

# A Comprehensive Review of the Last 50 Years of Research on Thoracic Outlet Syndrome: A Bibliometric Analysis

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## ABSTRACT

**Objective:** Numerous articles on Thoracic Outlet Syndrome (TOS) have been written by multiple generations of committed researchers worldwide. Knowing the present state of TOS research output requires performing a bibliometric examination of the literature. This study aims to identify the top 50 cited articles published over the previous 50 years on thoracic outlet syndrome.

**Materials and Methods:** A title-specific search was executed in March 2024 on the Web of Science database, using "thoracic outlet syndrome" as the primary search term. The selected timespan for the search extended from 1975 to 2024. The top 50 most-cited articles were reviewed for the analysis.

**Results:** The articles received a mean citation of  $81.26 \pm 32.97$  per article. The top 10 articles were published between the years 1982 and 2016. The top 5 journals with the most publications were Journal of Vascular Surgery, Annals of Vascular Surgery, Muscle & Nerve, Archives of Surgery, and American Journal of Roentgenology, respectively. Machleder HI and Sanders RJ were the most productive authors in the field with 5 and 4 papers respectively. Most of the publications (25) concentrated on the surgical management of the syndrome, along with 5 studies focusing on imaging and radiological aspects, 3 on rehabilitation, and 1 on social issues regarding the syndrome.

**Conclusion:** It is foreseeable that TOS will continue to be a focal point of future research. This study serves as a valuable resource for researchers to identify potential collaborators and partner institutions, thereby contributing to the advancement of further research in the field.

**Keywords:** Bibliometric analysis, current literature, Thoracic Outlet Syndrome

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## INTRODUCTION

The lower neck region consists of 3 anatomical spaces between the clavicle bone and the first rib: the subcoracoid space, the costoclavicular space, and the interscalene triangle. This space also named the thoracic outlet is the pathway to numerous neurovascular structures.<sup>[1,2]</sup> Thoracic Outlet Syndrome (TOS) refers to the compression of significant structures in this region, including the brachial plexus, subclavicular vein, and subclavicular artery.<sup>[3]</sup>

Terms including cervical rib syndrome, scalenus anticus syndrome, subcoracoid-pectoralis minor syndrome, and costoclavicular syndrome were used before thoracic outlet

syndrome was defined in 1956.<sup>[4,5]</sup> The clavicle, first rib, scalene muscles, and humeral head are among the anatomical features that could cause compression on neurovascular structures. Compression leading to TOS can also be caused by clavicle fractures, fibrotic bands between the cervical ribs, tumors, and trauma to the area.<sup>[6,7]</sup>

Numerous etiological factors and clinical manifestations have led to the establishment of several classifications comprising neurogenic, venous, and arterial TOS. In addition, each group has been subdivided into traumatic, functional acquired, and congenital subgroups.<sup>[8,9]</sup> Most cases (90–95%) are considered neurogenic, according to current literature.<sup>[10]</sup>



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Women are more likely to have TOS with the symptoms typically manifesting between 20 and 50 years of age.<sup>[11]</sup> These patients are frequently misdiagnosed and deemed to need needless medical care, including surgery.<sup>[12]</sup> The clinical presentation can vary based on the compressed structure. Pain is the primary symptom and it's crucial to experience discomfort, particularly while resting or sleeping.<sup>[13]</sup> A comprehensive history, a physical examination, provocative tests, imaging techniques, and neurophysiological evaluations are used to make the diagnosis.<sup>[3]</sup>

Neurogenic TOS may result in pain, paresthesia, and weakness in the nerve-innervated areas depending on the compressed portion of the brachial plexus.<sup>[14]</sup> Venous TOS, also known as Paget-Schroetter syndrome, is characterized by cyanosis, edema, discomfort, and dullness in the extremities. Arterial TOS is the most hazardous but least common variety. Claudication symptoms, such as coldness, numbness, and exhaustion, as well as ischemia in the upper limbs from arterial embolization, may be present.<sup>[15,16]</sup>

When there is no muscle atrophy, vascular occlusions, or general weakness, conservative treatment is preferred. This includes rest, patient education (including correction of posture disorders, control, and avoidance of manipulative movements), and physical activity that includes stretching and strengthening the muscles concerned.<sup>[17]</sup> When imaging and electrophysiological findings are insufficient, ultrasound-guided scalene and/or pectoralis minor blocks are advised to confirm the diagnosis and enhance conservative treatment methods such as exercise and postural correction.<sup>[18]</sup> For patients with significant compression signs who do not respond to conservative treatment for 8 to 12 weeks, surgical treatment can be planned.<sup>[19]</sup>

Alan Pritchard introduced the phrase "bibliometrics" (the science of measurement) in *The Journal of Documentation* in 1969. The term is derived from the Greek terms *biblion*, which means book, and *metricus*, which means measure.<sup>[20,21]</sup> Bibliometric studies examine academic research on a chosen topic published between predetermined dates and its authors, citations, keywords, and additional features. Researchers also consider impact factor, h-index, and the caliber of the journals that publish the findings when evaluating criteria.<sup>[22,23]</sup>

Bibliometrics is a discipline that performs qualitative and quantitative analyses of literature using mathematical and statistical methods. It provides a global perspective on the development of a specific field through visual analyses of countries, institutions, journals, and authors. Additionally, bibliometrics can assess and predict the foundation and

emerging trends in scientific research by analyzing the co-occurrence and emergence of references and keywords.<sup>[24]</sup>

As far as we know, no study in the literature investigates the quality of academic research work on TOS. Therefore, this study, utilizing a bibliometric analysis to examine the knowledge structure of thoracic outlet syndrome research over the past 50 years, aims to provide insights into the current state of research, identify critical areas for further investigation, anticipate future research trends, and recognize the key contributors, institutions, and countries that have shaped the field. The findings of this study have the potential to significantly advance research in this domain.

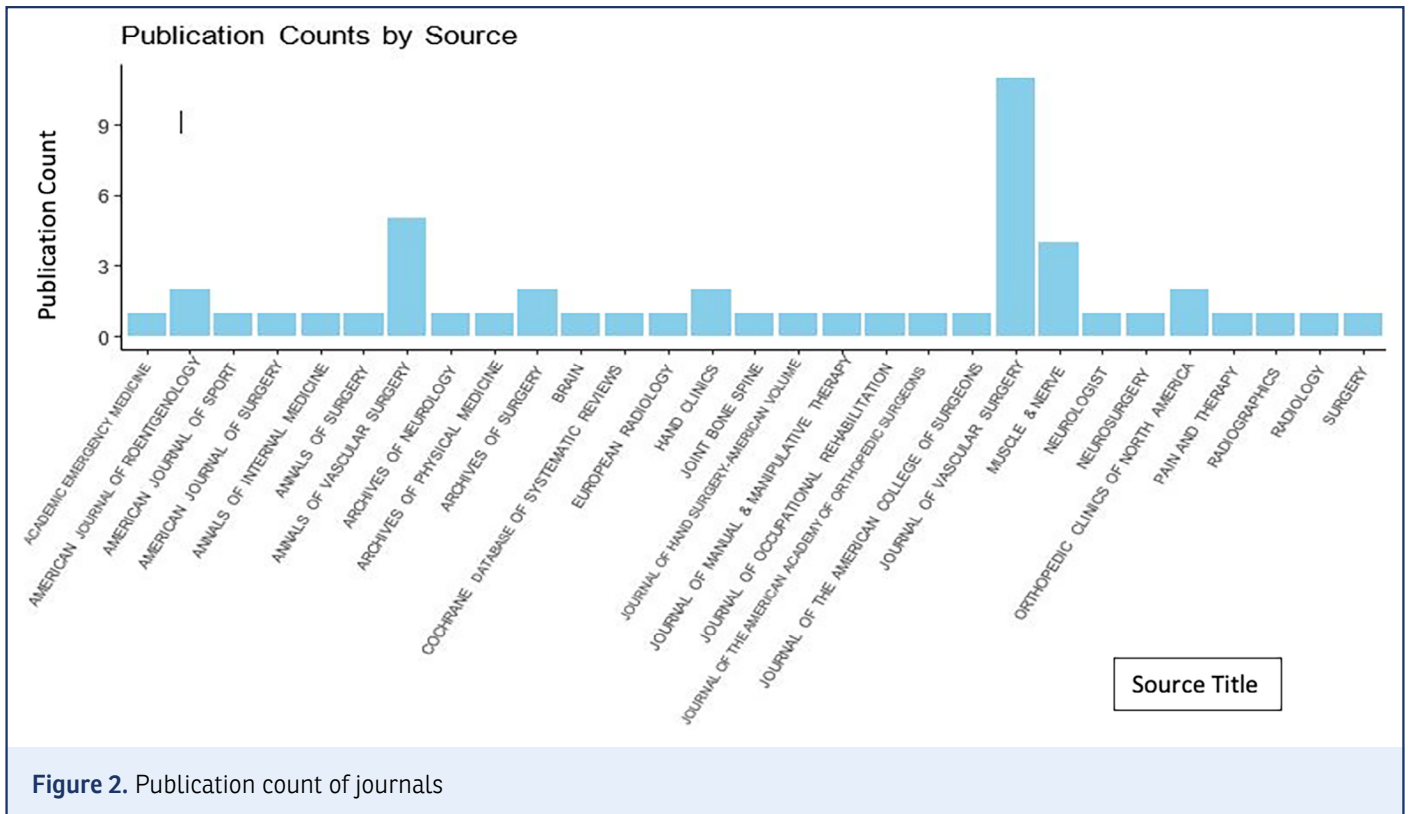
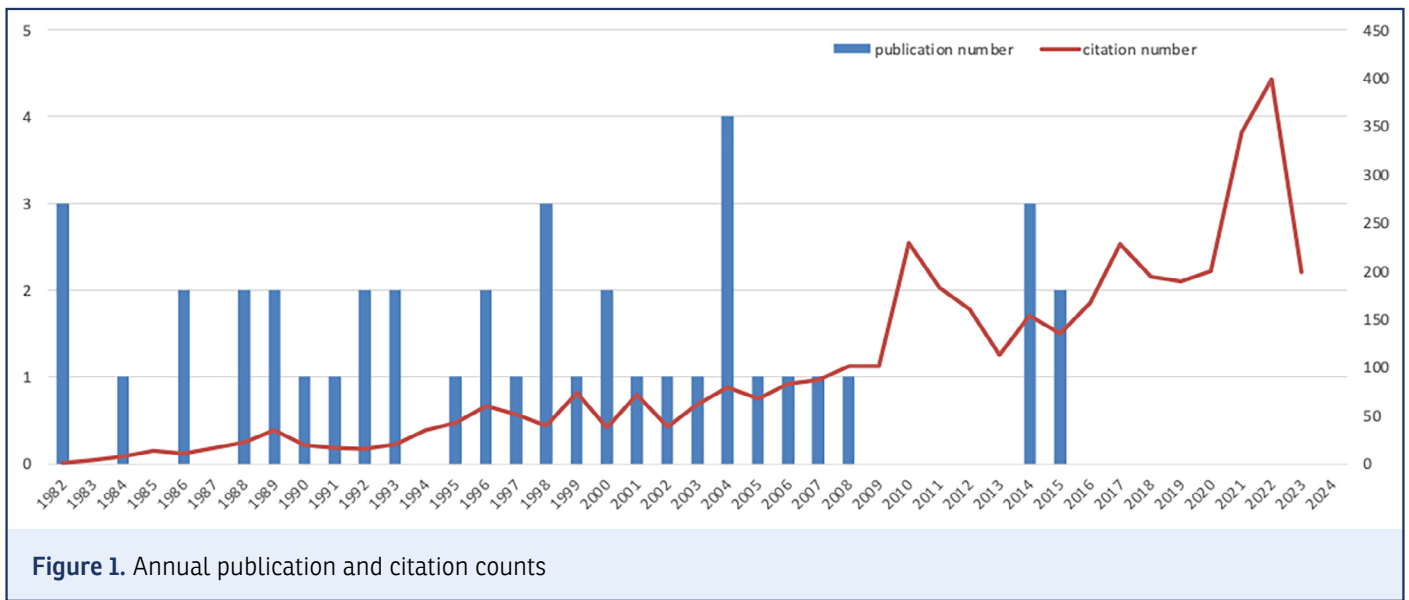
## MATERIALS and METHODS

To identify highly cited articles published between January 1975 and January 2024, a title-specific search using the term "thoracic outlet syndrome" was carried out in the Web of Science (WoS) database by Clarivate Analytics in March 2024. The utilization of the Web of Science database was imperative, given its recognition as the most authoritative and comprehensive indexing tool for scientific and technological research citations. Articles were examined by 3 independent reviewers, and a list of articles was retrieved and arranged in descending order of the number of citations. Ethical approval or informed consent was not necessary since there were no human or animal subjects.

The top 50 articles with the most citations were reviewed. An examination of the abstract, article, and data, including the paper's title, publication year, names and number of authors, design of the study, journal name, article type, quantity of citations, distribution of studies, and citations to these studies by years was performed. Additionally, the country of origin and the primary institute where the study was held were determined by the address of the first author. Based on the major topic of interest, articles were categorized into 12 groups; surgery, peripheral vascular disease, clinical neurology, orthopedics, radiology and imaging, neurosciences, rehabilitation, general internal medicine, sports sciences, emergency medicine, rheumatology, and social issues. When more than 1 department was the primary focus of the research, some articles took part in multiple groups.

## RESULTS

The total sum of the times cited for 50 articles was 4063. The articles received a mean citation of  $81.26 \pm 32.97$  per article, the annual publication and citation counts are presented in Figure 1. The years in which the most citations occurred were 2022, 2021, and 2017 with 398, 343, and 228 citations respec-

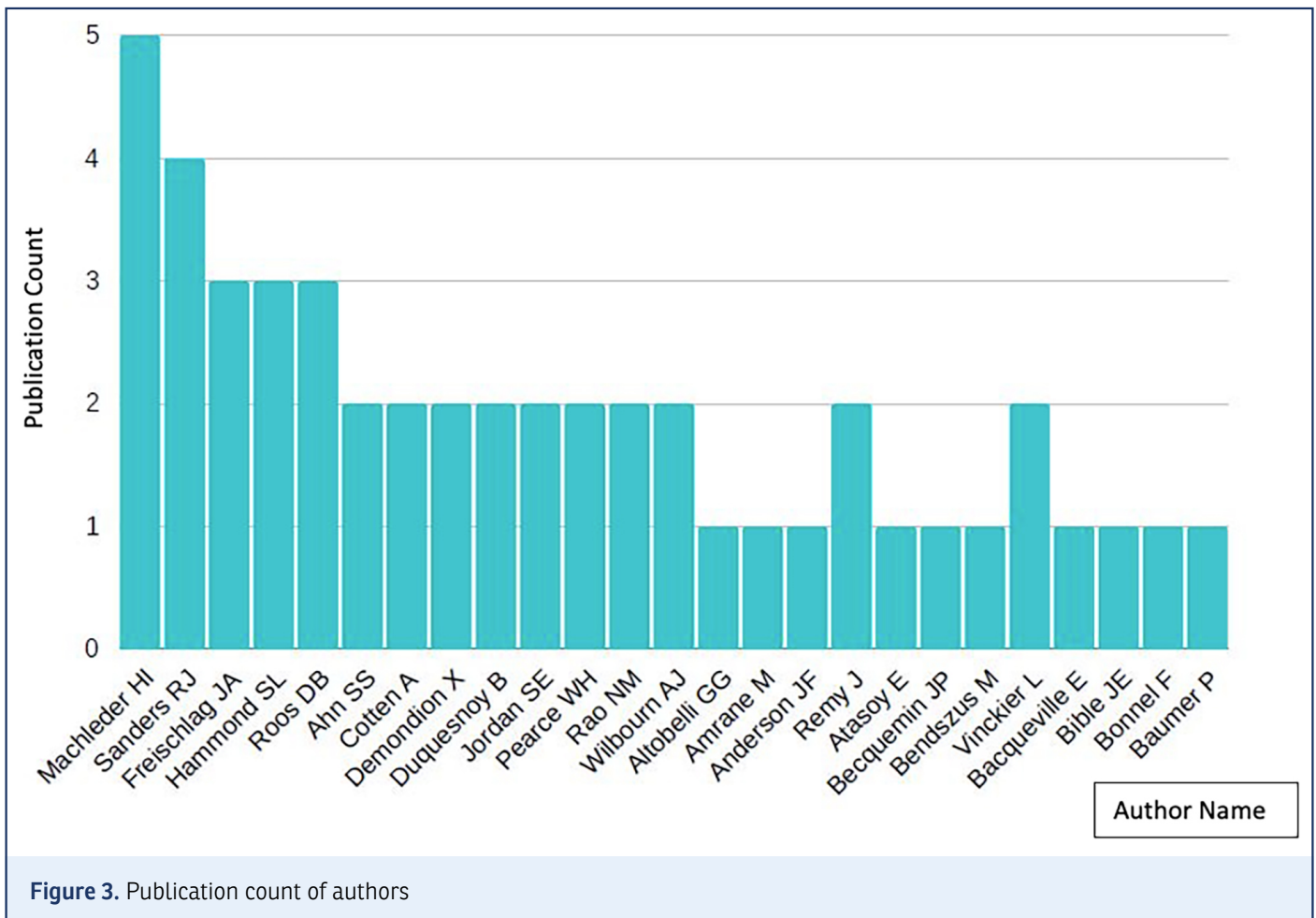


tively. The top 10 articles were published between the years 1982 and 2016. The years with the highest number of articles in the top 50 list were 2004, 2014, 1998, and 1982.

The journal with the most publications was the Journal of Vascular Surgery with 11 papers, followed by Annals of Vascular Surgery with 5, Muscle & Nerve with 4, and Archives of Surgery and American Journal of Roentgenology with 2

apiece (Fig. 2). Other journals had 1 publication each on the list. The papers published in the Journal of Vascular Surgery received a mean citation of 99.36 per article which is the highest for journals with more than one publication on the list.

According to the information obtained from the author's affiliations, the top 3 countries with the most publications were the United States of America (USA), France, and the United



**Figure 3.** Publication count of authors

Kingdom (UK). The most productive primary research institutions were the University of Colorado, the University of Colorado System, the University of California System, and the University of California Los Angeles.

When the authors were examined, Richard J. Sanders and Herbert I. Machleder, both vascular surgeons, stood out as the authors with the most studies (Fig. 3). 44 authors as first authors and 116 as co-authors have contributed to the top 50 most-cited papers. 15 authors had 2 or more articles in the top 50 list.

## DISCUSSION

Using performance indicators and citation data, bibliometric analysis makes it possible to evaluate the quality of academic research publications. A shift in the assessment of research emerged: the Science Citation Index (SCI) was introduced in 1963 to help readers and scholars find the most significant journals in specialized fields. Citation data was soon used to quantify journals and their influence on the creation and distribution of information.<sup>[25]</sup> However, despite a thorough

search of the literature no citation analyses of the most cited articles on thoracic outlet syndrome were found.

The findings showed that the top 50 most cited articles on TOS were issued in 31 different journals, with 11 of them being published in the *Journal of Vascular Surgery*, 5 in the *Annals of Vascular Surgery*, 4 in *Muscle & Nerve*, and 2 in the *Archives of Surgery*. The 29 remaining articles were published in different subspecialty journals, ranging from neurology to emergency medicine. This demonstrates the huge variations in viewers' interests and research across various medical disciplines and subspecialties in TOS. Accordingly, the most appealing research topics were those related to surgery, which is the most investigated field. However, there were other areas of study where the focus was on imaging and rehabilitation, which are extremely valuable scientific subjects in the management of TOS.<sup>[9,15,26]</sup>

The *Journal of Vascular Surgery*, a first quartile (Q1) journal in cardiology and cardiovascular medicine according to the WoS database, was the top journal not only with the

most articles (n=11) in the list but also with the highest per article mean citation (PAMC) score of 99.36. The *Annals of Vascular Surgery*, a second quartile (Q2) journal in cardiology and cardiovascular medicine according to the WoS database, came in second with 5 articles, however, had a PAMC score of 68.4, which is just shorter than the *Archives of Surgery's* 2 articles which had a PAMC score of 73. Even though there is a wide range of journals on the top 50 list, the fact that these journals rank in the top 3 in citation scores indicates how dominant surgery journals are in this field.

An article is considered a "classic" in a particular discipline if it has 100 or more citations.<sup>[27]</sup> 11 of the top 50 articles matched the aforementioned requirement based on the citation count. The by far most cited article in this top 50 list with 243 total citations was "Diagnosis of Thoracic Outlet Syndrome" by Sanders et al.<sup>[28]</sup> This review paper was published in September 2007 in the *Journal of Vascular Surgery* and is also referred to as a clinical update. The article highlights that "TOS" is not a precise diagnosis; rather, the clinician should further identify it as arterial, venous, or neurogenic TOS after taking the proper history and doing a physical examination. The authors bid the clinicians to abandon "vascular" TOS as a classification option, and not to take the Adson test as a reliable option to distinguish neurogenic TOS due to the test being a vascular maneuver. The ruling out of the Adson test which had been a key element of the physical exam for years before, and identifying the classification of the disease may have brought about a large number of citations for this paper. Differential diagnosis of TOS remains to be challenging for clinicians to this day and the classification system mentioned in this article remains to be up to date which are enhancing factors in still citing this article.<sup>[15,16]</sup>

The second most cited article, "Imaging Assessment of Thoracic Outlet Syndrome," was authored by Demondion et al.<sup>[29]</sup> and published in the *Radiographics* in November 2006. This article identifies the normal and aberrant anatomy of the thoracic outlet on detailed anatomic sections and explains the use of postural maneuvers in association with several imaging modalities including ultrasound imaging, magnetic resonance imaging, and computed tomography in the assessment of TOS. This article was a conference proceeding paper for the "90<sup>th</sup> Scientific Assembly and Annual Meeting of the Radiological Society of North America", with vast coverage and consensus, translating into its extensive coverage and readership.

The 2016 paper "Reporting Standards of the Society for Vascular Surgery for Thoracic Outlet Syndrome" which

was published in the *Journal of Vascular Surgery*, by Illig et al.,<sup>[15]</sup> was the fourth most cited article. Although being more recent than most of the articles in the list, this paper was fourth in total citation count (n=125) and first in average citations per year with almost 16. This article aims to provide insight into future research by ensuring that definitions, nomenclature, and terminology surrounding TOS all refer to the same things, and by creating comparable reporting guidelines for all 3 types of TOS. Given the citations the paper has garnered in the 7 years after it was published, it appears like the vision has been achieved in terms of laying the groundwork for further research in the field.

The majority of the top 50 most cited articles on TOS were produced by USA institutions. Authors from USA, Richard J. Sanders and Herbert I. Machleder were the most productive authors in the list accordingly. Given the enormous support lavished by corporate organizations and the USA government for science and technology, it is barely noteworthy that the USA continues to lead the world in this field.<sup>[30]</sup> France and the UK were also found to be quite active in this domain. The years in which the most citations were made were 2022, 2021, and 2017 with 398, 343, and 228 citations respectively which illustrates the increasing attention that thoracic outlet syndrome is receiving and indicates that more work in this field may be accomplished in the years to come.

This research has certain limitations, just like any other in its area. First of all, the assessment was restricted to the top 50 cited papers as evaluating more publications exceeded the scope of available resources. Furthermore, the study only included the WoS database citation data, which is the most trustworthy data available; a more comprehensive perspective may be provided by using other citation platforms more broadly. However, we think that these findings fairly depict larger material on various platforms.

## CONCLUSION

To the best of our knowledge, this study is the first to look into the bibliometric analysis of thoracic outlet syndrome-related literature. Current trends suggest the understanding and management of TOS will continue to improve as a growing number of academics are devoting their time to studying TOS. The proper classification and treatment using recent advances in technology are expected to be the primary focus of study in the future. This study is a useful tool for scholars looking to find possible partner institutions and collaborators, which advances the field's future research.



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