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ORIGINAL RESEARCH

Top-cited articles on simulation in the medical education field

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Abstract

Simulation-based medical education (SBME) has been widely used in various medical fields. Simulation enables learners to acquire not only clinical techniques but also professionalism, communication, and teamwork skills. Simulation is also a useful method for clinical teachers to assess learning outcomes. Our study examined the evolution and focus of SBME through a review and analysis of the top-cited articles in the field of medical education. The search strategy was based on the following algorithm in Scopus to obtain SBME-related articles published in English before October 31, 2020: ("simulation" [All Fields] OR "simulated" [All Fields] AND ("education, medical" [MeSH Terms] OR ("education" [All Fields] AND "medical" [All Fields]) OR "medical education" [All Fields]). Most of the top-cited articles were published between 2005 and 2010 (n = 58; 58%). Original research was the most common research type (n = 58; 58%), followed by reviews (n = 33; 33%). The most commonly studied subject was "critical care medicine" (n = 20; 16.1%), followed by "emergency medicine" (n = 18; 14.5%). The leading research target groups were health care providers (n = 54; 50%), postgraduates (n = 28; 25.9%), and undergraduates (n = 8; 7.4%). In conclusion, simulation was most widely used in critical care medicine and emergency medicine. Junior residents and medical students were the most common learners in these studies. Simulation was also useful for training for specific procedures and team resource management, especially in multidisciplinary groups.

Keywords

Simulation; Medical education; Residents; Team resource management; Procedure training

1. Introduction

Medical education began to develop after its importance was recognized in the first half of the 19th century in Europe and the mid-19th century in the United States [1]. Researchers and practitioners agree that repeated practice is a crucial component of medical education; however, learning clinical skills through this method has become increasingly difficult for medical students and junior residents owing to concerns over patient rights and safety. Simulation was first used in aviation training, which, similar to the medical field, involves life-threatening risks [2]. Later, simulation was introduced to medical education and then applied widely [3].

Currently, simulation-based medical education (SBME) is widely used and has become crucial to various medical fields. SBME not only provides an alternative approach to acquiring new skills but also creates an interactive learning environment for teachers and learners. Additionally, it helps learners acquire clinical competencies such as professionalism, communication skills, and teamwork, rather than techniques only [4–6]. Simulation is also a useful method of assessing learning outcomes in a controlled environment [7]. Simulation-based assessments such as objective structured clinical examinations (OSCE) can not only test medical knowledge but also facilitate the efficient evaluation of clinical competency.

SBME has been extensively studied in recent years, and related articles are numerous and dazzling. In this study, we aim to examine the evolution and focuses of simulation in medical education through a review and analysis of the top-cited articles in this field. Understanding this topic will help illuminate the areas of focus of researchers in this field and promote further research and development in SBME.

2. Materials and methods

2.1 Study design and setting

We conducted a systematic review of the literature according to a predesigned protocol and inclusion and exclusion criteria. The study was approved by our institutional review board (IRB no. 202100675B1).

2.2 Study protocol

We aimed to include the most influential articles on the application of simulation to medical education according to their number of citations. Using the database Scopus, we collected articles on SBME and recorded the collected data with a predesigned Excel form. Research articles on the use of simulation in medical education, published in English, were included. Simulation studies that did not involve medical education or were published in other languages were excluded.

The search strategy was based on the following algorithm: ("simulation" [All Fields] OR "simulated" [All Fields]) AND ("education, medical" [MeSH Terms]) OR ("education" [All Fields] AND "medical" [All Fields]) OR ("medical education" [All Fields]). The search was limited to English-language publications.

The literature search was conducted between October 21 and October 30, 2020, and 5544 articles were identified. These articles were then reviewed in descending order according to the number of citations. Two independent reviewers (YRL and SYC) screened the titles and abstracts of the articles according to the inclusion and exclusion criteria. Next, the two reviewers shared their results and extracted articles that they had both included. Any conflicts between the two reviewers were resolved through discussion with a third reviewer (CHL). This review process finally yielded 100 top-cited articles. We used a customized Excel form to record information on each article as follows: article type, first author, research target group, study subject, publication date, journal category, and country of publication. The 100 included articles were further quantitatively analyzed or described narratively.

2.3 Data analysis

Descriptive statistics of the aggregated data are presented using counts and proportions. Separate descriptive analyses according to publication date, country, and specialty were conducted. Further sub analyses were conducted according to study content, research target group, specialty category, article type, and research trend. Statistical analysis was performed using Microsoft Excel 2016 (Microsoft Corporation, Seattle, WA, USA).

3. Results

A total of 5544 articles was generated from our result of search between 1946 to 2019. According to its publication type, they were classified as 3985 articles (71.9%), 613 conference papers (11.1%), and 571 reviews (10.3%). The overall cited number of the searched articles was 92,699 and the average cited times was 16.72. The included 100 top-cited articles, which accounted for only 1.8% of the articles, had a total 15,077 cited times (16.26% of the total cited times) and a much higher average cited number (140.91 times).

Supplementary Table 1 summarizes the top 100 articles in descending order by number of citations, along with the following information: (1) rank, (2) first author, (3) title, (4) publication year, (5) publishing journal, (6) article type, (7) number of citations, and (8) country of publication. The most frequently cited article was "Anesthesia crisis resource management training: Teaching anesthesiologists to handle critical incidents" by Howard, which is an original article published in *Aviation Space and Environmental Medicine* in 1992 and has been cited 502 times. The second most-cited article was "Low- to high-fidelity simulation: a continuum of medical education?" by Maran, a review article published in the *Medical Education* supplement in 2003, the peak publication period of these articles.

The 100 top-cited articles were distributed between 1992 and 2015, with most being published between 2005 and 2010 (n = 58; 58%) and the peak publication year being 2008 (n = 42; 42%; Fig. 1). Most of the articles were original articles (n = 58; 58%) and review articles (n = 33; 33%; Fig. 2).

Fig. 3 illustrates the study categories. Because the articles could be attributed to different categories simultaneously, according to Journal Citation Reports, the denominator for percentages was greater than 100. The most commonly studied subject was "critical care medicine" (n = 20; 16.1%), followed by "emergency medicine" (n = 18; 14.5%), "medicine, general & internal" (n = 17; 13.7%), "health care, sciences, & services" (n =16; 12.9%), and "surgery" (n = 11; 8.9%). The most common research target group was "health providers" (n = 54; 50%), meaning that the target group included mixed job categories or was not well defined in the articles (Fig. 4). Besides health providers there were postgraduate year (PGY) residents (n = 28; 25.9%) and undergraduate year (UGY) students (n = 8; 7.4%). In terms of the country of publication, an overwhelming majority of articles were from the United States (n = 74; 74%), followed by the United Kingdom (n = 11; 11%; Fig. 5).

Among the 100 included articles, 17 were associated with skills training, including central venous catheter insertion, airway management, endoscopy, and arthroscopy (Table 1). Finally, 11 articles focused on team resource management (TRM) in medical education.

TABLE 1. Most common topics of top-cited articles on simulation in medical education.

Practice of skills	Article number
CVC	4
airway	3
endoscope	4
arthroscope	3
others	3
TRM learning	
emergency medicine	4
ACLS	1
pediatric	1
teamwork	5

CVC, central venous catheter; TRM, team resource management; ACLS, advanced cardiac life support.

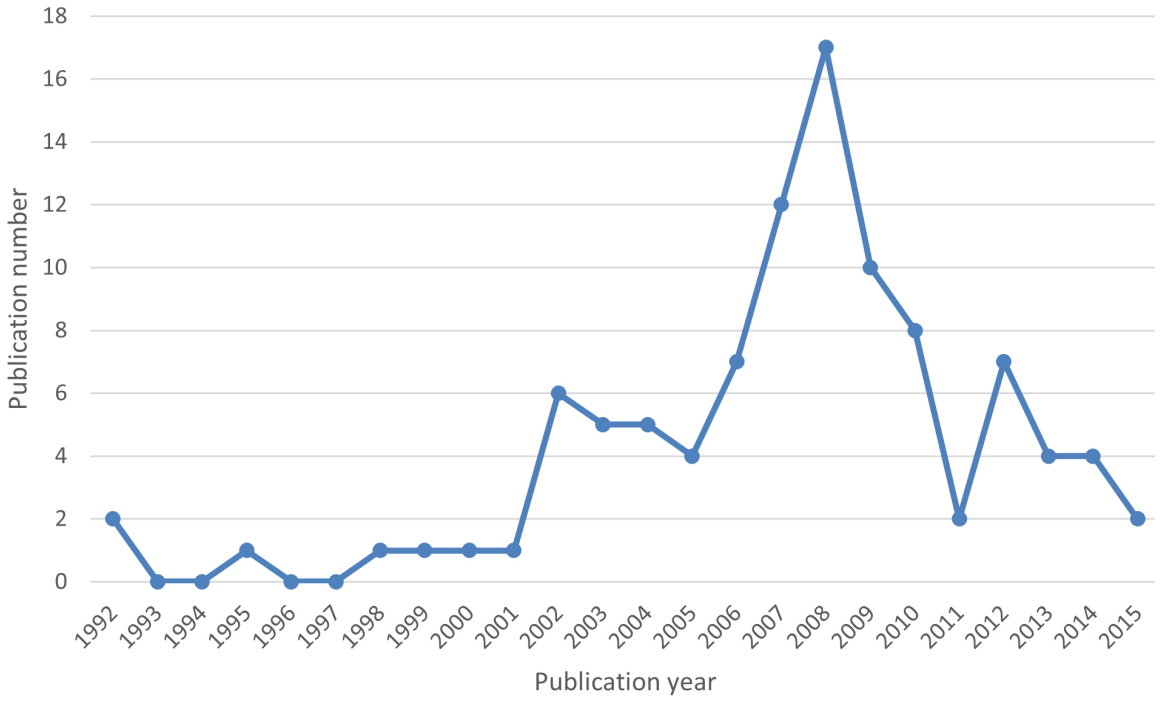

FIGURE 1. Distribution of top-cited articles by year.

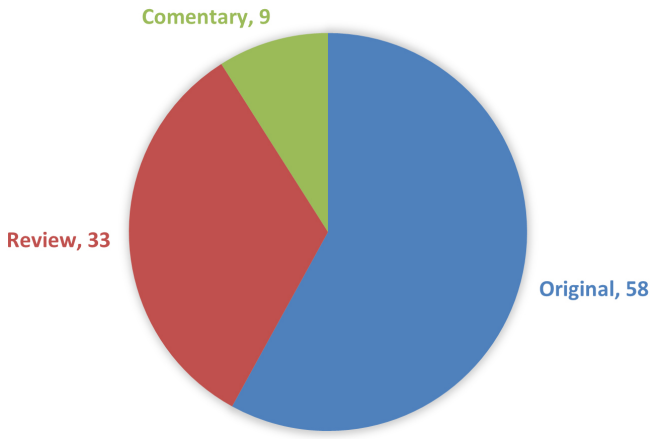

FIGURE 2. Publication types of top-cited articles.

4. Discussion

Simulation is a well-studied and widely applied teaching method in medical education [8–10]. Research on simulation in medical education increased rapidly over the past few decades; in fact, our study revealed that most of the top-cited articles on the topic were published between 2005 and 2011. The observed decrease in the number of top-cited publications in recent years could be attributed to advances in simulation technology. Simulation has been used in nearly all disciplines of medical education since the past few decades, and its applications and effects were well studied in the top-cited articles. Naturally, these articles were cited much more than newer articles. By contrast, simulation-based methods using newer technology, such as virtual reality (VR) and augmented reality (AR), are still in development, and citations of related articles are increasing. New articles on the application of new technology to SBME are expected to form the bulk of top-cited articles in this field in the future [11].

The most common topics identified from these articles were critical care medicine, emergency medicine, and internal medicine. In critical care medicine and emergency medicine, clinical reasoning and decision-making are essential and can be practiced in simulated scenarios [12–15]. Simulation can effectively instill the ability to detect dangerous signs quickly and to respond appropriately in critical conditions. It is also useful for practicing specific skills, such as central venous catheter insertion, airway management, and endoscopy. In addition, a simulated environment affords beginners the opportunity to practice procedures in more accurate steps and to accelerate their skill acquisition. Beginners who participate in simulated education have increased levels of self-reported confidence and perform better after simulation training [16]. Simulating real surgical conditions is difficult in the surgical field, which limits the application of simulation in surgical education [17]. However, with new technologies such as AR and VR, this difficulty could be resolved in the future [18–21]. With the current development of new technologies such as high-resolution screens, mobile graphics processing units, and position-sensing devices, the application of relatively low-cost "new-generation" AR/VR devices in surgical training may grow on a large scale in the next generation [22].

Among the 100 articles, the most common target group of SBME was health care providers, with multiple job categories. Simulation is appropriate for teamwork training in the medical field because simulation and team resource management were learned from aviation [19, 23]. In a simulated scenario, cooperation between different roles as well as key elements of teamwork, such as leadership, communication, mutual support, and situation monitoring, can be practiced repeatedly [24–26]. The next most common target groups were PGYs and UGYs. For junior PGYs and UGYs, inadequate clinical

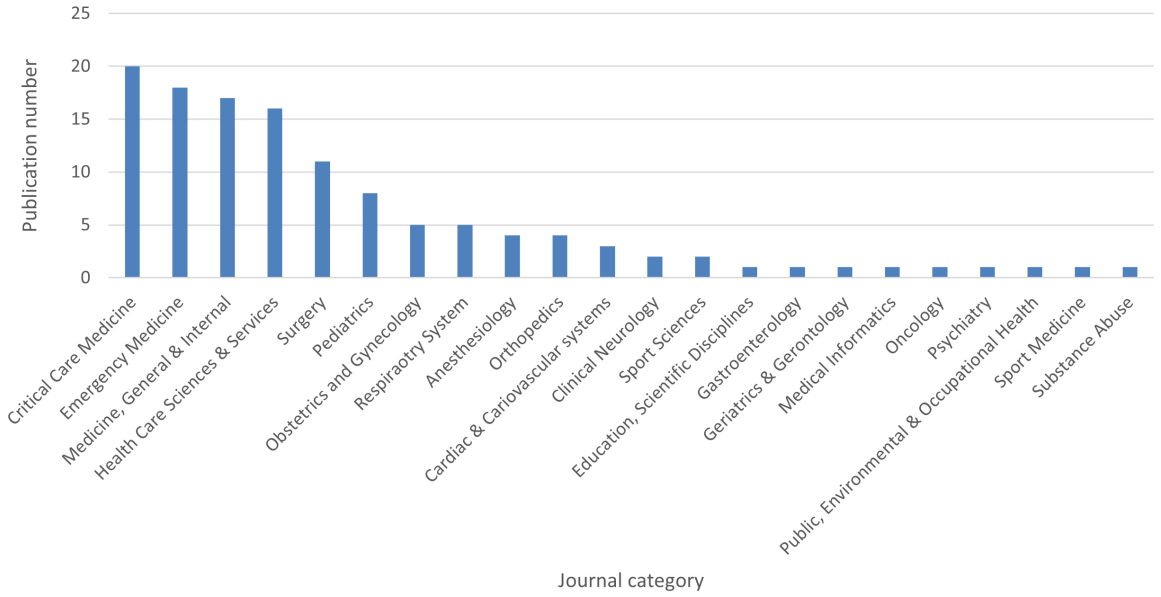

FIGURE 3. Categories of top-cited articles.

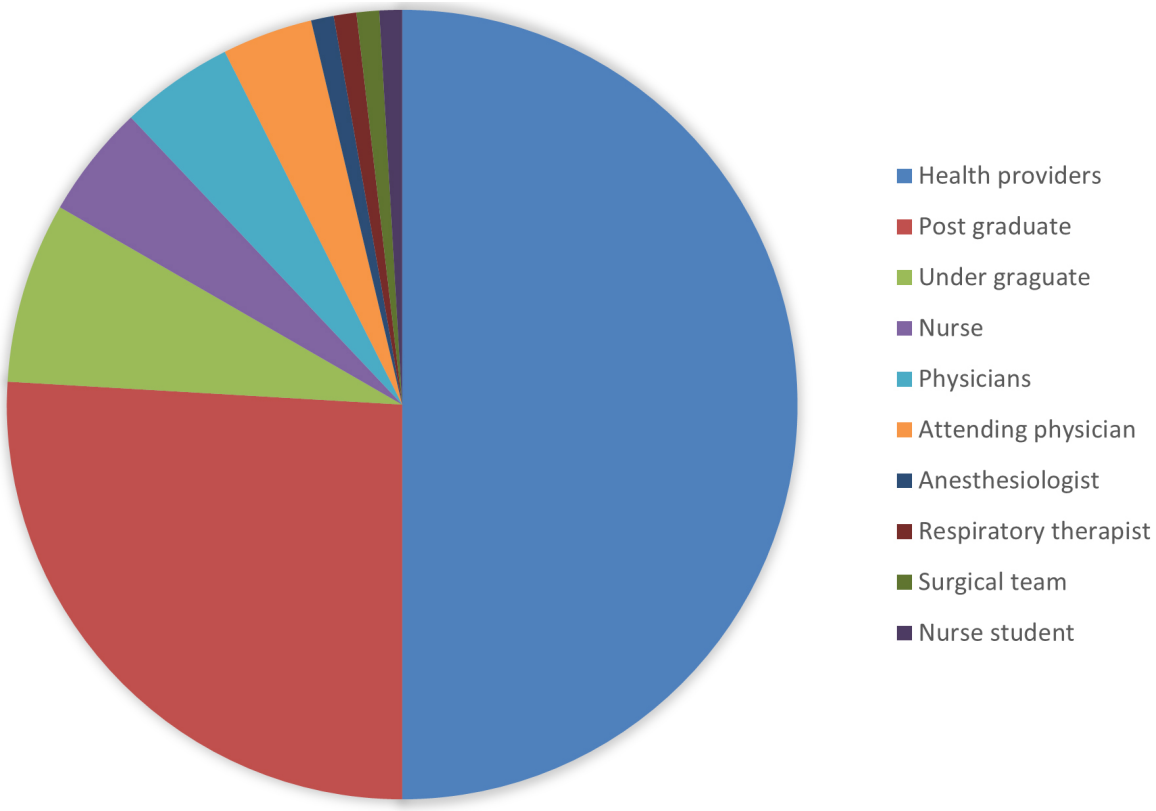

FIGURE 4. Research target group of top-cited articles.

experience and unfamiliar skills could be compensated for through simulated learning, which facilitates the safe and rapid acquisition of clinical competencies. Moreover, simulated learning could be employed in critical but less common topics, such as toxicology and emerging infectious diseases (e.g., coronavirus disease 2019) [27–29]. This makes simulation suitable for PGY/UGY training.

Geographically, the top-cited articles were published mainly in North America and Europe. Early development of simulation in medical education and adequate research resources are both possible explanations for this geographical concentration. Research on medical education in regions outside North America and Europe (e.g., Asia) has increased owing to increased attention to medical education in recent years. The application and effect of simulation in medical education could be influenced by different cultures and educational backgrounds. Furthermore, the comparison of simulated learning between different countries and cultures may provide a basis for future research.

Simulation plays a crucial role in medical education. With

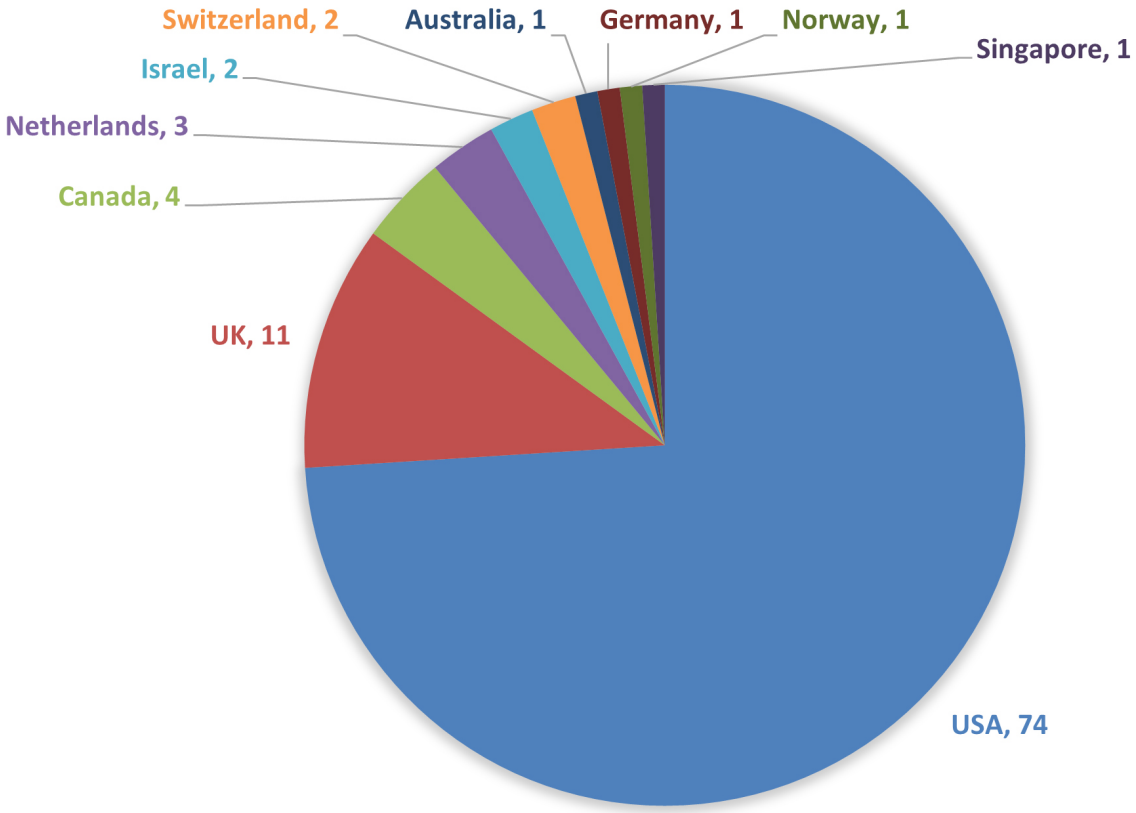

FIGURE 5. Countries of publication of top-cited articles.

the rapid advancement of technology, simulation could become more lifelike and capable of replicating complicated situations with real-time interactions and reactions. Studies on VR- and AR-based simulation in medical education have grown rapidly in recent years [30]. Artificial intelligence is another new technology that could improve simulated learning [31]. Research on the application of these new technologies to SBME is becoming popular, and relevant articles are expected to be cited considerably in the future. Although simulated medical education improves constantly, it should be noted that there are some differences between simulated medical education and clinical practice education, such as individual differences of patients' clinical manifestations and some influencing factors occurring in the clinical setting. While applying simulated medical education with advanced technologies, clinical teaching should be emphasized simultaneously to make medical education more comprehensive.

5. Limitations

This study had several limitations. First, we searched the top-cited articles in only one database, Scopus; the citation numbers and rankings of the articles may have been different if we had used other databases. However, our aim was to identify the top-cited articles rather than determine their ranks. Although the number of citations may have differed among databases, the first 100 articles would have been practically the same and would not have changed the analysis and outcomes. Second, we limited our search to articles written in English, meaning that several influential articles in other languages may have been missed in our study. Finally, our analysis focused on articles with high numbers of citations. Several valuable articles may be less cited if they are not recognized by the medical community, hence their exclusion from our study. Besides, some influential studies published in recent years may not be included in our study because of inadequate time to accumulate citation times. Further study focusing on these new publications would be necessary to know the new trend of this field.

6. Conclusions

Our analysis of top-cited articles revealed current trends and applications of SBME in the field of medical education. Simulation was most widely used in critical care medicine and emergency medicine. Junior residents and medical students were the most common learners in the studies. Simulation was also useful for training specific procedures and team resource management, especially in multidisciplinary groups.

ABBREVIATIONS

SBME, simulation based medical education; PGY, postgraduate years; UGY, undergraduate years; OSCE, objective structured clinical examination; VR, virtual reality; AR, augmented reality; CVC, central venous catheter; TRM, team resource management.

AUTHOR CONTRIBUTIONS

SYC conceived and designed the study, undertook data acquisition, and carried out data analysis and data interpretation. YRL wrote the manuscript draft. YCC provided statistical expertise. CHL undertook critical revision of the manuscript for important intellectual content. All authors read and approved the final version of this manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the institutional review board of the Chang-Gung Memorial hospital, Taiwan (IRB no. 202100675B1).

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Shou-Yen Chen is serving as one of the Guest editors of this journal. We declare that Shou-Yen Chen had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to XJ.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.signavitae.com/mre-signavitae/article/1470320914216173568/attachment/Supplementary%20material.zip.

AVAILABILITY OF DATA AND MATERIALS

The dataset supporting the conclusions of this article is included within the article and its additional file. The searching result from Scopus is named **Supplementary Table 2**. The summary and analysis of the included top 100 articles was named **Supplementary Table 3**.

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