Commentary on:
The Spectrum of Altmetrics in Neurosurgery: The Top 100 "Trending" Articles in Neurosurgical Journals
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Publication Metrics in Neurosurgery

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Evolutionary changes in health care over the past 2 decades have dramatically altered the landscape of academic medicine. Increasing clinical responsibilities, constant documentation reminders, repeated retraining requirements, complex quality metrics, and relative value unit productivity targets are the parameters by which physicians are measured today. These strictures are ever-present and have a great impact on salary and reimbursement and frequently influence physician comportment. For academic physicians, there is 1 more aspect to address or be cognizant of: scholarly efforts in the form of teaching, lectures, research, and publications. Published works in particular are valued and considered sine qua non for the career of an academic physician. They have a significant impact on promotion and tenure decisions. In fact, the privilege of being involved in resident education in the context of an American Council for Graduate Medical Education—accredited program comes with the requirement for publication, preferably in indexed and peer-reviewed journals. This is reported annually, and programs can be cited if their physician or resident faculty have inadequate records of publications. However, there are tangible benefits; published works elevate the silhouette of a program or department, increase its attractiveness to applicants, and raise the profile of the individual physician among academic peers or physicians from other disciplines.

Time, of course, is of the essence. The pressure on physicians to be clinically busy has eroded the protected time that used to be dedicated to research or scholarly endeavors. On occasion, academic physicians abandon these efforts and settle into a clinical track of patient care and teaching; others modify their practices and carefully parcellate time for patient care while staying active in the research and publishing arena. There are also different levels of published material; articles based on randomized controlled multicenter trials or externally funded basic science research are considered top-drawer, but scholarly production may also be in the form of book chapters, published abstracts, technical or case reports, or cohort studies. Social media posts such as blogs or online topic reviews are additional forms that have entered this arena in the age of the Internet. In some instances, especially to the lay public, the last-mentioned forms may actually be more accessible and hence may influence referral patterns and the clinical practice of a physician. Thus, each form of scholarly output potentially serves an important role. It is imperative that they are properly developed and inform in a way that positively influences the care of patients. It is also imperative that we develop methodologies to measure the impact of these disparate academic outputs so as to appropriately accord credit to physicians for their work.

Traditional bibliometrics used to evaluate academic faculty for promotion and tenure apply analytic tools and statistical methods to examine scholarly publication and citation. These are also used to compare same-specialty departments at different institutions.[1-5] Material indexed in databases such as PubMed are easily accessed and quantified and can provide a rapid estimate of an individual's portfolio.[1,2] Physicians also provide updated curriculum vitae or other documents to substantiate their efforts, but this may be less precise or more difficult to correctly attribute credit to. To address some of these concerns, in 2005, Hirsch[2] introduced a more sophisticated method to assess the impact

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Table 1. Summary of Common Bibliometric Indices

Index	Year Introduced	Definition	Uses	Advantages	Limitations
h-index	2005	Number of articles (h) with at least the same number (h) of citations	Measures individual published scholarly output with scientific impact based on citations; most widely used author metric	Easily calculated, easily understood; available from Web of Science, Scopus, Google Scholar, Harzing's Publish or Perish	Every author gets equal credit, favors older authors and larger specialties
m-index	2005	h-index divided by number of years since author's first publication	Allow comparisons of researchers with different career lengths	Allows younger authors and researchers to receive more credit	Every author gets equal credit
g-index	2006	Articles ranked in decreasing order of number of citations received; g-index is the largest number such that the top g articles received together at least g2citations	Gives more weight to highly cited articles	Allows highly cited articles to bolster less cited articles	Saturates when average number of citations for all published articles exceeds total number of published articles
e-index	2009	Square root of surplus of citations in the h-set beyond h2	Differentiate between scientists with similar h-indices but different citation patterns	Allows for higher impact researchers with high-impact concepts to be differentiated	Cannot calculate e-index independent of h-index
i10- index	2011	Number of publications with at least 10 citations	A simple way for comparing author impact	Simple, straightforward	Used only in Google Scholar

of an individual's work. He termed it the "h-index" and based it on the number of published papers an individual has that have the same number of citations.[2] The h-index may seem simplistic, but it is a remarkably accurate measure of an individual's scientific productivity and the scientific impact of the work. It is also an excellent predictor of the scientific impact of an individual's work and future potential, and it allows comparison of an individual with his or her academic peers.[1] The h-index has gained popularity and is now easily available through online databases such as the Web of Science, Scopus, and Google Scholar, and it complements other citation analysis tools. Most medical and nonmedical scientific disciplines have embraced it; Spearman et al.[1] sampled data pertaining to 1120 academic neurosurgeons and noted an average h-index of 9 and an increasing h-index linked to increasing academic rank.

Measures of academic productivity such as the h-index are not perfect and have limitations. For example, publications may not be universally listed in all databases, and citation analysis tools may not have access to all databases, or the tool may be susceptible to repeated self-citation. Other criticisms are that the h-index credits review articles as much as original research, it gives equal credit to all authors listed on a publication, it has a "ceiling effect" (some articles may not be accorded credit in the h-index if the number of citations overall for that author's work are low), it favors senior researchers who have a longer window of time to accumulate citations, and it favors fields with greater numbers of researchers and publications (the h-index should not be used to compare researchers in different fields).[1,5,6] There are other limitations; younger authors may take years to accumulate citations, seminal work that is ahead of its time may not be recognized for years, and finally there is concern that the h-index values quantity over quality.[5,6] The h-index and other citation analysis or bibliometric tools also vary on the accessibility and fidelity of the database used to determine their value. Google Scholar is free, is frequently updated, and has a wide coverage, but it does not list all its sources and includes citations in non—peer-reviewed publications, such as conference proceedings or books.[5,6] Scopus is considered most appropriate for bibliometric analysis at an individual level, but it does not count citations before 1996.[5,6]

Hirsch[2] suggested modifying the h-index by dividing it by the author's years in the scientific field; the m-index is defined as the h-index divided by the number of years since the individual's first publication.[1,5,6] In 2006, Egghe[3] introduced the g-index; this tool takes into account articles by an author that have a greater impact than other works that may be less cited.[6] However, even these metrics have limitations; an author who has published only a few articles but of a very high quality that are frequently cited may have a low h-index or g-index; in these cases, a traditional qualitative analysis would perhaps be most appropriate.[5,6] There are other metrics as well that are less well known. In 2009, Zhang[4] introduced the e-index; the square root of the difference between the total number of citations in h articles minus h^2.[6] Another alternative is Google's i10 index, which is the number of articles with $\geq$10 citations.[5,6] All these metrics provide the ability to carefully distill the significance of a researcher's work, but in the end, their utility is valid only when viewed in the context of an individual's entire portfolio

in a particular field as assessed by their peers; they are an excellent inflection point that can strongly guide additional discussion (**Table 1**).[1-6] In fact, decisions regarding academic advancement should take into account other, equally important factors, such as departmental and organizational citizenship, clinical volume and outcomes, quality metrics, teaching and mentorship, board certification, leadership in professional organizations, acquisition of research funding, and presentations at national or international conferences.[1,5]

The evolution of the World Wide Web, Internet, and social media has altered the dynamics of scientific access and visibility.[7-10] Google and other search engines are initial choices for quick searches on a particular topic and guide subsequent forays into a deeper review of subject matter; it may be into the PubMed portal sometimes but at other times, it may be into other sources that are also very informative. Patients and physicians use these tools daily and ubiquitously. In addition, organizations and institutions are increasingly recognizing the power of social media and establishing Facebook, Twitter, or other accounts to increase the visibility of the work of their physicians and scientists. The Internet has also changed the dynamics of both scientific and nonscientific publications—communication is seamless and rapid, collaboration between researchers at different locations is significantly easier, scholarly output is more easily assessed, and publication and production costs are dramatically decreased.[7] Service providers harvest and capture select information sources, and institutions have implemented the Semantic Web and protocols to promote interoperability between different systems.[7] Articles are now individualized with their own unique identity rather than grouped together as an indivisible unit bound in 1 journal issue, facilitating incredibly accurate and instant tracking of published manuscripts and authors.[7] This allows appropriation of credit to individual authors more accurately and impacts hiring, promotion, and funding decisions.[7] It also changes the dynamics of how scientific credit is appropriated.

The San Francisco Declaration on Research Assessment, which was drafted by a group of editors and publishers in collaboration with the American Society for Cell Biology and adopted in 2012, encourages funding agencies, institutions, publishers, and researchers to consider the value of all research outputs and to specify the criteria and methodology used in the assessment process in making promotion and tenure decisions. When we accessed it on June 7, 2017, at 12:30 PM, there were 859 organizations and 12,719 individuals who had indicated their acceptance and support and cosigned this declaration. In 2014, *Nature* published the Leiden Manifesto for Research Metrics, which lay forth 10 important principles in assessing scholarly work, as follows: 1) qualitative and quantitative assessment; 2) measurement of performance in the context of the research mission of the institution or research group; 3) promoting excellence in locally relevant research; 4) open, transparent, simple data collection and analytic processes; 5) processes for data verification and analysis; 6) accounting for variation in publication and citation based on the field of research; 7) qualitative assessment of a researcher's entire body of work; 8) avoidance of misplaced or unsubstantiated conclusions; 9) recognition of the systemic effects of the research; and 10) regular scrutiny and updating of metrics and indicators.[7,8] The sum total of the deliberations from these scientific bodies was recognition of the complex nature of research and scholarly productivity and the need for careful appraisal to accord appropriate credit to researchers individually and as a group.

To address the issue of bibliometrics in the Internet age, the field of altmetrics was introduced in 2010.[7-11] Altmetrics complement traditional research impact metrics with article-level metrics by measuring article views, downloads, and mentions in social and other online media. They are based on sources widely available on the web and social media that allow one to assess the impact of a particular body of research or published work on the general public, administrative bodies, or one's peers.[7-11] Altmetrics cast a much wider net scooping up mentions on social media, online encyclopedias such as Wikipedia, reference managers such as Mendeley, or public policy documents. Researchers and institutions recognize the importance of these sources and are using the metrics to complement traditional metrics; in fact, altmetrics may even predict which articles will receive traditional citation recognition in the long run. Altmetrics are a record of the attention a work receives, the extent of its dissemination, and an indicator of its impact; they are rapidly available from websites such as PLoS, altmetric.com, impactstory.org, or citedin.org.[9] They are qualititative and quantitative data that complement traditional citation metrics such as the h-index.[7-10] However, they are not reflective of the quality of the individual's work; they are merely an indicator of interest or attention paid to a particular topic or article and at times may be susceptible to artificial inflation.[10] However, they do provide a more complete picture of how a researcher's work has influenced conversation, thought, and behavior and ultimately society as a whole.[10] Almost a quarter of traditional journals themselves publish altmetric scores. Publications from social sciences, humanities, life sciences, and medicine are most represented in altmetric analyses, suggesting both a value and a need to be attentive to these metrics in these fields.[9]

Although altmetric scores may have some predictive value on a citation index, they are not reflective of the quality or long-term impact of a particular article on the field. However, traditional bibliometrics are also handicapped.[7] It used to be easy to spot the best journals and focus one's attention on them, whether as a contributing author or as an interested reader. However, the unfettered proliferation of scientific journals has blurred the landscape significantly. Similarly, the process of scholarly work and manuscript publication has been diluted to some extent. Institutions with fellows or similar personnel who can devote the time and effort to manuscript preparation are advantaged, and scores of manuscripts emerge from their institutions with senior authors accumulating large volumes of publications with limited effort. Certainly, they deserve credit for their mentorship and guidance of these efforts, but promising individuals at institutions without these support structures are unfairly disadvantaged. Their time and talent are occupied in clinical care; their intellectual contributions are less recognized, and they represent an untapped pool of intellectual talent. Their efforts may surface on the web but may not rise to the level of peer-reviewed premier publications. It is possible that altmetrics may serve as a tool to provide recognition to these individuals by providing data that offer a compelling narrative of the reach and interest in their work.

We must carefully set the standard, especially in the present constantly evolving world of electronic media. Carefully regulated, meticulously peer-reviewed publications and traditional metrics such as the h-index remain the gold standard, and it behooves the scientific community to adhere to these measures.[7] They have stood the test of time and likely will retain their value. The other numerous sources of information readily available on the Internet are not held to the same standards or as carefully vetted. They may serve a purpose, but they are not ready for "prime time" in terms of decision making for career advancement or grant funding decisions.[10] It is hence imperative for researchers and authors to adapt to this changing environment but not sacrifice quality or the fidelity of their communications. The best journals and authors recognize this and have established a presence on social media to complement their academic portfolio.[7,9,11] That is the best-case scenario, as these are the most reliable sources of medical information.

Toward this end, in their article recently published in **WORLD NEUROSURGERY**, Wang et al.[12] give us a useful snapshot of the blending of these 2 disparate universes; they provide evidence that our best journals and authors are also socially accepted and respected. That is exactly where we want to be as a neurosurgical community and profession; data available via altmetrics can reflect a more complete picture of neurosurgery's research and scholarly output to the world. It allows us to leverage the social media narrative so that it reflects the best and latest technologies and advances that have been properly vetted and provides sources of reliable and accessible information to the general public. It is unlikely that altmetrics will replace traditional bibliometrics in the assessment of academic physicians, but they will likely play a complementary role that is unlikely to diminish.[10] This article from a reputed academic group provides excellent validation to this concept of academia in the new universe of social media.[12]

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