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Top 100 most-cited articles on pediatric anesthesia from 1990 to 2023

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ABSTRACT

Pediatric anesthesia presents greater challenges than does adult anesthesia. This bibliometric analysis aimed to analyze the top 100 most cited articles to be better understand the hot spots and prospects in pediatric anesthesia. Articles and reviews related to pediatric anesthesia were retrieved from the Web of Science Core Collection from 1990 to 2023. A bibliometric analysis of the top 100 most cited articles was also performed using information such as topics, author names, countries, institutions, publication years, and journals. A total of 32 831 articles were identified, with a total of 32 230 citations for the top 100 articles. The peak period for pediatric anesthesia research was from 2005 to 2009. The USA has emerged as the most active country in pediatric anesthesia research. Major journals published included *Anesthesia and Analgesia*, *Anesthesiology*, and *Pediatrics*, underscoring their authority in the field. Clinical studies on the top 100 most cited articles have focused on different stages of the perioperative period, the use of different anesthetic agents, and adverse outcomes in pediatric patients. The current study conducted a bibliometric analysis of the top 100 most cited articles in the field of pediatric anesthesia. Such insights are valuable for identifying research hot spots, assessing academic impact and collaboration in pediatric anesthesia, and guiding future research directions.

INTRODUCTION

Research in the field of pediatric anesthesia began in the early 20th century, although early studies focused primarily on adults.[1] As medical science has advanced, pediatric anesthesia has gradually gained increasing attention and poses more challenges than adult anesthesia.[2 3] Children differ significantly from adults in physiological function, metabolism, and drug response.[4 5] Pediatric patients have higher oxygen consumption, decreased functional residual capacity, and increased CO_2 ratios, making them more susceptible to perioperative hypoxia compared.[6] Current concerns also include the comparison between general anesthesia and sedation in pediatric populations, and the challenges associated with each approach.[6] Psychological factors, such as anxiety due to the unfamiliar hospital environment and separation from parents, further complicate pediatric anesthesia.[7–9] The increasing focus on pediatric anesthesia aims to select appropriate anesthetic protocols, reduce severe critical events, and improve understanding of the physiological and psychological well-being of children during the perioperative period, ultimately improving the quality of care.

Analyzing highly cited articles in pediatric anesthesia can reveal key research trends and guide future directions. Previous studies have examined the top 100 (T100) most cited articles in general anesthesia[10] and the characteristics of highly cited articles in specific journals.[11] Similarly, the bibliometric analysis in the field of pediatric anesthesia was performed for the years 2002–2022.[12] However, a comprehensive systematic analysis of highly cited articles in pediatric anesthesia remains lacking. To fill this gap, we conducted and extended the analysis covering the years 1990–2023, offering a thorough understanding of the T100 most cited publications in pediatric anesthesia by bibliometric analysis, identifying key topics and trends, improving pediatric anesthetic management, and guiding future clinical research.

METHODS

Literature sources and search strategy

A comprehensive literature search between January 1, 1990 and December 31, 2023 was conducted using the Web of Science Core Collection (WOSCC) database. The search was performed using the following formula: TS (Topic)=('Pediatric' OR 'Pediatrics' OR 'Child' OR 'Children' OR 'Infant' OR 'Newborn' OR 'Neonate' OR 'Neonatal') AND TS=('Anesthesia' OR 'Anaesthesia' OR 'Anesthetic' OR 'Anaesthetic' OR 'Anesthesiology' OR 'Anaesthesiology' OR 'Sedation') NOT TS=('Animal'). Subsequently, the results were refined by selecting 'Article' and 'Review' categories and restricting the language to English.

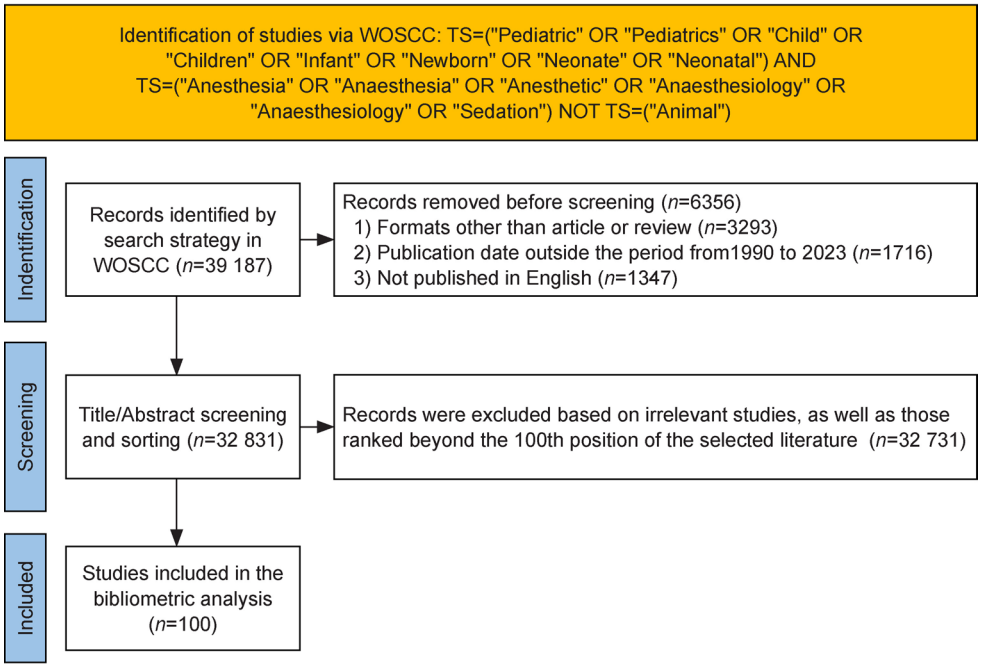

Figure 1 Flow chart of the screening process. WOSCC, Web of Science Core Collection. TS: Topic

Publication selection and data extraction

The literature search was conducted in April 2024 to minimize potential bias from database updates. Inclusion criteria are all articles related to 'pediatric anesthesia' that are not purely basic animal research. Exclusion criteria are: (1) formats other than article or review (including guidelines); (2) publication date outside the period from 1990 to 2023; and (3) articles not published in English. We reviewed the title and abstract of each article to ensure relevance to 'pediatric anesthesia'. We sorted all the included articles by citation frequency and selected the T100 most cited articles (figure 1). For each of the T100 articles, we extracted detailed information, including title, authors, institutions, country or region, year of publication, journal source, total number of citations, and annual number of citations.

Data analysis

We downloaded the raw data from the WOSCC in plain text format and exported complete records and citation references. Descriptive analysis was performed on the T100 cited articles using Microsoft Excel. The exported data were analyzed using VOSviewer to construct a visual network of the 100 selected literature articles by country, author and keyword for visualization purposes.[13] Visualization maps typically consist of nodes and links. The size of the nodes represents the number of publications, while the links between the nodes illustrate the associations. For country/institution analysis, all listed countries and institutions were included for comparison if an article had authors from multiple locations. In addition, all authors were included in the study, allowing for a comprehensive comparison of individual contributions. In addition, we entered the T100 articles into Elsevier's Scopus database to evaluate the field-weighted citation impact (FWCI), which is defined as the ratio of the total number of citations received by a publication to the expected average number of citations in its field. The FWCI can be obtained directly from the Scopus database.[11]

RESULTS

The T100 most cited articles in pediatric anesthesia literature are listed in online supplemental table S1. These articles were published between 1990 and 2023, accumulating a total of 32 230 citations. The number of citations ranged from 164 to 1378, with a median of 271 citations. The earliest article in the T100 was published in 1990 in the journal *Anesthesia and Analgesia*, titled 'Pediatric anesthesia morbidity and mortality in the perioperative period', and focused on the morbidity and mortality associated with pediatric anesthesia. The period with the highest proportion of T100 was 2005–2009, accounting for 27 out of 100 articles (figure 2).

Online supplemental table S2 presents a comparison of FWCI, total citation counts, and annual citations for T100, sorted in descending order by FWCI. Among the top 10 articles ranked by FWCI, six also appeared in the top 10 by total citations. In addition, eight of these top 10 articles were published after 2010.

Publications in different countries

Researchers from 21 different countries contributed to the selected literature, with the majority of contributions coming from the USA (63 articles, 63%), followed by France (5 articles, 5%), while Australia, Canada, and Switzerland each had four articles in the T100 (4%).

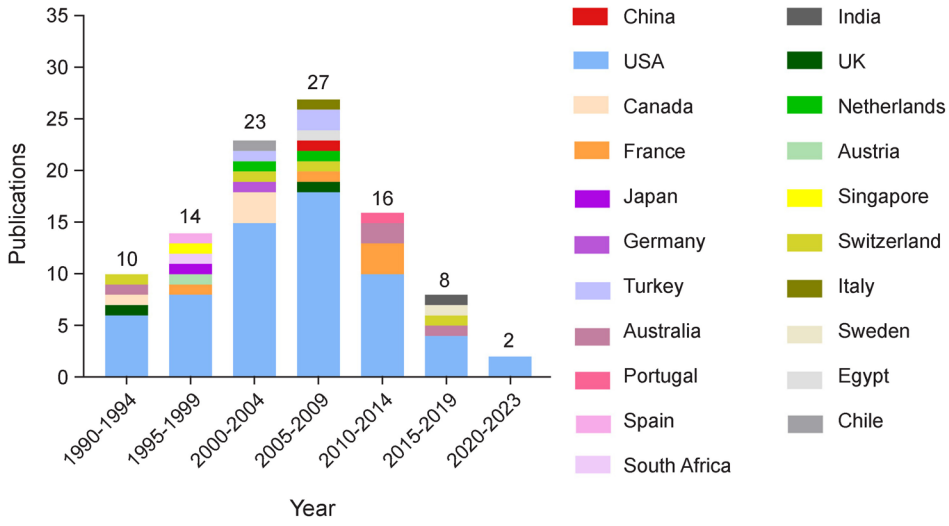

Figure 2 Number of publications per country in different years.

The USA played a dominant role, maintaining a central position with extensive cooperation with countries such as Canada, Germany, France, and Switzerland (online supplemental figure S1). Strong communication was also evident between European countries, particularly Germany and France. However, cooperation between Asian countries, such as China, and European or American countries, was relatively limited.

Institutional affiliation in the T100 articles

The top three institutions in terms of publications were all affiliated with Harvard University in the USA (11 articles, 11%). Nine of the top 10 most cited institutions were located in the USA. Outside the USA, the highest ranking institution was the University of Toronto in Canada, which contributed 6% of the publications in the T100 most cited articles.

Journal sources of the T100 articles

Of the T100, 21 were published in the journal *Anesthesia and Analgesia*, 18 in *Anesthesiology*, and 14 in *Pediatrics*. These journals were the top three sources, each publishing 10 or more of the T100 articles (online supplemental figure S2).

Most frequently cited and annually cited articles

The most cited article is by Gross *et al.*, published in *Anesthesiology* in 2002, titled 'Practice Guidelines for Sedation and Analgesia by Non-Anesthesiologists'.[14] This article has accumulated 1378 citations and an average of 59.91 citations per year. The article with the highest annual citation count is '2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway' by Apfelbaum *et al.*, published in *Anesthesiology* in 2022, with an average annual citation count of 115.[15] This guideline also ranks the highest FWCI with a value of 109.70.

Proportion of different article types in the T100 articles

The majority of T100 were clinical research studies, comprising 82 articles (82%), followed by 11 guideline articles (11%) and 7 reviews (7%). Clinical research, particularly in perioperative behavioral studies, has mainly focused on the postoperative period, with numerous studies investigating various doses and types of anesthetics, as well as postoperative outcomes. Guideline articles mainly focus on difficult airway management, perioperative fasting, analgesia and sedation management, and postoperative complications such as pain, nausea, and vomiting. Online supplemental figure S3 shows the distribution of article types in the T100 across each decade. From 2000 to 2009, clinical research dominated, producing much of the high-impact literature. Although guidelines were fewer in number, they had significant influence, while reviews, more prevalent in the 2000s, largely focused on adverse events in pediatric sedation and analgesia.

Patterns of collaboration among authors of the T100 articles

Further visual analysis revealed that Kain ZN emerged as the most prolific author in terms of publications. Five distinct groups of authors were identified based on their research focus: Kain ZN *et al.* concentrated on pediatric perioperative anxiety and behavioral changes; Gan TJ *et al.* focused on the management of postoperative complications in children, such as nausea and vomiting; Jevtovic-Todorovic V *et al.* focused on the impact of anesthesia on pediatric neurodevelopment and cognitive impairment; Green SM *et al.* studied perioperative sedation in pediatric patients; Cohen MM *et al.* researched perioperative morbidity and mortality in pediatric anesthesia (online supplemental figure S4). Within each group, there was close collaboration among authors, but limited interaction was observed between different groups.

Co-occurrence of keywords in the T100 articles

The most important keywords were grouped into four main clusters: perioperative characteristics and inhalational anesthetics (halothane and sevoflurane); factors related to pediatric anesthesia (sedation, analgesia, adverse events, and complications); anesthetics and neurotoxicity (neurodegeneration and neurotoxicity); and the use of intravenous anesthetics in pediatric general anesthesia (propofol and midazolam), with 'children' and 'anesthesia' positioned at the center of all keywords (online supplemental figure S5). These four main clusters are inter-related, with terms like 'anesthetics' and 'children' appearing across multiple clusters.

DISCUSSION

In this study, we identified and analyzed the T100 most cited studies in pediatric anesthesia. The majority of these studies were clinical research, focusing on perioperative behavioral studies, postoperative outcomes, specific anesthetic use, and guidelines for perioperative anesthetic management.

Given the differences in organ development and drug metabolism between children and adults, re-evaluation of drug selection and dosage is essential in pediatric anesthesia.[16] Lerman *et al.* indicated that sevoflurane is appropriate for neonates, infants, and children.[17] However, volatile anesthetics such as sevoflurane, isoflurane, and enflurane are known to contribute to early postoperative vomiting and agitation.[18 19] Dexmedetomidine, a highly selective α-2 adrenoreceptor agonist, provides sedation and analgesia without respiratory depression and is effective in attenuating sevoflurane-induced agitation without additional adverse effects.[20 21] These studies highlight the importance of continued clinical research in pediatric anesthesia.

A significant proportion of the T100 most cited studies have focused on the effects of anesthetics on cognitive function in children. Sun *et al.* found that a single exposure to anesthesia may not adversely affect cognitive development later in childhood.[22] Another study linked exposure to anesthesia before the age of 4 days with a small decline in academic performance and IQ test scores.[23] Studies in juvenile animal models suggest that N-methyl-D-aspartic acid receptor antagonists and drugs targeting gamma-aminobutyric acid signaling transduction may be neurotoxic to the developing brain.[24] These clinical findings contrast with previous basic research and highlight the need for further investigation into the long-term cognitive effects of anesthetic agents in children.

Kain ZN is the most prolific first author among the T100 most cited studies, focusing on pediatric perioperative anxiety and behavior. Studies on this topic emphasize the complexity of children's anxiety, which includes fear of the surgical procedure, unfamiliar environment, separation from family, and unfamiliar medical procedures, resulting in emotional and cognitive distress. In addition, these issues are not limited to the day of surgery and can have potentially long-term negative effects on children's psychology. This highlights the importance of early prevention and timely intervention. Non-pharmacological methods, such as play therapy and family involvement, can help mitigate anxiety and improve cooperation during surgery.[25]

Perioperative adverse events are critical in pediatric anesthesia, especially in infants under 1 month of age who are prone to respiratory and cardiovascular complications.[26 27] These findings underscore the need for improved education and strategies within the anesthesia teams to improve the quality of pediatric anesthesia care.[28] In addition, a prospective cohort study found that recent upper respiratory tract infection, family history of asthma, atopy, or smoking predicted a higher risk of adverse respiratory events.[29] Additionally, Mamie *et al.* showed that using relaxants for tracheal intubation could reduce the risk of perioperative respiratory complications, but increases the risk associated with ear, nose, and throat surgery when performed by non-specialist pediatric anesthesiologist.[30] Moreover, airway complications accounted for 64% of anesthesia-related cardiac arrests with a mortality rate of 29%, compared with a mortality rate of 70% for anesthesia-related cardiac arrests occurring during all stages of anesthesia.[31]

Difficult airway management is a major challenge in pediatric anesthesia. Fiadjoe *et al.* reported a 3% first-attempt success rate for direct laryngoscopy compared with 55% for indirect video laryngoscopy in difficult pediatric airways.[32] The 2022 American Society of Anesthesiologists (ASA) Practice Guidelines emphasize optimizing oxygenation, limiting intubation attempts, and promptly seeking help or using invasive techniques when multiple intubation attempts fail.[15] Sequera-Ramos *et al.* found similar success rates and complication rates for tracheal intubation between groups, although the sedation group had fewer severe complications.[33] Napolitano *et al.* showed that providing apneic oxygenation via nasal cannula during the apneic period of tracheal intubation was associated with fewer adverse events in children, highlighting the importance of maintaining oxygenation during difficult airway management.[34] Another study compared the efficacy of hybrid techniques (video laryngoscopy and flexible bronchoscopy) with flexible bronchoscopy alone and reported similar success rates for intubation, with fewer complications observed in the former approach group.[35] These findings underline the impact of updated guidelines on anesthetic management in pediatric anesthesia.

The use of cuffed endotracheal tubes in pediatric anesthesia remains a subject of debate. Khine *et al.* demonstrated that cuffed endotracheal tubes can prevent repeated checks, minimize low flow rates, and lower anesthetic concentrations.[36] Reports by Weiss *et al.*[37] and Khine *et al.* further support this view, while Newth *et al.*[38] reported no significant difference between the use of cuffed and uncuffed tubes. Conversely, some researchers express concerns about cuffed tubes, citing potential

problems such as airway trauma, increased difficulty in intubation, and concerns about the appropriateness of airway size in children. Additionally, the use of cuffed tubes may lead to subglottic swelling, increasing the risk of postoperative laryngospasm.

Sedation is essential due to the difficulties young children face in cooperating with invasive procedures. It helps manage behavior, alleviate physical discomfort or pain, and minimize negative psychological reactions.[13] Research suggests that nasal or oral sedatives in pediatrics can provide satisfactory sedation with a low incidence of adverse events. The American Academy of Pediatrics established guidelines for pediatric sedation in 1985, with updates in 1992 and 2019.[39–41] In 1997, studies highlighted the risks associated with pediatric sedation and the need of appropriate monitoring by trained personnel.[42] In addition, Hoffman and colleagues outlined the risks assessment and strict adherence to guidelines could reduce the incidence of complications.[43] While serious adverse events are rare with pediatric procedural sedation, they are more common in ASA grade III or IV children.[44–46] The above studies are all among the T100 most cited articles, indicating the importance of pediatric procedural sedation.

Non-traditional indicators, such as the FWCI, provide insight into the impact of articles by making weighted comparisons, effectively accounting for differences in size, discipline, and publication time. By comparing the FWCI with the total number of citations, we observed that articles with higher citation counts generally have higher FWCI values, suggesting that citation counts tend to reflect impact. However, the correlation between these two metrics is not always consistent, possibly due to factors such as publication year or document type. As a result, the non-traditional FWCI metric can serve as a valuable complement to traditional citation measures.

Our study examines a wide range of sources and incorporates findings from highly cited research. It highlights the predominant focus of clinical research and guidelines in pediatric anesthesia, identifies key areas of research and academic contributions, and helps shape future research directions. However, this article has several limitations. First, we selected the T100 cited articles from 1990 to 2023 for analysis, resulting in a relatively small sample size. Future research could enhance the comprehensiveness by analyzing the T100 cited articles from each decade within this period. Second, citation counts are affected by publication year, with older articles tending to accumulate more citations, potentially excluding recent high-impact publications. Moreover, classic literature may experience 'obliteration by incorporation', where citation rates decline as the content becomes incorporated into common knowledge, potentially missing current advances such as novel drugs like remimazolam.[47 48] Third, some of the T100 articles may contain outdated information on anesthetics and techniques, such as the reduced use of halothane, which limits their relevance in current clinical guidelines. In addition, factors such as the publication language, the selected journal, and the number of similar high-impact publications within the same field can influence citation results.

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