

Long-acting HIV treatment and prevention: a bibliometric analysis and science mapping

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Abstract

Long-acting antiretroviral therapy and long-acting pre-exposure prophylaxis (PrEP) have rapidly become prominent areas of HIV research. To our knowledge, as of June 30, 2026, no previous bibliometric study had jointly mapped the long-acting HIV treatment and prevention literatures within a single Scopus-based science-mapping framework. We conducted a comprehensive bibliometric analysis of English-language research articles and reviews indexed in Scopus, with no restriction on publication year. A total of 1573 publications met the inclusion criteria. Publication output, citation patterns, collaboration networks, conceptual structure, and thematic evolution were examined using co-authorship, keyword co-occurrence, bibliographic coupling, co-citation, and thematic-map analyses. The literature showed an annual growth rate of 32.1%, and 36.1% of publications involved international co-authorship. The United States was the leading corresponding author country, followed by several European countries. Scientific output increased rapidly, with early growth centered on cabotegravir/rilpivirine trials and more recent expansion involving lenacapavir-related research. Keyword and thematic analyses identified long-acting PrEP and cabotegravir/rilpivirine as central, well-established topics, whereas lenacapavir has emerged as a recent and increasingly central research theme. A substantial share of the most-cited literature was linked to industry-funded or industry-affiliated clinical development programs. These findings provide an integrated map of long-acting HIV treatment and prevention research and may inform future research priorities, international collaborations, and implementation research.

Keywords: HIV infections. Lenacapavir. Islatravir. Cabotegravir. Delayed-action preparations. Bibliometrics.

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Introduction

Long-acting antiretroviral (LA-ART) approaches have become an increasingly visible area of HIV treatment and prevention research.¹ The adherence burden of daily dosing, treatment fatigue, stigma concerns linked to visible medication use, and difficulties in maintaining consistent access to care have all contributed to growing interest in alternative strategies with longer dosing intervals.²

The cabotegravir/rilpivirine combination has emerged as one of the leading examples of long-acting injectable HIV treatment in the clinical literature,^{3,4} whereas long-acting cabotegravir has represented a major advance in pre-exposure prophylaxis (PrEP).^{5,6} More recently, lenacapavir has gained prominence in both treatment and prevention research,^{7,9} whereas islatravir has featured in the LA-ART development and pharmaceutical manufacturing literature.¹⁰

Despite this rapid progress, the long-acting HIV literature remains divided across distinct research strands, including treatment trials, PrEP studies, emerging ART agents, pharmacokinetics, patient preferences, implementation, and access. The field therefore warrants evaluation not only in terms of clinical outcomes but also scientific output, citation impact, collaboration networks, and thematic development. Recent bibliometric work has separately mapped the PrEP literature¹¹ and the two-drug HIV treatment literature¹² using Web of Science data with VOSviewer and Bibliometrix, but these analyses examined treatment and prevention as separate literatures rather than within a single, jointly mapped dataset. Our literature search did not identify a bibliometric study that jointly maps the long-acting HIV treatment and prevention literatures, linked through shared long-acting drug classes, within a single Scopus-based science-mapping framework. To our knowledge, as of June 30, 2026, this is the first such bibliometric review, additionally classifying the funding and industry affiliation of the field's most-cited publications.

This study aimed to provide a comprehensive assessment of the bibliometric characteristics of the literature on long-acting HIV treatment and prevention. Publication trends, scientific productivity, citation patterns, international collaboration, conceptual structure, and the evolution of research themes over time were analyzed using bibliometric methods.

Methods

Study design and data source

This study was designed as a bibliometric analysis to assess the quantitative output, citation impact,

collaboration networks, and conceptual structure of the scientific literature on long-acting HIV treatment and prevention. Scopus served as the data source, chosen for its broad journal coverage, citation infrastructure suited to bibliometric analysis, and strong compatibility with Bibliometrix and VOSviewer. The literature search was conducted on June 30, 2026.

The search strategy combined terms linking HIV to LA-ART therapy, injectable ART therapy, long-acting PrEP, and the leading ART agents in this field. The search was run in Scopus using the TITLE-ABS-KEY field, covering title, abstract, and keyword fields. The full search strategy is provided in supplementary table S1.

Only English-language research articles and reviews were included, with no restriction on publication year or subject area. Editorials, letters, conference papers, book chapters, and non-English publications were excluded. The study selection process is summarized in a Preferred Reporting Items for Systematic Reviews and Meta-Analysis-Style flow diagram (Fig. 1).

Data extraction and preprocessing

Records retrieved from Scopus were exported in CSV and BibTeX formats, matching the data structures required by Bibliometrix/Biblioshiny and VOSviewer, respectively. The exported dataset included publication title, author information, source title, publication year, abstract, author keywords, institutional and country affiliations, citation counts, and reference lists.

The dataset underwent quality control before analysis. Author keywords were first reviewed to standardize variant spellings, abbreviations, plural forms, and other inconsistencies that referred to the same concept. A custom thesaurus file compatible with VOSviewer was built for this purpose. HIV-related variants were merged under "HIV," PrEP-related terms under "pre-exposure prophylaxis," and synonymous terms describing long-acting treatment under "long-acting ART." Variant spellings of drug names such as cabotegravir, rilpivirine, lenacapavir, and islatravir were likewise standardized. The validated thesaurus was applied to the VOSviewer author-keyword co-occurrence analysis. Keyword harmonization and a separate stopword list were used for the Bibliometrix thematic-map analysis. The thesaurus file and matched terms used for keyword standardization are provided in supplementary table S2.

Generic terms with low topic specificity or with no meaningful contribution to network structure (e.g., "article," "review," and "clinical study") were removed. All standardization steps were applied to the full dataset

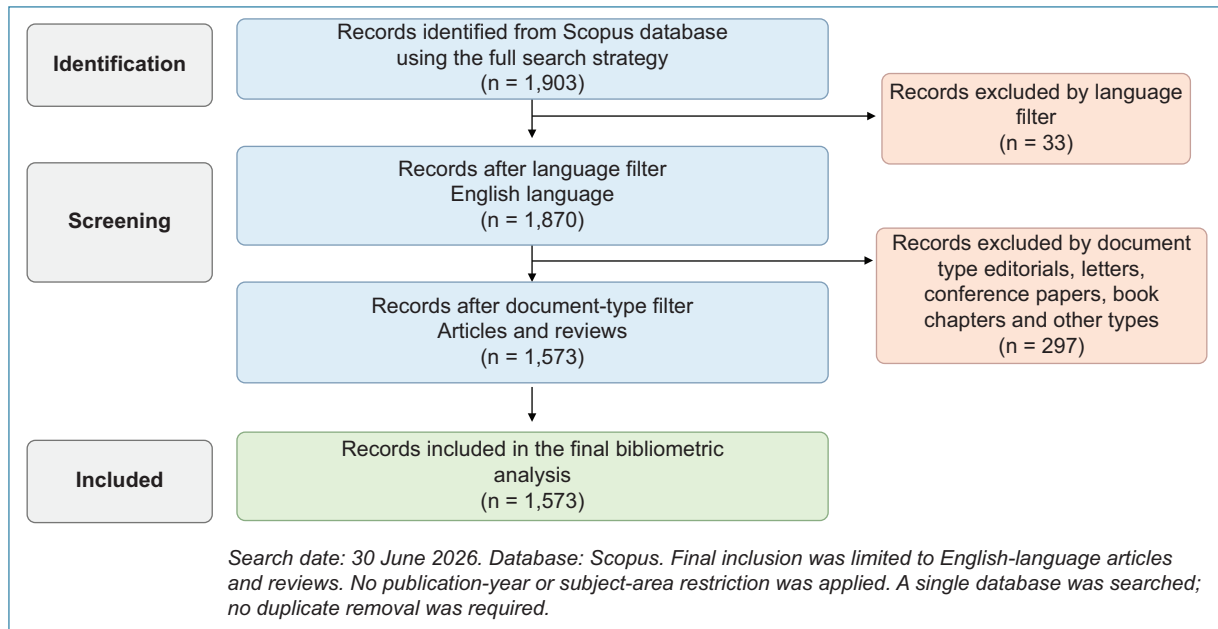


Figure 1. Preferred reporting items for systematic reviews and meta-analyses-style flow diagram: study selection process.

in a single pass prior to analysis, to reduce conceptual fragmentation in the network analyses.

Bibliometric analysis

Descriptive bibliometric analyses were performed using the R-based bibliometrix package and its Biblioshiny interface. The analyses assessed total publication count, document types, number of sources, annual scientific output, annual growth rate, mean citation count, number of authors, co-authors per document, and the proportion of internationally co-authored publications. The annual growth rate obtained from Bibliometrix should be interpreted with the incomplete 2026 data in mind.

The most productive sources, authors, institutions, and countries were examined separately. Country-level analysis was based on the corresponding author's country. Publications were classified as single-country or multi-country according to author affiliations, and the most-cited publications were ranked by global citation counts.

Network analyses

Scientific network analyses were performed using VOSviewer version 1.6.21 with full counting. Author-keyword co-occurrence analysis used a minimum occurrence threshold of 8. Country co-authorship analysis included countries with at least 5 publications, with a

maximum of 100 authors per document. Bibliographic coupling was performed at the document level using a minimum citation threshold of 20, retaining the 100 most strongly connected documents. Co-citation analysis included cited references with at least 20 citations, retaining up to the 100 most strongly connected references.

Funding classification of the 20 most-cited publications was performed independently by two researchers, based on the funding statement, author affiliations, conflict-of-interest disclosures, trial registration information, and sponsor acknowledgments reported in each original publication; disagreements were resolved by consensus. Publications reporting direct company funding were classified as "industry-funded;" those with at least one industry-employed author but no explicit funding statement were classified as "industry-affiliated;" publications with both public and company support were classified as "mixed;" studies with no identifiable industry support were classified as "public/academic;" and professional-society recommendations were classified as "guideline/consensus." This *post hoc* descriptive analysis was not incorporated into the bibliometric network analyses.

Thematic analysis

Conceptual structure was assessed through thematic map analysis in Biblioshiny, based on author keywords.

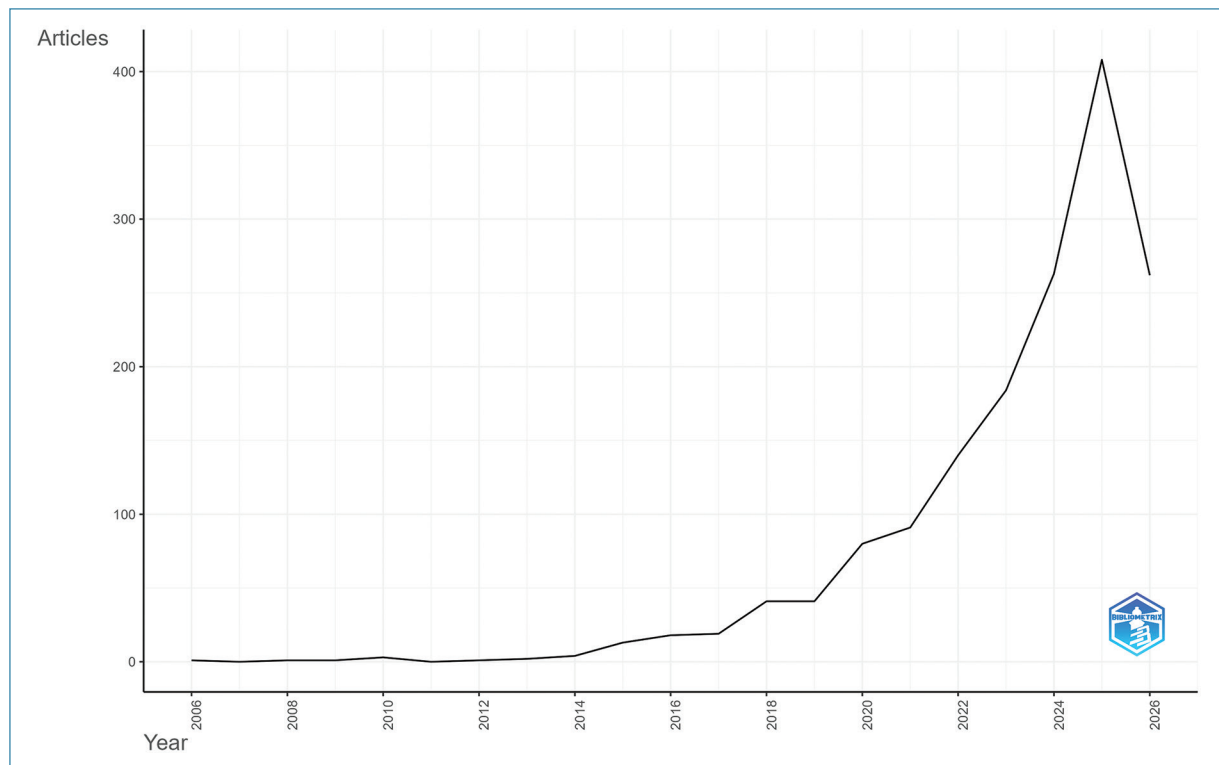


Figure 2. Annual scientific production (2006-2026).

A minimum cluster frequency of 5 was applied, and no word stemming was performed. Generic terms that introduced noise were removed using a stopwords list.

The thematic map classified keyword clusters as motor themes, basic themes, niche themes, or emerging/declining themes according to their centrality and density values. A trend-topic analysis was also performed on author keywords; rather than being presented as a main figure, its output was used to support the interpretation of topic evolution over time.

Ethical statement

This study relied solely on publicly available bibliographic data. As it did not involve individual patient data, clinical records, or human participants, institutional ethics approval was not required.

Results

General bibliometric characteristics

The final dataset retrieved from Scopus comprised 1573 publications from 2006 to 2026. Of these, 1242 (79.0%) were research articles and 331 (21.0%)

were reviews, published across 389 distinct sources. The dataset included 9712 authors, 56,274 references, and 2425 author keywords. Mean citations per publication were 18.49, and the annual growth rate was 32.1%. The mean number of co-authors per publication was 10.7, and 36.1% of publications involved international co-authorship (Supplementary Table S3).

Annual scientific production

Annual publication output remained fairly limited between 2006 and 2014. A gradual increase began after 2015, followed by a marked acceleration after 2020. Growth was fastest in the 2022-2025 period, with the highest annual output recorded in 2025. The apparent decline in 2026 should be interpreted with caution, as the search was conducted before the year was complete (Fig. 2).

Most productive sources, authors, and institutions

AIDS and behavior was the most productive source, followed by Open Forum Infectious Diseases, Current Opinion in HIV and AIDS, and Clinical Infectious Diseases (Table 1).

Table 1. Top 10 journals by number of publications

Journal	n
<i>AIDS and Behavior</i>	67
<i>Open Forum Infectious Diseases</i>	62
<i>Current Opinion in HIV and AIDS</i>	58
<i>Clinical Infectious Diseases</i>	55
<i>Journal of the International AIDS Society</i>	52
<i>AIDS</i>	41
<i>The Lancet HIV</i>	40
<i>Journal of Antimicrobial Chemotherapy</i>	39
<i>HIV Medicine</i>	37
<i>AIDS Patient Care and STDs</i>	31

STD: sexually transmitted diseases.

The most productive authors included Spreen WR, Landovitz RJ, Grinsztejn B, Ford SL, Bekker L-G, D'Amico R, and Margolis DA. At the institutional level, the largest contributions came from the University of California, the University of Washington, ViiV Healthcare, the University of Nebraska Medical Center, and the University of Cape Town.

Production and collaboration by country

Based on corresponding author's affiliation, the United States accounted for the largest share of publications, ranking first by a wide margin with 827 publications, followed by the United Kingdom, Italy, South Africa, Spain, and France (Supplementary Table S4). Examination of multiple-country publication rates showed particularly high levels of international collaboration for Uganda, Switzerland, the Netherlands, South Africa, and the United Kingdom.

The country collaboration network comprised 42 countries in 4 clusters. The United Kingdom, Italy, France, Germany, Spain, and Belgium occupied relatively central positions in the network visualization, whereas Turkey was located in a more peripheral, less connected position (Fig. 3).

Most-cited publications

The most-cited publication was the 2021 study by Landovitz et al.⁵ in the *New England Journal of Medicine*, followed by the 2019 Science paper by

Huffman et al.¹⁰ describing the biocatalytic manufacture of islatravir, the 2020 *New England Journal of Medicine* study by Swindells et al.,³ the 2023 JAMA publication by Gandhi et al.,¹³ and the 2017 Lancet study by Margolis et al.¹⁴ Classification of these 20 publications by funding source showed that 10 (50%) were directly industry-funded and 5 (25%) were industry-affiliated or had mixed-funded; the remaining 5 were publicly/academically funded or represented independent society guidelines. One of the publicly funded studies (HPTN 083) reported public funding alongside an industry-supplied study product (Supplementary Table S5).

Keyword co-occurrence network

Co-occurrence analysis of author keywords, with a minimum occurrence threshold of 8, identified 42 keywords forming a network of 6 clusters, with 421 links and a total link strength of 3,575 (Fig. 4).

One of the largest and conceptually most distinct clusters comprised the keywords PrEP, HIV prevention, long-acting PrEP, men who have sex with men, transgender women, and adherence; another comprised cabotegravir, rilpivirine, long-acting ART, and virological failure; a third comprised keywords related to lenacapavir, pharmacokinetics, drug resistance, and islatravir.

In the overlay visualization, lenacapavir, long-acting PrEP, pharmacokinetics, and viral suppression were among the keywords with the most recent average publication years.

Thematic structure

The thematic map divided the field's conceptual structure into four main regions. PrEP, HIV prevention, and men who have sex with men fell within the motor-themes region, whereas HIV, cabotegravir, and ART therapy were located in the basic-themes region. Lenacapavir, drug resistance, and islatravir also fell within the basic-themes quadrant, with a high level of centrality.

Implementation science, HIV treatment, and cabotegravir/rilpivirine fell within the niche-themes region, whereas dapivirine and tenofovir formed a separate niche cluster with low centrality and relatively high density. Long-acting ART and ART therapy were located in the emerging/declining themes quadrant (Fig. 5).

Bibliographic coupling and co-citation analyses

Bibliographic coupling analysis of 100 documents produced 6 clusters, concentrated around highly connected

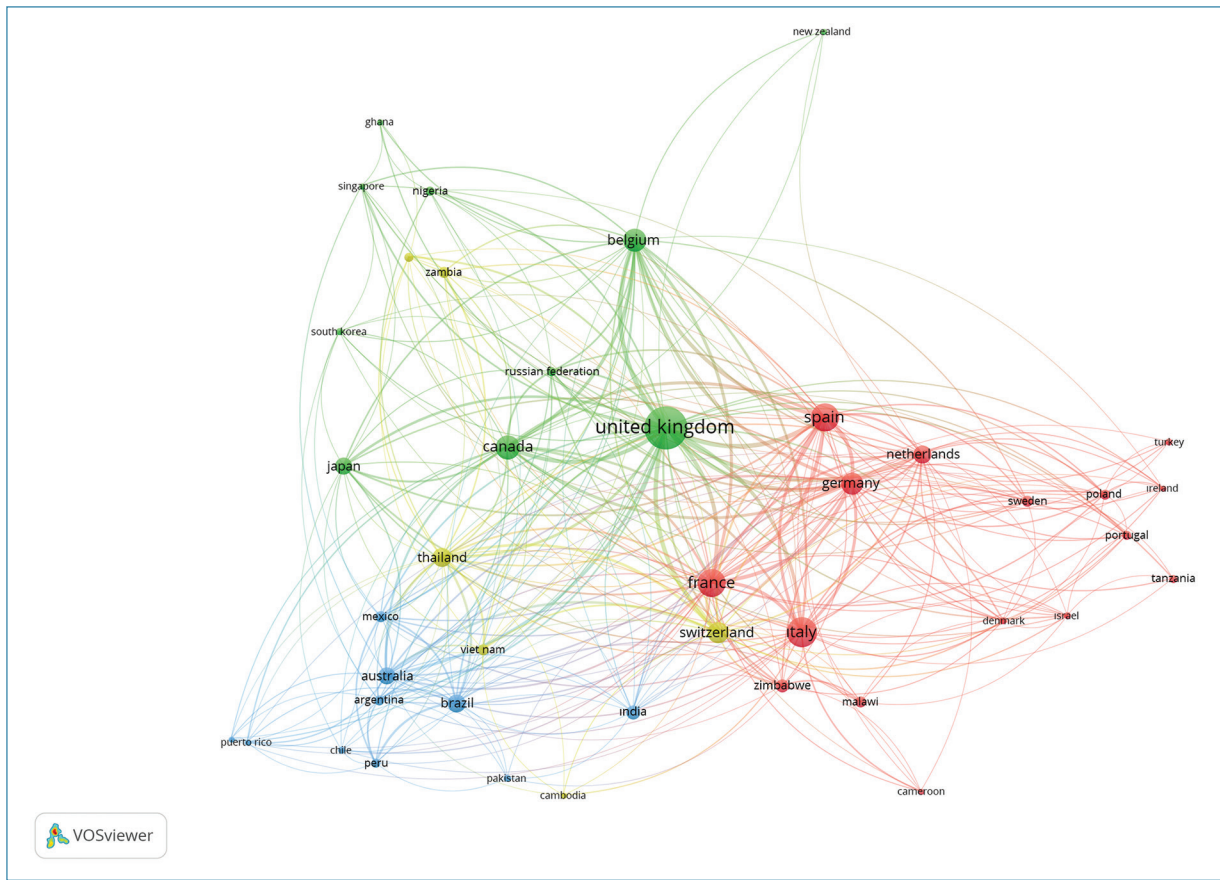


Figure 3. Country collaboration network (42 countries, 4 clusters). Node size represents the country's publication count, colors represent clusters, and link thickness represents the number of co-publications between two countries.

publications by Landovitz et al.,⁵ Margolis et al.,¹⁴ Swindells et al.,³ Overton et al.,¹⁵ and Gandhi et al.¹³ (Supplementary Fig. S1).

Co-citation analysis included the 31 references meeting the minimum citation threshold, yielding 6 clusters and 165 links. The principal co-citation clusters comprised references related to cabotegravir/rilpivirine clinical trials, long-acting PrEP research, HIV treatment guidelines, and, more recently, lenacapavir-related publications (Supplementary Fig. S2).

Discussion

This bibliometric analysis shows that the scientific literature on long-acting HIV treatment and prevention has grown substantially over the past two decades, with a marked acceleration in output after 2020. This growth coincided with the clinical development and adoption of long-acting injectable regimens, the expansion of long-acting PrEP research, and the

emergence of newer agents such as lenacapavir in the literature.

These findings are broadly consistent with earlier bibliometric studies examining different subfields of the long-acting HIV literature. Chen and Lai's analysis of the PrEP field identified long-acting injectable PrEP as one of its emerging research directions.¹⁶ A recent bibliometric study of HIV-1 drug-resistant minority variants similarly reported increasing publication output and examined the field's structure using VOSviewer and Bibliometrix.¹⁷ More recently, separate bibliometric analyses have mapped the global research landscape of PrEP¹¹ and of two-drug HIV treatment regimens¹² using Web of Science-based science-mapping methods. Together, these studies support the systematic applicability of bibliometric and science-mapping methods to specialized subfields of HIV research.

Previous bibliometric studies, including those noted above,^{11,12,16,17} have addressed specific subtopics of HIV treatment and prevention separately. To our knowledge,

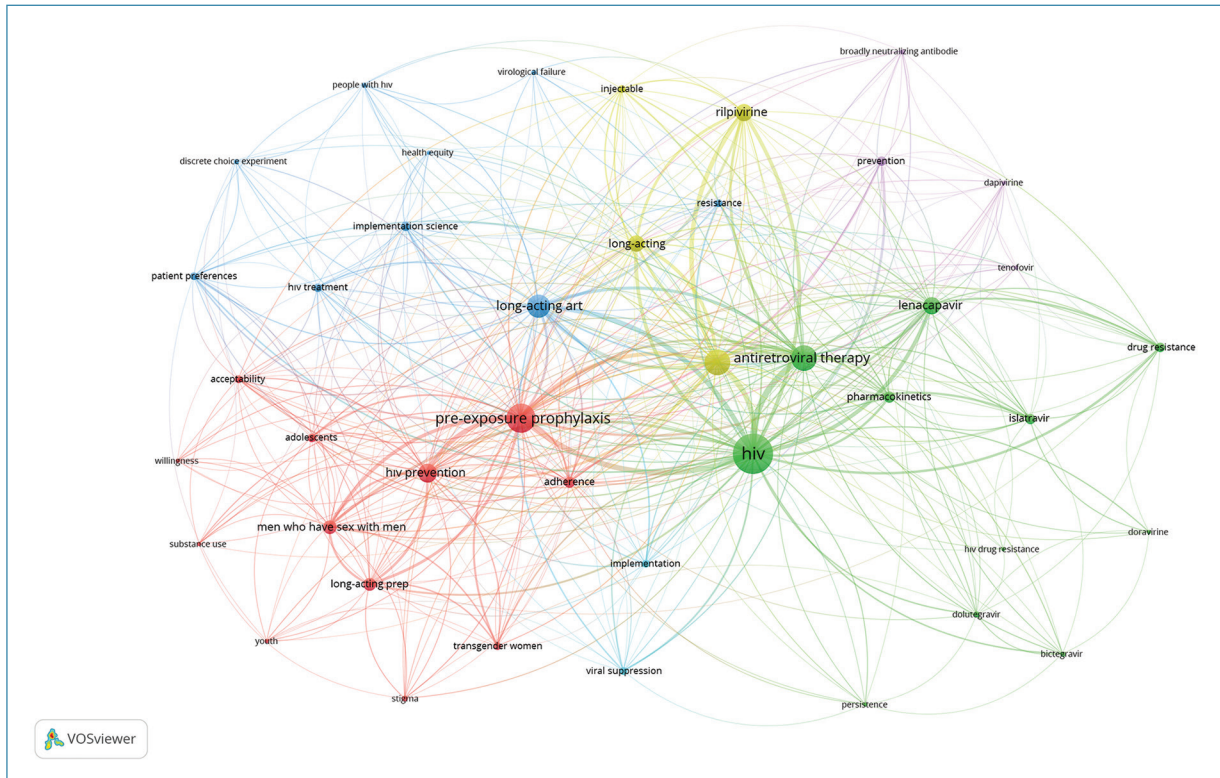


Figure 4. Keyword co-occurrence network (42 keywords). Node size represents keyword frequency, colors represent clusters, and link thickness represents the co-occurrence frequency of two terms.

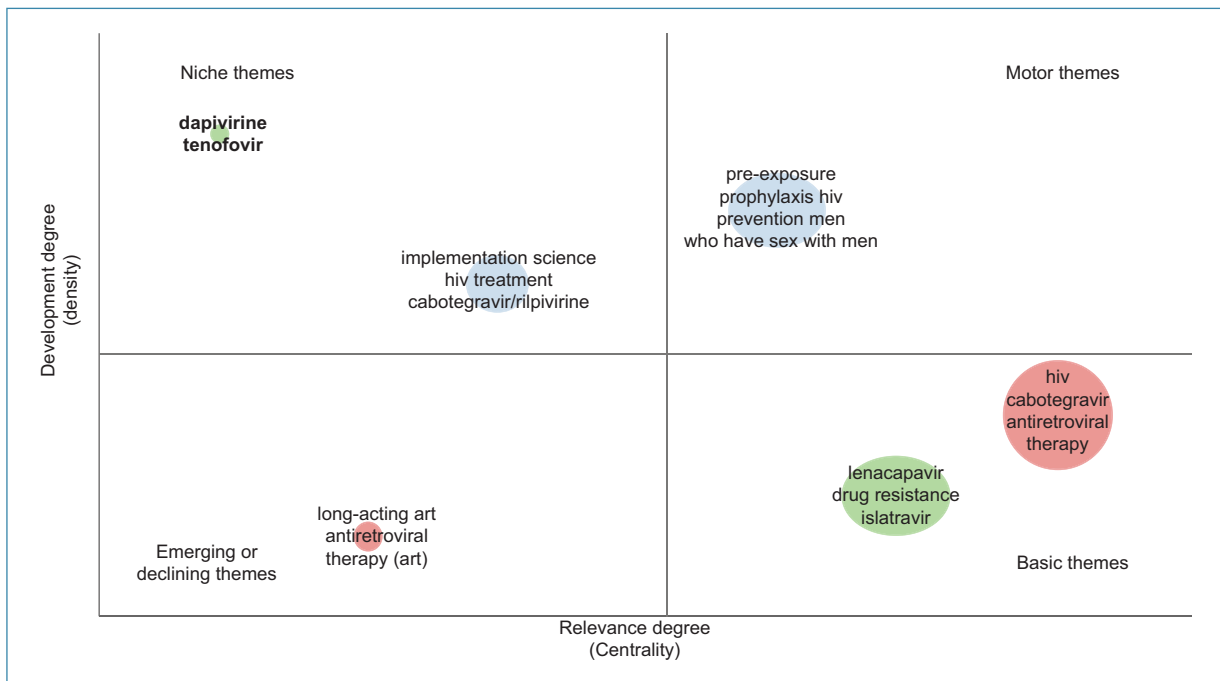


Figure 5. Thematic map: motor, basic, niche, and emerging/declining themes. Bubble size represents the frequency/weight of the corresponding thematic cluster.

as of June 30, 2026, the present study is the first to bring together the long-acting treatment and prevention literatures within a single Scopus-based science-mapping framework, linked through shared drugs, keywords, authors, and citation networks. Distinct from these prior analyses, our approach further classifies the funding and industry affiliation of the field's most-cited publications, an aspect not addressed in the PrEP- or treatment-focused bibliometric studies noted above. The keyword and thematic-map findings show that PrEP, HIV prevention, and PrEP are among the field's motor themes, suggesting that long-acting approaches have gained a central position in both treatment and HIV transmission-prevention research.

In the treatment domain, the cabotegravir/rilpivirine combination emerged as one of the most frequently studied topics in the literature.^{3,4,18} The keyword network and bibliographic coupling analyses showed strong connections among cabotegravir, rilpivirine, and long-acting ART, reflecting the central place of long-acting injectable maintenance regimens on the research agenda for virologically suppressed people with HIV. At the same time, the presence of terms such as virological failure, adherence, patient preferences, and acceptability in the network indicates that the field is evaluated not only in terms of antiviral efficacy but also patient experience, sustainability, and successful implementation. Medication adherence has previously been identified as a distinct research focus in the HIV bibliometrics literature.¹⁹

Another notable finding is the speed with which lenacapavir became one of the field's high-centrality basic themes.^{8,9} In the thematic map, lenacapavir, drug resistance, and islatravir were positioned within the basic-themes quadrant, whereas the overlay analysis placed the average publication year of these terms in the most recent part of the timeline. Taken together, these findings suggest that the long-acting HIV literature has expanded from its early cabotegravir-centered phase toward newer agents offering longer dosing intervals and different mechanisms of action. Lenacapavir's use in both treatment and prevention⁷⁻⁹ suggests that this theme is likely to retain its importance in the coming years.

The country and collaboration analyses showed that research output was concentrated markedly in the United States, followed by several European countries. This dominant US position may be related to the scale of NIH-supported HIV research infrastructure, pharmaceutical industry investment, and the coordination of multinational phase 2 and 3 trials by US-linked research

networks. Notably, however, South Africa, Uganda, and several other African countries showed high rates of multiple-country publications. This pattern may partly reflect the participation of high-incidence settings in multinational phase 3 prevention trials, in addition to broader academic partnerships.⁶

Research output was concentrated in countries with well-established HIV research infrastructure and active participation in multinational clinical trials. These findings primarily reflect scientific productivity and collaboration patterns rather than the real-world availability or implementation of long-acting HIV therapies.

The fact that most of the highly cited publications are clinical trials, guidelines, or highly influential basic research reflects the field's close ties to clinical development. Studies such as those by Landovitz et al.,⁵ Swindells et al.,³ Margolis et al.,¹⁴ Bekker et al.,⁸ and Overton et al.¹⁵ are among the key references of the long-acting men who have sex with men and long-acting ART literature. The co-citation analysis further supported the importance of cabotegravir/rilpivirine clinical trials, long-acting PrEP research, and, more recently, lenacapavir publications to the field's intellectual base. High citation counts, however, may also reflect the visibility of multicenter trials, large sample sizes, and extensive co-authorship networks and should therefore not be treated as equivalent to clinical impact. The funding distribution reported in the results indicates that a substantial share of the most-cited literature is linked to industry-funded, industry-affiliated, or mixed-funded clinical-development programs, and citation patterns should be interpreted with this funding structure in mind.

Beyond the bibliometric expansion observed in our analysis, LA-ART strategies may have broader implications for the future delivery of HIV treatment and prevention. By reducing dependence on daily oral dosing, these approaches may alleviate adherence burden and treatment fatigue while providing greater flexibility for both treatment and PrEP. The field is also expanding beyond currently available injectable regimens toward alternative delivery platforms, including nanoformulations, implants, microarray patches, and ultra-long-acting prodrugs. As highlighted by Ullah Nayan et al., further progress will depend not only on extending dosing intervals but also on optimizing pharmacokinetic profiles, reducing administration burden, identifying suitable combination partners, and integrating these strategies into accessible healthcare delivery systems.²⁰ These developments suggest a broader transition toward less frequent and more individualized approaches to HIV treatment and prevention.

This study shows that the long-acting HIV treatment and prevention literature is no longer built around pharmacological efficacy alone. Implementation science, acceptability, patient preferences, access, health-system integration, and international collaboration are becoming increasingly prominent. Future research should therefore focus not only on the efficacy of new molecules but also on the real-world feasibility of these treatment and prevention approaches across different populations.

Strengths and limitations

The principal strength of this study lies in its integrated evaluation of long-acting HIV treatment and prevention within a single bibliometric framework, combining descriptive indicators with multiple science-mapping techniques. The combined use of publication output, citation impact, country collaboration, keyword networks, bibliographic coupling, co-citation, and thematic-map analyses allowed a comprehensive examination of both the quantitative and conceptual structure of the field.

The study nonetheless has several limitations. First, the analysis relies solely on Scopus, and some publications indexed in Web of Science, PubMed, or other databases may not have been captured. Recent comparable bibliometric studies have used databases other than Scopus,^{11,12,16,17} and the absence of cross-database validation in our study increases the likelihood that some findings are Scopus-specific. Second, restricting inclusion to English-language articles and reviews may have excluded relevant non-English literature. Third, because the search was conducted before 2026 was complete, publication counts for that year are incomplete. Fourth, citation-based indicators are time-dependent and may favor older publications. Fifth, uncertainties in author and institution name disambiguation may have affected productivity rankings. Sixth, the *post hoc* funding classification depends on the completeness of funding and conflict-of-interest disclosures in the original publications. Finally, self-citation and consortium-level citation patterns were not separately assessed.

Conclusion

This bibliometric analysis shows that the long-acting HIV treatment and prevention literature has grown rapidly, particularly since 2020. The field is currently driven by long-acting PrEP, cabotegravir/rilpivirine-based

therapy, patient-centered implementation research, and emerging agents such as lenacapavir. Cabotegravir and PrEP stand out as dominant themes in the literature, whereas lenacapavir represents a newer and rapidly developing area of research. Future studies should assess not only the efficacy of long-acting HIV strategies but also their real-world feasibility, accessibility, and acceptability across different populations.

Funding

None.

Conflicts of interest

None.

Ethical considerations

Protection of human subjects and animals. The authors declare that no experiments on humans or animals were performed for this research.

Confidentiality, informed consent, and ethical approval. This study does not involve personal patient data, medical records, or biological samples, and does not require ethical approval. SAGER guidelines do not apply.

Declaration on the use of artificial intelligence. The authors declare that ChatGPT was used for language editing and grammar improvement.

Supplementary data

Supplementary data are available at 10.24875/AIDSRev.26000016. These data are provided by the corresponding author and published online for the benefit of the reader. The contents of supplementary data are the sole responsibility of the authors.

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