ± 15	2 ± 2*
Instructors	4	3 ± 5	65 ± 112	8 ± 14	1 ± 2	4	1 ± 1	3 ± 4	2 ± 2	1 ± 1

NOTE. Data are mean ± standard deviation.

Abbreviations: Pubs, publications; Cites, citations.

*Significantly ($p < 0.05$) different from accredited.

academic cardiothoracic anesthesiologists with or without transesophageal echocardiographic credentials was similar independent of rank (Table 4).

DISCUSSION

The current results show that the average h-index of an academic cardiothoracic anesthesiologist is 6 ± 7. This average h-index in United States cardiothoracic anesthesiologists may be modestly higher than that observed in Canadian pediatric anesthesiologists[10]; O'Leary and Crawford[10] previously reported that the median (interquartile range) of the h-index in the latter cohort was 2 (1-5; range, 0-32). The average number of publications (28 ± 46) and citations per publication (13 ± 18) observed in the current survey also were somewhat greater than those described in this previous study (median [interquartile range] of 4 [1-9; range, 0-165] and 6 [1-15; range, 0-87], respectively). The precise distribution of faculty members among academic ranks was not specified in this pediatric anesthesiology study,[10] and, hence, a formal comparison between previous and current data is not possible. The current findings further indicate that h-index increases significantly among successive academic ranks from 1 ± 1 (instructors) to 18 ± 13 (department chairpersons). Differences in the number of publications and the total number of citations to these publications also were observed among academic ranks. In addition, senior faculty members had more citations per publication than their assistant professor and instructor colleagues. These findings were anticipated because the h-index and other citation metrics are dependent on the amount of time working in a given field.[5,15] The rank dependence of the h-index in academic cardiothoracic anesthesiologists observed here has been reported previously in other medical specialties.[5,6,8,16] For example, Lee et al[5] showed that the h-index increases with rank between instructor and full professor and is positively correlated with time after initial board certification and other citation parameters in academic neurosurgeons. Similar results were also observed in urologists[16] and radiologists.[8] The average h-index values observed in cardiothoracic anesthesiologists were very similar to those previously described in radiologists across academic ranks (eg, 12 ± 8 compared with 13 ± 11 for cardiothoracic anesthesiology and radiology professors, respectively)[8] but somewhat lower than their colleagues in neurosurgery and urology (16 ± 9 and 22 ± 11 for professors, respectively).[5,16] However, a formal comparison of h-indices among specialties may be not be entirely appropriate because the h-index is discipline dependent.[2,9] Indeed, faculty members who work in more highly specialized fields of study (such as cardiothoracic anesthesia) tend to have lower h-indices than their counterparts whose work may have a wider appeal in the scientific community as a whole.[2]

The current results also indicate that cardiothoracic anesthesiologists working in ACGME-accredited fellowship programs had evidence of greater scholarly output than their counterparts in programs that were not accredited. ACGME accreditation of an adult cardiothoracic anesthesia fellowship program is based on many factors, among which is the relative academic strength of its faculty members. From this perspective, the current findings showing differences in scholarly output among faculty

Table 4. Bibliometric Comparison of Cardiothoracic Anesthesiologists Based on Transesophageal Echocardiographic Credentials

	+ Credentials					− Credentials				
	n	Total Pubs	Total Cites	Cites-Pub	h-Index	n	Total Pubs	Total Cites	Cites-Pub	h-Index
Total	147	25 ± 44	432 ± 933	14 ± 20	6 ± 7	112	33 ± 48	588 ± 1,056	13 ± 14	6 ± 8
Chairs	3	111 ± 83	3,368 ± 4,110	24 ± 15	20 ± 16	6	124 ± 87	2,703 ± 2,507	18 ± 9	16 ± 13
Program directors	23	33 ± 38	607 ± 895	13 ± 13	8 ± 7	7	15 ± 12	283 ± 278	15 ± 9	5 ± 4
Professors	28	59 ± 46	1,123 ± 1,024	20 ± 14	13 ± 7	35	61 ± 52	1,012 ± 1,032	14 ± 8	11 ± 7
Associate professors	36	31 ± 61	331 ± 615	12 ± 7	6 ± 5	20	28 ± 19	584 ± 707	19 ± 19	7 ± 6
Assistant professors	73	8 ± 11	142 ± 317	13 ± 25	3 ± 3	50	6 ± 10	78 ± 159	9 ± 15	2 ± 3
Instructors	7	2 ± 3	30 ± 73	4 ± 9	1 ± 2	1	0	0	0	0

NOTE. Data are mean ± standard deviation.

Abbreviations: Pubs, publications; Cites, citations.

members at accredited compared with nonaccredited programs are intuitive. The differences in scholarly activity also may be related, at least in part, to the fact that anesthesiology departments with accredited adult cardiothoracic anesthesiology fellowship programs received more National Institutes of Health (NIH) grant support (data obtained from the Blue Ridge Institute for Medical Research [www.brimr.org]) than departments whose fellowship programs were not accredited ($2.26 ± $1.62 million compared with $0.96 ± $2.30 million, respectively, for fiscal year 2009). A correlation between departmental NIH funding and the h-index previously was shown in academic radiologists; chairpersons, professors, and associate professors from departments ranked in the top 25 NIH-funded radiology programs had more publications and higher h-indices compared with their colleagues working in programs with less NIH funding.[8] It appears highly plausible that the scholarly output of cardiothoracic anesthesiologists working in departments with greater NIH funding also benefits directly or indirectly from the presence of extramural grant support, but a formal analysis of a possible relationship between the relative publication success of anesthesiologists and the amount of departmental NIH funding has yet to be conducted. It also is likely that faculty members working in accredited programs may receive additional nonclinical time to pursue other academic activities (including the publication of peer-reviewed research) compared with their peers in nonaccredited programs, but whether this factor affected the current results could not be ascertained because this information was not requested from each cardiothoracic anesthesiologist. In contrast to the observations with program accreditation, the presence or absence of transesophageal echocardiographic credentials was not associated with the differences in scholarly output among cardiothoracic anesthesiologists at each academic rank. The authors were not entirely surprised by this result because the transesophageal echocardiographic credentialing process requires primary expertise in a set of specific clinical skills that may be unrelated to those necessary to publish work in the peer-reviewed literature. Transesophageal echocardiographic certification rates also may be lower in older cardiothoracic anesthesiologists, and this observation also may play a role in the lack of differences among groups.

The current results should be interpreted within the constraints of several potential limitations. The h-index derived from Scopus evaluates citations of work published after 1995. As a result, the true h-index of a senior faculty member with a substantial number of highly cited articles that were published before this date may be underestimated.[16] Nevertheless, significant differences in the Scopus-derived h-index were observed among academic ranks independent of the database's temporal bias. A positive correlation in h-index calculations between Scopus and Google Scholar (which includes work published before 1995) databases previously was shown.[5] Thus, the authors feel confident that the use of the Scopus database provided a reasonable estimate of the h-index in cardiothoracic anesthesiologists. The h-index may inappropriately favor well-known investigators,[5,17] thereby artificially increasing the h-index values of some chairpersons or professors who are particularly renowned in cardiothoracic anesthesia. This factor cannot be definitively excluded from the analysis. The h-index does not identify whether citations to a specific article are positive or negative in nature. As a consequence, a highly controversial article may be cited very frequently and generate a falsely inflated h-index for its authors, but it seems unlikely that such an error would influence the overall interpretation of the current data considering the sample size studied here. A high h-index in a given discipline is certainly a strong indication of academic productivity, but faculty members with a relatively small number of highly cited articles (and, hence, a low h-index) also may be viewed as quite influential.[10] Thus, the current results certainly do not imply that faculty members with higher h-indices are somehow exclusively important in their scholarly contributions to the specialty. A cardiothoracic anesthesiologist who is a frequent participant in large multicenter clinical trials with many coinvestigators also may have a disproportionately high h-index because the publications resulting from such studies often are cited extensively.[2,16] Whether this factor played a role in the current results is unknown, but many chairpersons and professors have conducted or participated in important clinical research, including multicenter trials, throughout their careers and their h-indices may have been elevated as a result. The authors were unable to ascertain whether accredited cardiothoracic fellowship programs had more members who were active in such large-scale clinical research projects than their counterparts in programs that were not accredited. The h-index does not discriminate between original research publications and review articles, the latter of which also may be cited extensively.[18] The authors did not attempt to exclude review articles or other publication formats from the analysis.

A number of other potential limitations also deserve comment. The h-index is a cumulative score for each investigator over the course of a career but does not provide information about annual productivity. Thirty United States adult cardiothoracic anesthesia fellowship programs, which included a total of 259 clinical faculty members, were selected randomly in an attempt to minimize selection bias. Nevertheless, the authors did not examine all the cardiothoracic anesthesiologists who participate in training fellows. Pediatric cardiothoracic anesthesiologists programs were not studied, and therefore, conclusions cannot be drawn about scholarly productivity of this subgroup. The authors did not attempt to make distinctions about the relative research, educational, and administrative time commitments of each academic cardiothoracic anesthesiologist. Clearly, those faculty members with dedicated research time may be expected to produce greater numbers of publications and have higher h-indices than those committed solely to clinical or administrative obligations. This observation may have contributed to greater scholarly output noted in accredited programs departments because of the suggested association with greater NIH funding. Whether the current bibliometric findings in United States academic cardiac anesthesiologists are similar to those in their colleagues in other countries is unknown, but the current data may facilitate subsequent comparisons of scholarly productivity between cardiac anesthesiologists in other countries and their American colleagues. Finally, the authors were unable to account for the possible effects of gratuitous authorship on the current bib-

liometric analysis because such "honorary" inclusion of chairpersons or senior faculty members may continue to occur despite the fact that journals have adopted more rigorous authorship guidelines in recent years.[19,20] In summary, the current results show that h-index increases progressively with academic rank and is dependent on fellowship program accreditation status but not TEE credentials in United States academic cardiothoracic anesthesiologists.

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