High-impact papers in the field of anesthesiology: a 10-year cross-sectional study
Manuscrits à fort impact dans le domaine de l’anesthésiologie : une étude transversale sur 10 ans

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Abstract
Purpose This study was performed to evaluate trends in and provide future direction for anesthesiology education, research, and clinical practice.
Methods We collected high-impact papers, ranking in the top 10% in the field of anesthesiology and published from 2011 to 2020, by the InCites tool based on the Web of Science Core Collection. We analyzed the trends, locations, distribution of subject categories, research organizations, collaborative networks, and subject terms of these papers.

Results A total of 4,685 high-impact papers were included for analysis. The number of high-impact papers increased from 462 in 2011 to 520 in 2020. The paper with the highest value of category normalized citation impact (115.95) was published in Anesthesia and Analgesia in 2018. High-impact papers were mainly distributed in the subject categories of “Anesthesiology,” “Clinical Neurology,” “Neurosciences,” and “Medicine General Internal.” They were primarily cited in “Anesthesiology,” “Clinical Neurology,” “Neurosciences,” “Medicine General Internal,” and “Surgery.” Most of these high-impact papers came from the USA, UK, Canada, Germany, and Australia. The most productive institutions were the League of European Research Universities, Harvard University, University of Toronto, University of London, University of California System, and University Health Network Toronto. Research collaboration circles have been formed in the USA, UK, and Canada. Subject-term analysis indicated postoperative analgesia, chronic pain, and perioperative complications were high-interest topics, and COVID-19 became a new hot topic in 2020.

Conclusions The current study provides a historical view of high-impact papers in anesthesiology in the past ten years. High-impact papers were mostly from the USA. Postoperative analgesia, chronic pain, and perioperative complications were high-interest topics, and COVID-19 became a new hot topic in 2020. These findings provide references for education, research, and clinical practice in the field of anesthesiology.

Résumé
Objectif Cette étude a été réalisée pour évaluer les tendances et fournir une orientation future à l’enseignement, la recherche et la pratique clinique en anesthésiologie.
Méthode Nous avons colligé des articles à fort impact, classés dans le top 10 % dans le domaine de l’anesthésiologie et publiés de 2011 à 2020, par l’outil InCites basé sur la Web of Science Core Collection. Nous avons analysé les tendances, les emplacements, la répartition des catégories de sujets, les organismes de recherche, les réseaux de collaboration et les termes des sujets de ces articles.

Résultats Au total, 4685 articles à fort impact ont été inclus pour analyse. Le nombre de manuscrits à fort impact est passé de 462 en 2011 à 520 en 2020. L’article ayant la valeur la plus élevée de l’impact normalisé des citations de catégorie (CNCI) (115,95) a été publié dans la revue Anesthesia and Analgesia en 2018. Les articles à fort impact ont été principalement distribués dans les catégories de thèmes « Anesthésiologie », « Neurologie clinique », « Neurosciences » et « Médecine générale interne ». Ils ont été principalement cités dans les catégories « Anesthésiologie », « Neurologie clinique », « Neurosciences », « Médecine générale interne » et « Chirurgie ». La plupart de ces articles à fort impact provenaient des États-Unis, du Royaume-Uni, du Canada, d'Allemagne et d'Australie. Les établissements les plus productifs étaient la League of European Research Universities, l'Université Harvard, l'Université de Toronto, l'Université de Londres, l'Université de Californie System et le University Health Network de Toronto. Des cercles de collaboration en recherche ont été formés aux États-Unis, au Royaume-Uni et au Canada.

L'analyse des termes indiquait que l'analgésie postopératoire, la douleur chronique et les complications périopératoires étaient des sujets suscitant un fort intérêt, et la COVID-19 est devenue un nouveau sujet brûlant en 2020.

Conclusion La présente étude propose une vue historique des articles à fort impact en anesthésiologie au cours des dix dernières années. Les manuscrits à fort impact provenaient principalement des États-Unis. L’analgésie postopératoire, la douleur chronique et les complications périopératoires ont été des sujets d’actualité, et la COVID-19 est devenue un nouveau sujet en 2020. Ces résultats fournissent des références pour la formation, la recherche et la pratique clinique dans le domaine de l’anesthésiologie.

Keywords anesthesiology · education · high-impact papers · InCites · research · visual analysis

Anesthesiology is a key discipline that ensures safety and comfort during invasive procedures, improves surgical work efficiency, and coordinates the relationships among various disciplines.1–3 In recent years, significant progress has been made in anesthesiology, involving perioperative organ protection, perioperative anesthesia management for the elderly, development of new anesthetic drugs, and basic research into the mechanisms of anesthesia and chronic pain.4–11 Especially during the COVID-19 pandemic, anesthesiologists played important roles12–14 and undoubtedly saved many lives. Anesthesiology practice has been improved by the development of new anesthetics and monitoring equipment,3 a better understanding of the physiologic changes during surgery and anesthesia,15 and evidence of the clinical benefits of optimal perioperative management strategies.16 Because of its multidisciplinary nature, anesthesiology research can be applied to neuroscience, surgery, cardiovascular medicine, respirology, critical care, and other fields.

Literature analysis using large bibliometric databases17 can qualitatively and quantitatively evaluate current research trends,18,19 to determine future research directions and provide policy guidance for decision-makers.20 Several studies have analyzed literature in the field of anesthesiology. Robert et al.21 analyzed the literature on pain from 1976 to 2007 and traced the evolution of the scientific literature on pain over 30+ years; they concluded that the evolution and explosion of pain research were rapid and caused substantial changes in the landscape of the contributing countries and the scientific journals in the pain field. Chen et al.22 reported research trends in anesthesiology from 1995 to 2004 by analyzing 64,199 articles with 1,084,491 citations. They found that the number of articles increased slightly in the second decade. More than 45% of papers were published by the top five journals, and most publications originated from North America and European countries. It helped clinicians and researchers to understand the anesthesiology research activities in the second decade. Chen et al.23 reported global publication trends in anesthesiology from 1999 to 2018 and argued that more high-quality research should be carried out in low and middle-income countries. Although these studies determined progress in anesthesiology research over specific periods, they did not identify high-impact papers. As a consequence, the research trends of high-impact anesthesiology papers are still unknown.

To analyze high-impact papers in other fields, previous studies have collected and analyzed the top 1% or 10% papers using the InCitesTM tool based on the Web of Science (WOS) Core Collection (ClarivateTM, London, UK) and provided important evidence and references for research or education in nursing management,24 pharmacology, and pharmacy.25 Nevertheless, no such study has been performed in anesthesiology. Therefore, we
designed a cross-sectional study to analyze the high-impact papers in anesthesiology.

**Methods**

**Study design and ethical involvement**

This was a cross-sectional study based on previously published studies, and institutional review board approval was not required.25

**Inclusion and exclusion criteria**

The following inclusion criteria were used: 1) study was in the field of anesthesiology according to the InCites tool based on WOS Core Collection; 2) type of study was an article or review; 3) study was published between 2011 and 2020; 4) paper was high impact (defined according to a previous study,24 using “% Documents in Top 10%” in the InCites tool, which meant the percentage of the top 10% of publications based on citations by category, year, and document type). The following exclusion criteria were used: 1) the study was not found in the WOS Core Collection and 2) data could not be found in the database.

**Literature search and data extraction**

We conducted the literature search on 25 October 2021, using the InCites tool to find high-impact papers in the field of anesthesiology,25 and the search was updated on 7 July 2022. A total of 4,685 studies were identified. All data were downloaded by the InCites tool. The following information was extracted: Category Normalized Citation Impact (CNCI), title of article, journal name, location (country/region), and organization. The CNCI of a document was calculated by dividing the actual number of citing items by the expected citation rate for documents with the same document type, publication year, and subject area. When a document was assigned to more than one subject area, an average of the ratios of the actual to expected citations was used.26 The CNCI values were used to represent the citation performance on the world average—a CNCI value of more than 1 meant the impact was higher than the global average.26 To find the information of country or institution, the location or institution filter was used, respectively.

**Statistical analysis and visualization analysis**

The statistical and visualization analyses were carried out using Numbers software (Apple Inc., Cupertino, CA, USA) and VOS viewer (Leiden University, Leiden, The Netherlands). The Numbers software was used to draw figures to show the numbers of studies and the trends of studies.25 VOS viewer was applied to construct and visualize bibliometric networks. The networks might include journals, researchers, or individual publications, and they could be built based on citation, bibliographic coupling, co-citation, or co-authorship relations.27 The CNCI values, trends in the number and citation impact, subject areas, countries, institutions, collaborative networks, and subject terms were analyzed.

**Results**

**Trends of high-impact papers in anesthesiology**

High-impact papers in the field of anesthesiology increased from 462 in 2011 to 520 in 2020. The average CNCI value of high-impact papers was 4.50, which ranked about 139 among the 254 research areas (Electronic Supplementary Material [ESM] eTable 1). It decreased from 4.69 in 2011 to 4.21 in 2017 and then increased to 4.38 in 2019. Finally, the CNCI value increased substantially in 2020, reaching 5.46 (Fig. 1). The characteristics of the top ten CNCI value papers and top ten cited papers are shown in ESM eTable 2. The study with the highest CNCI value was a methodological study entitled *Correlation coefficients: appropriate use and interpretation*, which was published in *Anesthesia and Analgesia* in 2018,28 with a total of 1,176 citations and a CNCI value of 115.95. The publication with the second highest CNCI value was a guideline entitled *Consensus guidelines for managing the airway in patients with COVID-19: Guidelines from the Difficult Airway Society, the Association of Anesthetists the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anesthetists*,29 which was published in *Anaesthesia* in 2020, with a total of 335 citations and a CNCI value of 75.75. The most cited publication was a review entitled *Central sensitization: implications for the diagnosis and treatment of pain*,30 which was published in *Pain* in 2011, with a total of 2,010 citations and a CNCI value of 40.52. The journals with the highest impact factors were *The Lancet*, *The New England Journal of Medicine* (NEJM), *JAMA*, and *The BMJ*, which published 15, four, 19, and 14 high-impact papers, respectively.

**Subject categories of high-impact papers**

When searching for the 4,685 papers via WOS Core Collection, only 4,682 were found, including 3,994 articles (reports of research on original works) and 688 reviews (renewed studies of material previously studied). The average and median citation times for articles were 72 and 57, respectively. The average and median citation times for
reviews were 120 and 89, respectively. The results suggested that the reviews were cited more than the articles. The 4,682 high-impact papers could be divided into 15 WOS subject categories (ESM eFig. 1). After “Anesthesiology,” “Clinical Neurology” had the highest number of papers ($n = 1,475$), followed by “Neurosciences” ($n = 1,126$) and “Medicine General Internal” ($n = 331$). The 4,582 high-impact papers were cited by a total of 179,117 papers, which were distributed in more than 100 WOS subject categories. The 15 most frequently cited subject categories are shown in ESM eFig. 2. “Anesthesiology” accounted for the largest number of papers, with 39,402 citing papers. The citation impact of these high-impact papers extended to “Clinical Neurology” ($n = 19,835$), “Neurosciences” ($n = 17,944$), “Medicine General Internal” ($n = 15,170$), and “Surgery” ($n = 12,688$).

**Location of high-impact papers**

The locations that published the most high-impact papers in the field of anesthesiology were the USA, UK, Canada, and Germany (ESM eTable 3).

**Organization of origin of high-impact papers**

The organizations that published the most high-impact papers in anesthesiology were the League of European Research Universities, Harvard University, University of Toronto, University of London, University of California System, and UDICE-French Research Universities (ESM eTable 4). The top 15 organizations and their CNCI values are shown in Fig. 2 and ESM eTable 4, respectively.

**Cooperation network of institutions of high-impact papers**

Figure 3 shows the network of cooperation among institutions with the highest number of high-impact papers in anesthesiology from 2011 to 2020. Each color represents a cluster, which means that there was cooperation between institutions with the same color. The size of each node represents the number of papers, and the connecting line indicates cooperation. The network map revealed that there were six leading collaborative circles among institutions, which were mainly universities from the same country and region. Specifically, the largest node was the university groups from the USA and Canada (at the above corner), including the University of Toronto, Stanford University, and Duke University. The top
collaborative circles were mainly in the USA, UK, and Canada (ESM eFig. 3).

Subject-term heatmap of high-impact papers

We used VOS viewer to perform natural language processing on the titles and abstracts of the 4,682 high-impact papers and divide the processed subject terms and phrases into clusters. The warmer the color of topic terms on the heatmap, the higher the frequency of terms appeared in the literature. In the heatmap of all studies (Fig. 4), three main hot research topics were found. Postoperative analgesia was the first hotspot, including “analgesia,” “block,” “ultrasound,” “opioid consumption,” “pain score,” “Visual Analogue Scale,” and “vomiting.” Pain, especially chronic pain, was the second hot research topic, including “pain,” “chronic pain,” “pain intensity,” “pain severity,” “pain modulation,” “depression,” and “disability.” Perioperative complications was the third research hotspot, including “complications,” “mortality,”

Fig. 2 Numbers of high-impact papers in anesthesiology and CNCI values of the top 15 production institutions. APHP = Assistance Publique Hopitaux Paris; Inserm = Institut National de la Sante et de la Recherche Medicale, National Institute of Health and Medical Research in France; CNCI = Category Normalized Citation Impact; LERU = League of European Research Universities; UDICE = French Research Universities

Fig. 3 Map of collaborative networks among institutions of high-impact papers
“delirium,” “cardiac surgery,” “failure,” “discharge,” and “comorbidity.”

To evaluate the latest progress, we performed a subject-term heatmap analysis on papers published in 2020. From the heatmap (ESM eFig. 4), COVID-19 was found to be the new research hotspot, which included “COVID,” “pandemic,” “recommendation,” “risk factor,” and “coronavirus disease.”

To evaluate the difference in progress between article types, we performed a further analysis based on the article and review. In the heatmap of all articles (ESM eFig. 5), three main hot research topics, including postoperative analgesia, pain, and perioperative complications, were found. In the heatmap of reviews (ESM eFig. 6), postoperative analgesia, pain, perioperative complications, and COVID-19 were the main research topics.

To evaluate the most high-impact papers, we performed a further analysis based on the top 1% papers. A total of 482 papers were included. In the heatmap (ESM eFig. 7), four main hot research topics were included, which included postoperative analgesia, pain, perioperative complications, and COVID-19.

Discussion

In the present study on high-impact papers in anesthesiology over the past ten years, we hope it could provide reference for future education, research, and clinical practice in anesthesiology. We found that the number of high-impact papers published each year varied from 462 in 2011 to 443 in 2019 and significantly increased in 2020. The increased number of papers in 2020 might be due to the COVID-19 pandemic because anesthesiologists played important roles in fighting COVID-19. The increasing trend of high-impact papers in 2020 was similar to the results from previous pharmacology and pharmacy studies, indicating that COVID-19 had influenced global studies.

In this study, we compared a few top CNCI value papers and top-cited papers. The results show that the papers with high CNCI values were all published in journals of the Anesthesiology category, and four of them were published in 2020 with the COVID-19 topic. The top ten cited papers were published from 2011 to 2018 and were mainly published in anesthesiology journals, and their CNCI values ranged from 15 to 115. The papers with the highest impact were published in the top four medical general journals—Lancet, NEJM, JAMA, and BMJ published 15, four, 19, and 14 papers, respectively.
Interestingly, the top ten cited papers were not from the top impact-factor journals, which indicate that the research published in anesthesiology journals could be both high impact and highly cited. It was particularly encouraging that seven of the top ten cited papers were published in journals with an impact factor below 10. This observation indicates a wide range of citation models in individual journals. Therefore, the impact factor of a journal should not always be used to assess the feature of citation and the impact of papers.

In the study, we analyzed the interactions between different subject categories by papers and their citations. All high-impact papers were from 15 WOS subject categories and cited by more than 100 WOS subject categories, which suggests a strong influence from the anesthesiology high-impact papers. Anesthesiology is a multidisciplinary category that has attracted attention from various categories. Besides “Anesthesiology,” “Clinical Neurology” and “Neurosciences” were the top citing categories, indicating that the most important progress in anesthesiology has been made in the fields of “Clinical Neurology” and “Neuroscience.”

The results revealed that League of European Research Universities, Harvard University, University of Toronto, University of London, University of California System, and University Health Network Toronto were leading organizations in anesthesiology. Top-level cooperation was mainly based in the USA, Canada, and the UK, which implies that researchers collaborated more inside their own countries. It is necessary to conduct research cooperation with international institutions. The results show that the USA, UK, Canada, Germany, and Australia published the most high-impact papers, consistent with a previous study. It suggested that the high-impact papers had always been from high-income countries, and not so many papers were from low- and middle-income countries because low- and middle-income countries might lack funds, skills, and technology, leading to limited research level and ability. It is necessary to improve research ability and increase funds and training to reduce inequity, and promote publications from low- and middle-income countries.

To analyze the difference between types of studies, we performed a further analysis based on the types of published papers. For articles, we found three main hot research topics, which were almost the same as the total analysis; for reviews, COVID-19 emerged as the new hot topic, which was slightly different from articles, suggesting that COVID-19 had a high impact on the field. In addition, we performed a further analysis of the most high-impact papers (top 1% papers), and the results were almost the same as the data in 2020, which suggests the high impact of COVID-19.

There are several limitations to this study. First, the search was based on the “Anesthesiology” category, which might have missed some studies. Second, we only searched published papers from 2011 to 2020. Papers published before and after this period were excluded so that some other high-impact papers might have been missed. Another limitation was the inherent bias in the high-impact papers, which referred to the top 1% or 10% papers in a certain research field. The number of citations of papers accumulates over time, and thus, some papers might not be high impact at present, but they could be after a few months. This could have led to inaccuracy in analysis. Lastly, the study was based on the InCites tool. Misclassification that could not be excluded from research in some papers might also have led to inaccurate results.

Overall, the current research provides a historical view of the research progress in anesthesiology over the past ten years. High-impact papers were mostly from the USA. Postoperative analgesia, pain, and perioperative complications were topics of high interest, and COVID-19 emerged as a new hot topic in 2020. This research provides a reference for future education, research, and clinical practice in anesthesiology.

**Author contributions** Yonggang Zhang designed the study and edited the manuscript; Lingmin Chen searched for the data, analyzed the data, and drafted the manuscript; and Nian Li analyzed the data and drafted the manuscript.

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