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A Bibliometric Analysis of the Application of Artificial Intelligence in Adolescent Idiopathic Scoliosis

Chenlu Rao[1,2], Jinming Wang[1,3], Xiaojuan Ma[3], Meiyuan Hu[3], Jiaxin Zhang[1], Ying Xu[4], Wenjuan Zhou[2*]

[1]Medical School of Yangtze University, Jingzhou, China
[2]Operating Room, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China
[3]Department of Orthopedics, Operating Room, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China
[4]Medical School of Jishou University, Jishou, China
Email: 2207149961@qq.com, *zwj1321892677@163.com

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Abstract

Objective: This study aims to systematically analyze the research status, hot direction and development trend of AI-related literature in the field of AIS through the method of literature metrology, and provide reference for future research and clinical application. **Method:** Retrieve the AIS + AI literature as of May 6, 2026 in the Scopus database, and a total of 366 literatures were retrieved, and finally 134 literatures were included for analysis. Use literature metrology methods such as keyword co-analysis, cluster analysis and sudden word analysis to evaluate research hotspots, academic co-operation and development trends. **Results:** China and the United States occupy a central position in literature output and international cooperation, while Canada, Switzerland and some Asian countries play a bridge role. Core institutions include University of Alberta, Peking Union Medical College Hospital and The University of Hong Kong; core works Such as Lou, Edmond, Wong, Jason, Labelle, Hubert form the cooperation center. Keyword and cluster analysis shows that the research hotspots focus on AIS disease ontology, image evaluation, AI methods, spinal modeling, automatic seg-mentation and diagnostic prediction; keyword burst analysis shows that research has gradually evolved from algorithm development to clinical prediction and AI auxiliary tools. **Conclusion:** AI research in the field of AIS presents the trend of deepening multidisciplinary integration, enhancing international cooperation, clinical application orientation, iteration of technical methods and multi-center data sharing, providing theoretical and technical support for accurate diagnosis, individu-

alized intervention and interdisciplinary collab-oration. This research systematically sorts out the academic status, hot spots and development trends of AIS AI research, and provides a reference basis for future research and clinical practice.

Keywords

Adolescent Idiopathic Scoliosis, Artificial Intelligence, Documentary Metrology, Research Trends, Multi-Center Cooperation

1. Introduction

Adolescent Idiopathic Scoliosis (AIS) is the most common three-dimensional spinal deformity in adolescence, with an incidence of about 2% - 4%, and the incidence of female patients is significantly higher than that of men [1]. The clinical manifestations of AIS are usually scoliosis, shoulder balance or pelvic tilt. As the course of the disease progresses, some patients may have chest deformity, limited respiratory function and mental health problems, which have a significant impact on the quality of life [2]. Although the cause of AIS is not fully clear, research shows that it may be closely related to genetic factors, neuromuscular development abnormalities, endocrine regulation and environmental factors [3].

Although AIS has a clear clinical definition and epidemiological characteristics, the natural course of AIS is highly heterogeneous, and the curvature may progress rapidly in adolescence. Early identification and evaluation are of key significance to the effect of intervention. The latest review emphasizes that early detection, individualized evaluation and timely intervention of AIS are crucial to improving the prognosis and quality of life of patients, especially at the stage when the curvature is still small and can be stabilized or corrected by non-surgical means [4]. Early detection helps to identify patients with high-risk progression before conservative treatment (such as brace correction and specific rehabilitation exercises) takes effect, thus reducing the risk of progression to surgical signs [5]. In addition, the modern management guidelines emphasize that the standardized diagnosis and intervention process of AIS should be promoted on the basis of systematic screening, scientific assessment and programming [6]. Standardized assessment includes curvature quantification, bone maturity assessment and risk stratification assessment, which helps to formulate personalized intervention plans (such as whether it is suitable for support, physical therapy or more active monitoring) [7]. Therefore, standardized screening and early intervention are important measures to reduce curvature progression, reduce the burden of treatment and improve the quality of life.

In recent years, the research on the diagnosis of adolescent idiopathic scoliosis has pointed out that the progress of imaging technology has significantly improved the diagnostic accuracy and treatment planning ability of AIS. A recent review summarizes the latest progress of AIS diagnosis and management, empha-

sizing that low-radiation imaging technology (such as EOS system) is attracting more and more attention in clinical applications because of its ability to establish three-dimensional reconstruction models. It is of great significance for accurately measuring spinal curvature and rotation characteristics, and can assist preoperative planning. And individualized intervention decision-making [5]. Similarly, a systematic literature review points out that in addition to traditional two-dimensional X-rays, three-dimensional imaging methods such as MRI and CT play an important role in the visualization of complex anatomical structures. Among them, CT three-dimensional reconstruction can accurately show the bone structure morphology and heterogeneous deformation of the spine, which is conducive to evaluating the severity of scoliosis and surgical planning, while MRI is improving the overall diagnostic ability of AIS as a supplementary imaging means because it has no ionizing radiation and sensitivity to soft tissue details [8]. In addition, with the development of computer-aided analysis and image processing technology, three-dimensional image reconstruction, automatic measurement and deep learning-assisted evaluation have gradually entered the field of clinical research, which can achieve more accurate 3D morphological analysis and reduce manual measurement errors, which is expected to further improve the effectiveness of AIS curvature evaluation and intervention [8].

Although significant progress has been made in non-surgical interventions (such as brace correction and rehabilitation training) and surgical treatment (such as spinal fusion and intravertebral arch fixation), the long-term effects and individualized interventions of different treatment strategies still need to be further explored. For example, a scope review system published in 2024 summarizes the application status of AI in adolescent idiopathic scoliosis, pointing out that AI has been widely used in AIS's automatic image analysis, curve classification/severity assessment, curvature progress prediction, and diagnosis and treatment decision-making support, including clinical decision-making such as auxiliary judgment brace treatment vs surgical management, but the review also clearly points out that most academic studies have not given clear clinical implementation guide-lines or practical standards at present, which limits the application and promotion of AI technology in practical clinical practice [9]. Not only that, recent studies show that deep learning-based models have been gradually applied to AIS surgical decision support and postoperative prognosis prediction. For example, Chen *et al.* have built a variety of deep learning models to learn and analyze the preoperative and postoperative data of AIS patients, effectively predict the structural changes of the postoperative spine, and provide quantitative support for personalized surgical strategies [10]. Another study uses the AI system to predict postoperative rehabilitation results and health-related quality of life indicators to provide reference for the formulation of postoperative rehabilitation plans [11]. Therefore, although there are still challenges such as verification scale and ex-ternal application promotion, these advances show that AI has significant potential to achieve personalized treatment planning.

As a scientific quantitative analysis method, bibliometrics can comprehensively

reveal the development vein, research hotspots and academic influence of the discipline by counting the number of literature, citation frequency, core journals, author and institutional co-operation networks and other indicators [12]. In the field of AIS, literature metrology can help researchers identify high-output institutions, core research teams and major academic trends, and provide data support for resource allocation, scientific research cooperation and research direction decision-making.

Based on the above background, this study uses AI technology to conduct a systematic literature metrology analysis of AIS-related literature, aiming to comprehensively sort out research hotspots, reveal major academic contributors and institutional distribution, analyze international cooperation networks, and explore research trends. In this way, it can provide a scientific basis for the future scientific re-search direction, academic resource allocation and clinical practice of AIS, provide decision-making reference for relevant researchers, and promote international exchanges and collaboration in this field of research. This research not only helps to summarize the existing academic achievements in the field of AIS, but also provides methodological reference for subsequent research based on big data and AI technology, which helps to promote the further development of accurate diagnosis and treatment and scientific research of AIS.

2. Materials and Methods

2.1. Literature Search and Screening

This study conducted a literature search in the Scopus database, with the search completed on May 6, 2026. A total of 366 records were retrieved. Two researchers independently screened the titles and abstracts, and any disagreements were reviewed and resolved by a third researcher. Finally, 134 studies were included in the analysis.

The included studies were classified by research type. Algorithm/methodological studies accounted for the largest proportion, with 51 articles (38.1%), mainly focusing on artificial intelligence, deep learning, image recognition, image segmentation, and automatic Cobb angle measurement. Prediction model studies ranked second, with 29 articles (21.6%), mainly involving Cobb angle prediction, curve progression risk assessment, postoperative outcome prediction, and rehabilitation outcome evaluation. Original studies accounted for 22 articles (16.4%), and model development and validation studies accounted for 18 articles (13.4%). In addition, there were 5 comparative studies (3.7%), 4 retrospective/cohort studies (3.0%), 4 preliminary/proof-of-concept studies (3.0%), and 1 review article (0.7%). Overall, research in this field is gradually shifting from clinical observation toward model construction, performance validation, and intelligent decision support.

It should be noted that this study used Scopus as the sole data source and included only English-language records, which may have introduced database coverage bias and language bias. Different databases vary in journal indexing, disciplinary coverage, geographic distribution, and citation data; therefore, searching

a single database may not fully capture all relevant studies. In addition, non-English publications, particularly local studies published in Chinese, Japanese, and Korean, may be underrepresented, especially those related to scoliosis screening, rehabilitation, and nursing practice. Therefore, the findings of this study mainly reflect the research hotspots and trends in English-language literature indexed in Scopus, and readers should interpret the coverage and generalizability of the bibliometric mapping with caution [1] (**Figure 1**).

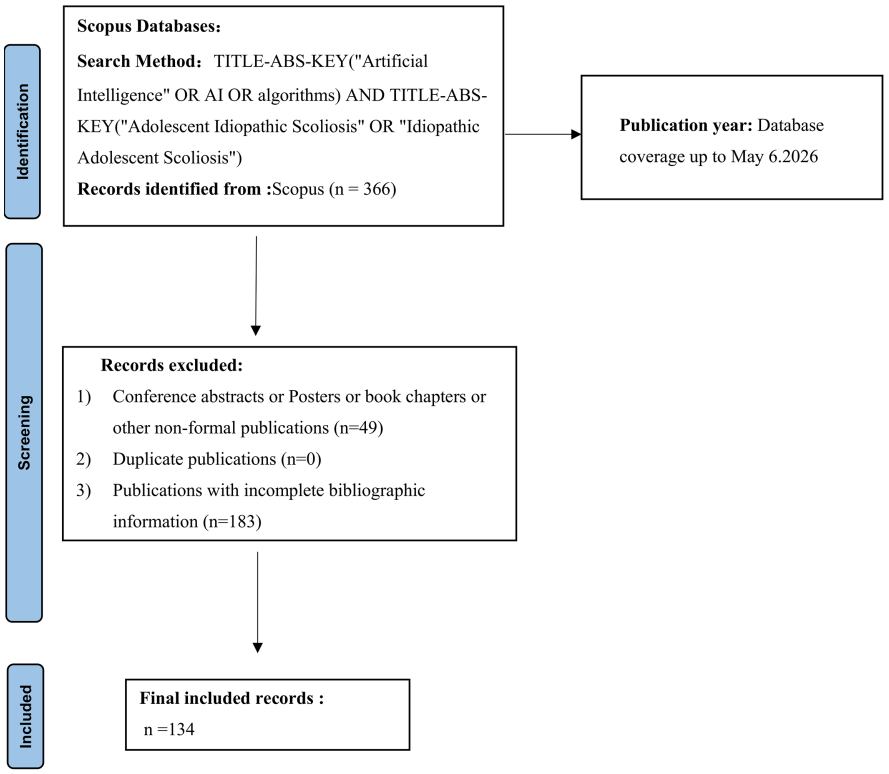

Figure 1. Flowchart of the study.

2.2. Inclusion and Exclusion Criteria

Inclusion criteria:

- The topic involves the application of artificial intelligence (AI) in the study of Adolescent Idiopathic Scoliosis (AIS);
- The types of literature include original research, review articles and academic literature that can be used for metrological analysis;
- The language of the literature is English;
- The literature provides complete information on topics, abstracts, authors, journals and years of publication.

Exclusion criteria:

- Only literature for conference abstracts, posters, book chapters or informal publications;
- Duplicate literature or literature that cannot obtain complete literature information.

3. Results

3.1. The Amount of National Documents

Judging from the number of literature published, China still dominates AI and adolescent idiopathic scoliosis (AIS) research, with a total of 64 literatures published, showing the highest research activity in this field in China.

Canada (28 articles) and the United States (21 articles) followed closely. Among them, the central value of the United States is 0.89 and that of Canada is 0.79, indicating that these two countries have a strong pivotal role in the international academic cooperation network and may play a key role in transnational research and the production of high-impact literature. The number of literature in other countries is relatively small, including Japan (9), South Korea (8), Switzerland (6), Türkiye (5), Australia (5), Spain (4) and France (3). Despite the small volume of literature, the participation of these countries shows that international research interest in the field is gradually expanding. The central values of Japan and Switzerland are 0.27 and 0.22 respectively, indicating that they still have a certain influence in the international cooperation network, while Türkiye, South Korea, Australia, Spain and France are less central, indicating that the core role in the global cooperation network is limited.

Overall, research in this field focuses on high-output countries in China and North America, and gradually extends to other countries and regions such as Asia, Europe and Oceania. In the future, with the in-crease of transnational cooperation, it is expected that the academic influence of other countries in the field of AI and AIS research may be further enhanced (Figure 2).

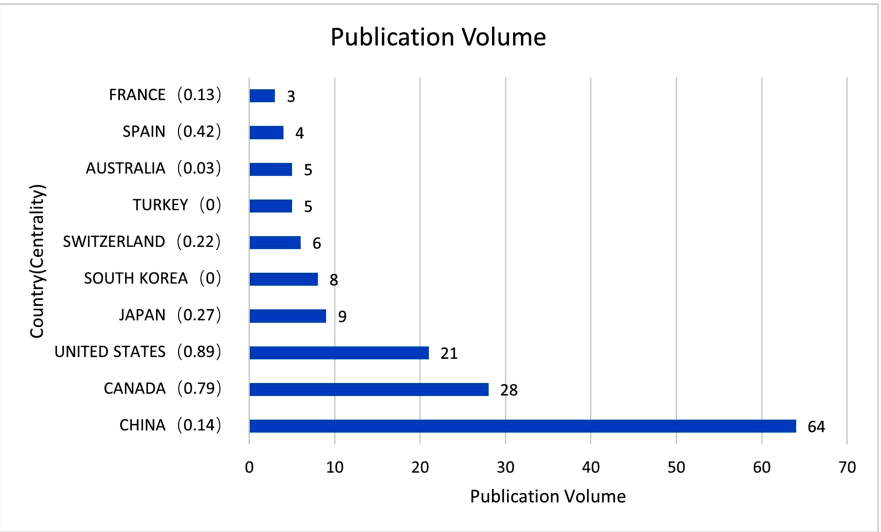

Figure 2. Publication volume.

3.2. Analysis of Highly Cited Literature and Core Journals

The figure shows (Figure 3) that the most cited literature is mainly concentrated in the research published from 2018 to 2023. Among them, the research of Wu H

et al. (2018, Med Image Anal) [13] topped the list with 136 citations, followed by Yang J *et al*. (2019, Commun Biol) [14], with 135 citations. Times. In general, the highly cited literature mostly involves the research of AI technology in scoliosis image analysis, machine learning algorithm application and clinical prediction models, showing the academic influence and research hotspots of these directions in the field. For example, the system review specifically analyzes the application of machine learning methods in the prediction of AIS curve progress, points out that machine learning models combining image data and clinical characteristics are superior to traditional methods in prediction accuracy, and emphasizes the clinical potential and challenges of these models [15].

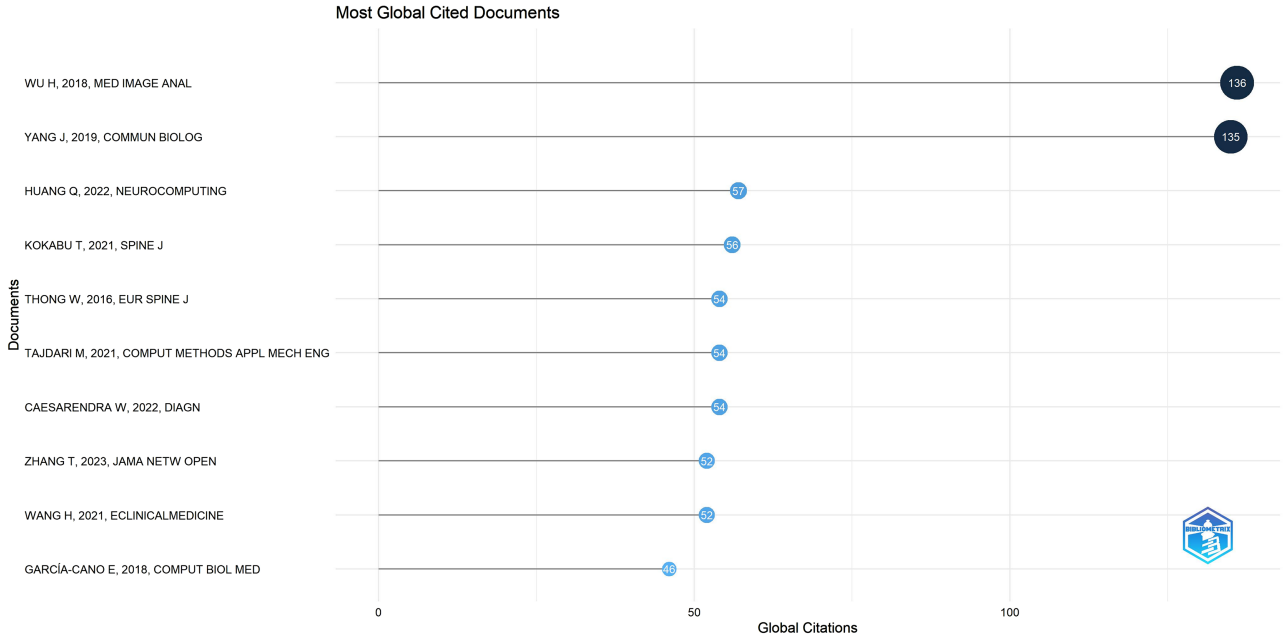

Figure 3. Most global cited documents.

From the analysis of the most relevant journal sources (**Figure 4**), the journal with the largest number of publications is European Spine Journal, with a total of 13 articles, followed by Spine Journal (5 articles) and Global Spine Journa. L (4 articles). Other journals such as Scientific Reports and Biomedical Signal Processing and Control have also published a certain number of publications. This shows that AI mainly focuses on spine professional journals in the study of adolescent idiopathic scoliosis. At the same time, some interdisciplinary journals have also begun to pay attention to this direction, reflecting the multidisciplinary cross-cutting characteristics of the research topic. The latest analysis of AI and scoliosis metrology shows that the number of literature in this field is growing rapidly. The application of AI technology includes but is not limited to automatic image analysis, feature extraction, machine learning prediction models, etc., which shows that not only the medical clinical field pays attention to this direction, but also the journals in the field of computer science and engineering Relevant research has also gradually shown interest.

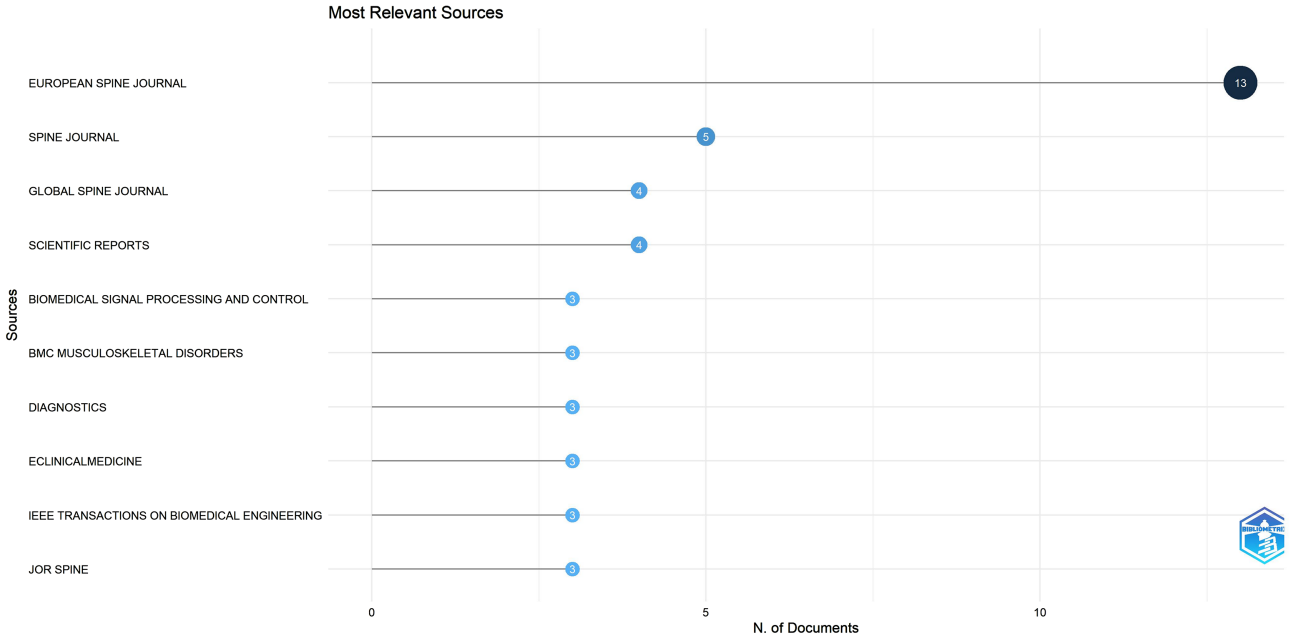

Figure 4. Most relevant sources.

3.3. Keyword Analysis

3.3.1. Clustering of Keywords

Figure 5 cluster analysis shows the theme clustering and its interrelationship of AI-based adolescent idiopathic scoliosis (AIS) study. The color of the node represents different research topics, the connection between nodes reflects the coexistence or reference relationship between the themes, and the size of the node corresponds to the frequency of keywords. The whole network consists of 332 nodes and 579 connections, with a network density of 0.0105. The rationality of the cluster structure is verified by the modularity Q = 0.5906 (>0.3) and the weighted average contour coefficient S = 0.8647 (>0.5), indicating that the identified clusters can highly consistently and reliably reflect the main research of AI in the field of adolescent idiopathic scoliosis. Investigate hot spots and development trends.

Not only that, cluster analysis also shows that the hot spots of adolescent idiopathic scoliosis (AIS) research mainly focus on the disease itself and its diagnosis and treatment, among which the core cluster #0 AIS covers the overall research topics related to the disease. Imaging research (#1 Radiography) and artificial intelligence application (#2 Artificial Intelligence) are the main supports of research, indicating that AI technology is promoting AIS's image analysis, automatic segmentation and clinical prediction models. Vertebra Modeling (#3 Vertebra Modelling), Gait Analysis (#9 Gait Analysis) and Humpback Related Studies (#7 Kyphosis) show attention to structural and functional evaluation, while diagnostic accuracy research (#6 Dia Gnostic Test Accuracy Study) emphasizes the importance of method verification. The emergence of cluster #4 ChatGPT suggests the potential of emerging intelligent tools in document collation and clinical decision-making assistance. In general, this field presents a knowledge structure centered on disease research, sup-

ported by imaging and AI technology, and given the same emphasis on diagnosis and functional evaluation, reflecting that AIS research is developing in the direction of multidisciplinary intersection and technology integration.

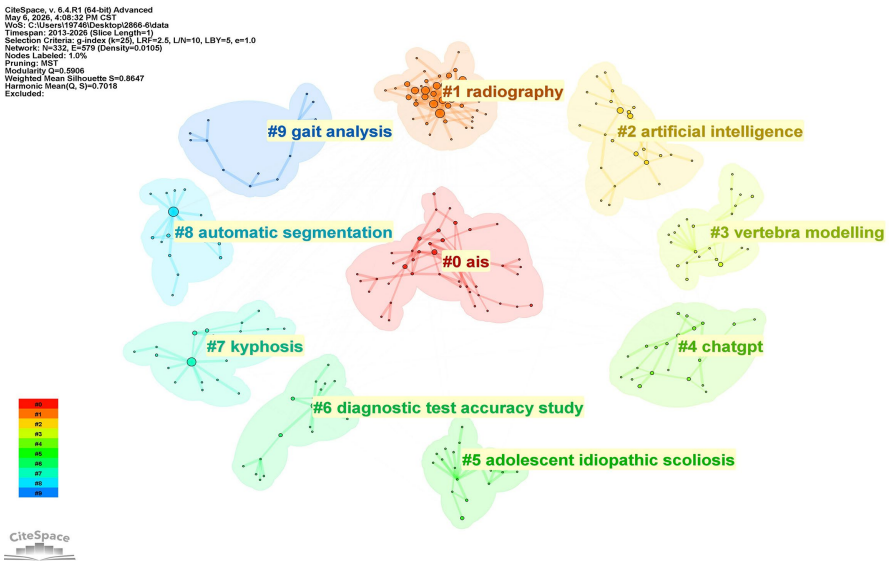

Figure 5. Clustering of keywords.

Table 1 lists the top keywords with the highest frequency and centrality in AI-based studies on adolescent idiopathic scoliosis. In terms of keyword frequency, "adolescent idiopathic scoliosis" (109 times), "female" (78 times) and "scoliosis" (77 times) are in the top three, showing that the research is mainly concentrated in youth Population characteristics and clinical research of juvenile idiopathic scoliosis. Other high-frequency keywords such as "male" (74 times) and "cobb angle" (65 times) reflect the gender difference in the literature. Attention to the measurement methods and research types of different and spinal deformities.

Table 1. Keywords by frequency and centrality.

Rank	Year	Keywords	Frequency	Centrality
1	2013	adolescent idiopathic scoliosis	109	0.28
2	2013	female	78	0.02
3	2013	scoliosis	77	0.02
4	2013	male	74	0.05
5	2013	cobb angle	65	0.03
6	2013	child	59	0.06
7	2019	deep learning	58	0.00

It is worth noting that "deep learning" appeared in the tenth place (58 times, central 0), marking that AI, especially deep learning methods, has gradually re-

ceived attention in AIS research in recent years, reflecting the technological update trend of research methods. In general, high-frequency keywords reflect the core research objects, clinical measurement indicators and emerging artificial intelligence technology applications in this field, revealing the theme structure and development focus of adolescent idiopathic scoliosis research.

3.3.2. Keyword Bursts

The chart shows (Figure 6) the 15 keywords with the most significant growth in adolescent idiopathic scoliosis (AIS) research and their time windows, revealing the evolutionary trajectory of the research hotspots. In the early days (2013-2019), the keywords "algorithms" and "priority journal" appeared suddenly, showing that algorithmic methods and high-impact journal publications were the initial focus of attention. In 2019, the sudden outbreak of "young adult" and "three-dimensional imaging" reflects the attention to specific age groups and three-dimensional imaging technology. In 2020-2022, the "convolutional neural network" burst showed that deep learning has developed rapidly in AIS image analysis. At the same time, "kyphosis" continued to occur in 2021-2023, showing that the research on spinal-related structures has been attracting attention for a long time. In 2021-2022, the sudden "musculoskeletal system" emphasized the comprehensive study of the spine and motor system. In 2022-2023, the sudden display of "diagnostic accuracy" and "random forest" showed that AI models have become research hotspots in terms of prediction and diagnostic accuracy. In 2023-2023, the sudden outbreak of "sensitivity and specificity" and "diagnostic test accuracy study" shows the rapid growth of diagnostic methods and verification research. From 2023 to 2024, the sudden display AI technology of "x ray" and "support vector machine" will continue to attract attention in image analysis and clinical applications. In 2024-2024, the "convolution" outbreak indicates that the convolution algorithm is still the focus of research. In 2024-2025, the "surgery" emerges, indicating that clinical surgery and AI-assisted decision-making have become a future research trend.

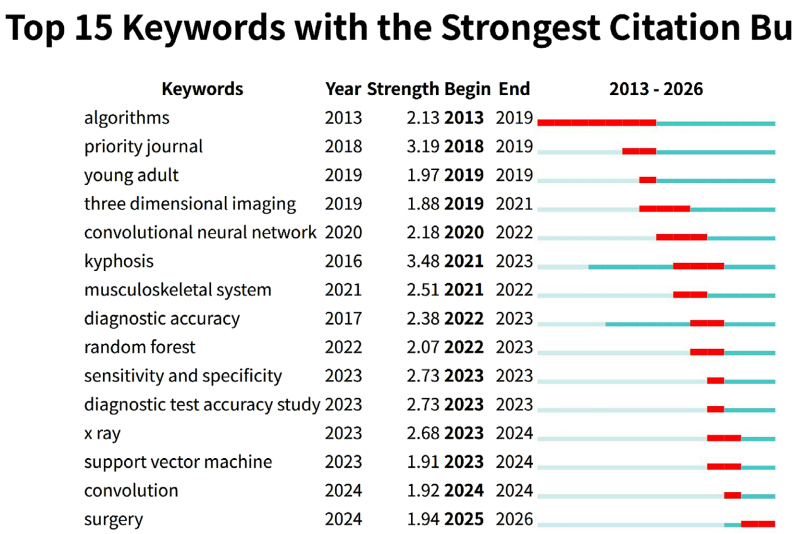

Figure 6. Keyword citation burst.

Overall, the research hotspots in the field of AIS present the evolution trend from algorithmic methods, imaging technology, deep learning models, clinical diagnosis and surgical applications, reflecting the characteristics of AI's gradual transformation from basic method development to clinical application in adolescent idiopathic scoliosis research, and at the same time shows this field Multidisciplinary cross-integration and development.

3.3.3. Keyword Timeline Analysis

According to the keyword timeline network (Figure 7), adolescent idiopathic scoliosis (AIS) research presents a multi-theme intertwined knowledge structure, in which the node size reflects the frequency of keywords, and the connection indicates the coexistence relationship between keywords. Clustering results show that AIS research covers the characteristics and classification of underlying diseases (such as "adolescent idiopathic scoliosis", "classification algorithm"), imaging analysis (such as "imag E segmentation", "angle measurement"), AI method application (such as "convolutional neural networks", "predictive model"), three-dimensional Spinal modeling and automatic segmentation, clinical diagnosis accuracy assessment, and accompanying symptom and function evaluation (such as "kyphosis" and "gait analysis") and other directions. This network reflects the development of AIS research from the analysis of basic disease characteristics to AI-driven image analysis, prediction models and clinical-assisted decision-making, showing the trend of diversified research methods, obvious interdisciplinary intersection and continuous technology iteration, providing important theoretical and technical support for accurate diagnosis and intervention.

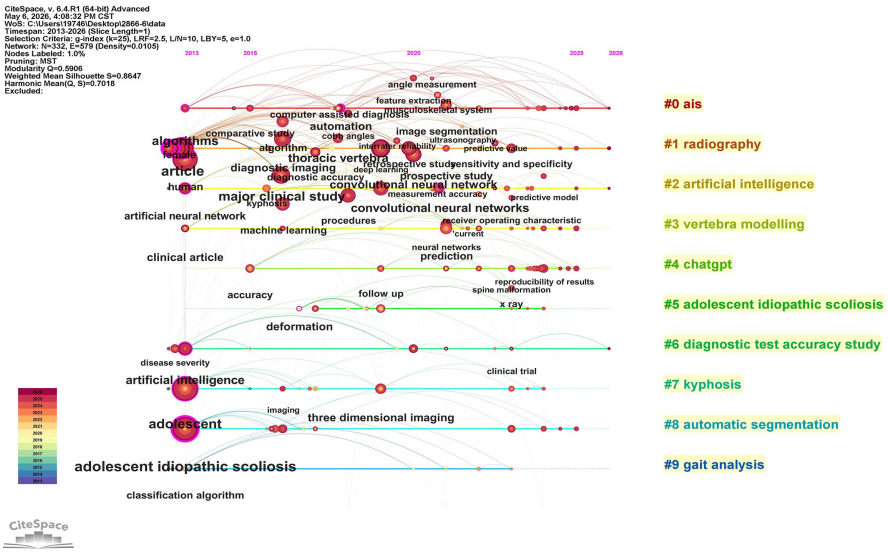

Figure 7. Keyword timeline analysis.

3.4. Collinearity Analysis

3.4.1. Country Collinearity

According to the International Cooperation Network (Figure 8), China and the

United States occupy a central position in adolescent idiopathic scoliosis (AIS) research, not only producing the largest number of literature, but also playing a hub role in the global cooperation network. In this study, nodes represent countries, node size reflects the number of publications from each country, the links between nodes indicate collaborative relationships, and the thickness of the links represents collaboration strength. To further evaluate the structural role of different countries in the collaboration network, this study used betweenness centrality to measure their potential "bridging role." Betweenness centrality reflects the extent to which a country lies on the shortest collaborative paths between other countries. The higher the value, the more likely the node is to facilitate information transmission, resource integration, and cross-regional connections among different collaborative groups.

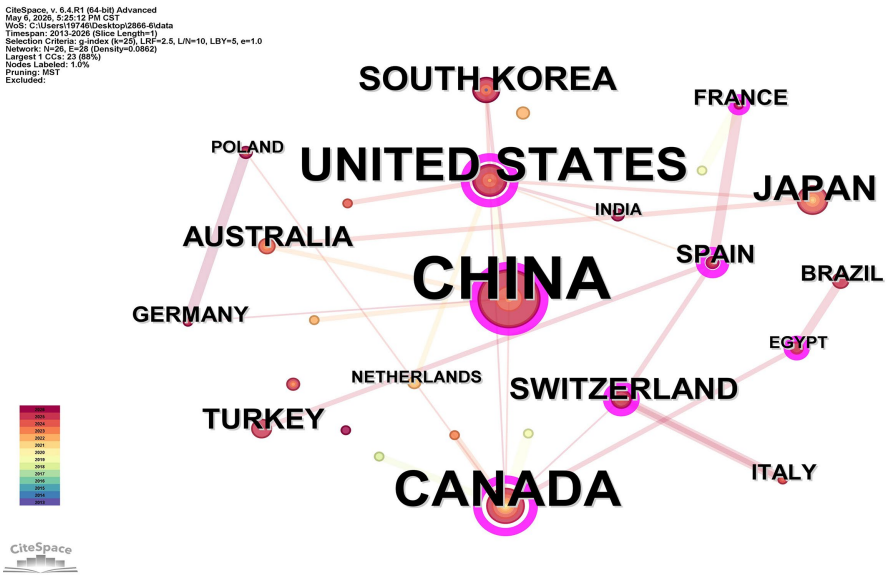

Figure 8. Country co-occurrence network analysis.

Canada and Switzerland have also shown high centrality, indicating that they play an important bridge role in transnational cooperation and high-impact research. Although other countries such as Japan, Australia, South Korea, Spain, France, Italy and Türkiye have relatively little output, it shows that the field is developing towards multi-center and cross-regional collaboration through participation in global research networks in cooperation with core countries. The size of the node reflects the literature output of each country, and the coarse details of the node connection reveal the intensity of cooperation. The close cooperation between China and the United States and the indirect connection between North American, European and Asian countries show that international cooperation is not only concentrated in a few core countries, but also shows a diffusion trend.

In general, the international cooperation of AIS research presents a globalization pattern with China and the United States as the core, cross-collaboration between North America and Europe, and the gradual integration of Asia and other

regions, which not only promotes the sharing of research results, but also provides a solid foundation for interdisciplinary and multi-method research, reflecting the multi-disciplinary cooperation in this field. Kindness and forward-looking.

3.4.2. Institutional Collinearity

The institutional cooperation network shows (Figure 9) that some core academic institutions and hospitals dominate international cooperation in the study of adolescent idiopathic scoliosis (AIS). University of Alberta, Peking Union Medical College Hospital and The University of Hong Kong are the core nodes in the network. It not only has a large output of literature, but also has close cooperation with other institutions. To more accurately interpret the structural position of institutions within the collaboration network, this study further introduced centrality indicators as supplementary measures. Unlike node size, which primarily reflects publication output, centrality is used to evaluate an institution's connectivity and sphere of influence within the overall collaboration network. Among these indicators, betweenness centrality reflects whether an institution lies on key connecting paths between different collaborative groups. A higher value indicates that the institution is more likely to facilitate knowledge transmission, resource integration, and collaborative coordination across different research teams, countries, or disciplinary areas.

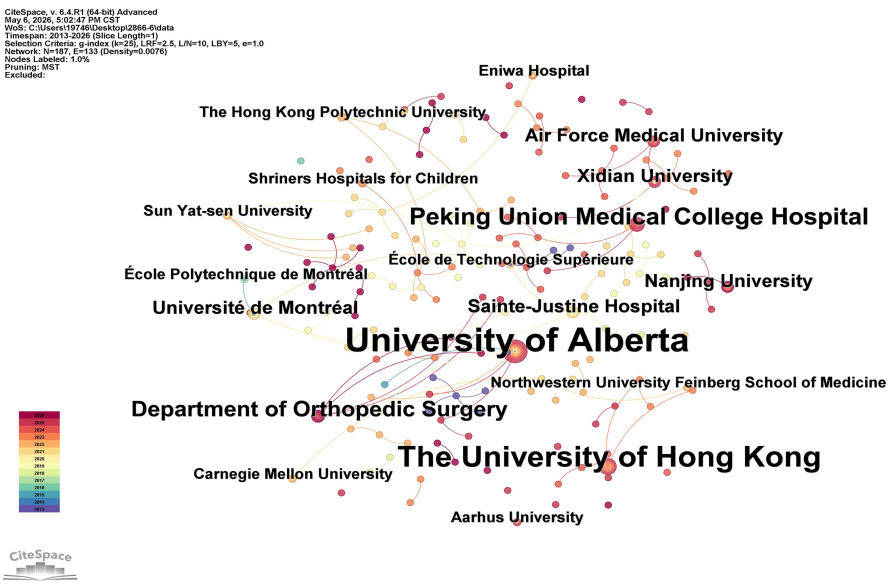

Figure 9. Institution co-occurrence network analysis.

Other active institutions such as Sun Yat-sen University, Xidian University, Nanjing University, Université de Montréal and École P Olytechnique de Montréal plays a bridge role in transnational and interdisciplinary cooperation. The size of nodes reflects the literature output of each institution. The connection between nodes shows the intensity of cooperation. It can be seen that the cooperation between core institutions is the closest, and some regional or emerging re-

search institutions indirectly participate in global cooperation networks through these core nodes.

Combined with institutional output analysis, University of Alberta ranked first with 12 documents, followed by The University of Hong Kong (8), and Peking Union Med Ical College Hospital (5 articles). Other high-output institutions include Department of Orthopedic Surgery, Sainte-Justine Hospital, Xidian University, Université de M Ontréal, Air Force Medical University, Nanjing University and Northwestern University Feinberg School of Medicine, each institution contributes 2 - 4 articles (Table 2). Most institutions have low centrality scores, which shows that although the output is high, it has not yet become a key intermediary node in the cooperative network. In general, institutional cooperation in the field of AIS presents a global cooperation pattern with top universities and hospitals in North America and Asia as the center, close collaboration between core institutions, and radiating the participation of multinational institutions. The literature output is concentrated in core institutions, showing that these units are promoting AIS research and international cross-university. It plays an important role in scientific cooperation.

Table 2. Top 10 contributing institutions in AIS research.

Rank	Year	Institution	Frequency	Centrality
1	2015	University of Alberta	12	0
2	2021	The University of Hong Kong	8	0
3	2024	Peking Union Medical College Hospital	5	0.01
4	2024	Department of Orthopedic Surgery	4	0
5	2018	Sainte-Justine Hospital	3	0
6	2019	Xidian University	3	0
7	2015	Université de Montréal	3	0
8	2024	Air Force Medical University	3	0
9	2024	Nanjing University	3	0
10	2021	Northwestern University Feinberg School of Medicine	2	0

3.4.3. Author Collinearity

According to the Authors' Cooperation Network (Figure 10), some core authors occupy a dominant position in international cooperation in AIS research. The size of the nodes in the network reflects the author's literature output, and the connection between nodes indicates the intensity of cooperation. Lou, Edmond, Wong, Jason, Labelle, Hubert, Zhang, Teng and Reformat, Marek are the core nodes, with large literature output and close cooperation, forming a network center area. Other authors such as Parent, Stefan, Kadoury, Samuel, Joncas, Julie and Galbusera, Fabio play a bridge role in connecting different research teams. On the

whole, the cooperation of the authors of AIS research presents a multi-center cooperation pattern with a few core authors as the center, close collaboration between core authors and radiating multi-team participation, reflecting the high degree of internationalization and interdisciplinary cross-disciplinary characteristics of research in this field.

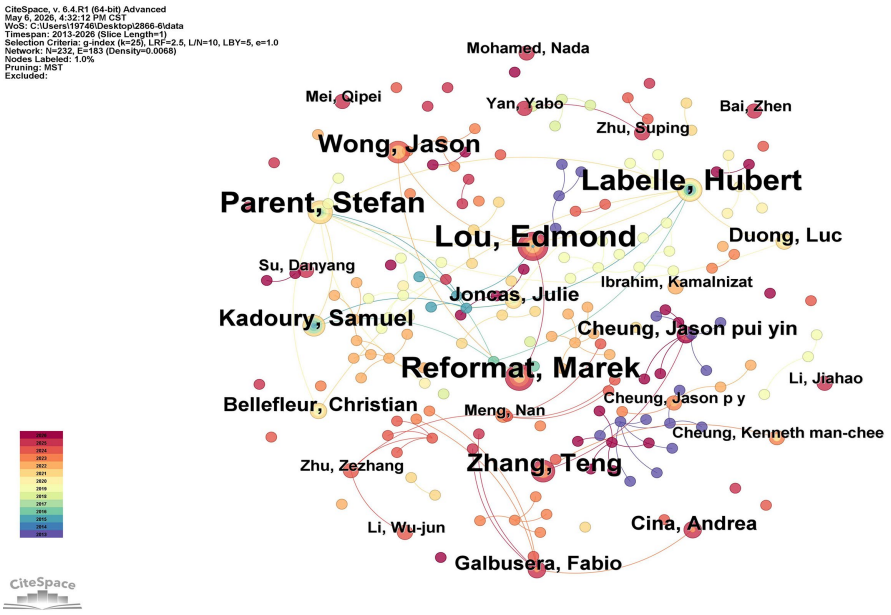

Figure 10. Author co-occurrence network analysis.

4. Discussion

4.1. Research Status

Based on the analysis of literature metrology, AIS research has shown a significant growth trend in the application of artificial intelligence (AI) in recent years. Judging from the timeline, the research from 2013 to 2018 mainly focused on AIS basic image analysis and manual Cobb angle measurement, and the application of AI technology was relatively limited; from 2019 to 2021, deep learning, convolutional neural networks and prediction models began to work in curve classification, imaging It is widely used in automatic segmentation and clinical prediction; after 2022, AI technology has shown rapid growth in multi-modal image analysis, automatic Cobb angle measurement, three-dimensional spinal modeling and clinical decision-making support systems. At the same time, multi-center and transnational cooperative research has emerged to improve diagnostic accuracy and clinical Operability. A systematic review has pointed out that 77.5% of AI applied research has been published in the past five years, showing that this direction is the current research hotspot. AI and machine learning technologies are more and more widely used in the diagnosis of AIS, curve classification, image analysis and prediction of clinical outcomes, among which convolutional gods Network, random forest and artificial neural network are the most commonly used technical routes [10]. Not only that, the research further proves the application value of AI

technology in AIS research. For example, using a deep learning model for automated Cobb angle measurement and curve severity classification of whole spine X-rays, the results show that they are highly consistent with expert evaluation, improving the objectivity and efficiency of image quantitative evaluation [16] [17]. In addition, a multi-center retrospective study used interpretative machine learning models to predict the risk of curve progression, showing high predictive performance, providing potential for early identification of high-risk patients and individualized interventions tools [18].

Country analysis shows that China and the United States have the highest literature output in this field and occupy a central position in the international cooperation network, which is consistent with the global AIS research trend. Some studies point out that with the increasing application of AI technology in AIS diagnosis and prediction models, Chinese and American research institutions have long been ahead of other countries in terms of the number of publications and the intensity of citations [19]. Countries such as Canada and Switzerland play a bridge role in transnational cooperation, while countries such as Japan, South Korea and Australia have gradually strengthened international cooperation with the growth of local scientific research. This global cooperative network structure promotes data sharing and the exchange of research methods, laying the foundation for multi-center research.

At the institutional level, University of Alberta, Peking Union Medical College Hospital and The University of Hong Kong are the core. Output institutions have high literature output and close cooperation. Although a literature measurement study for the whole field of AIS (1985-2020) did not focus on the AI direction, it also revealed the overall distribution of high-output institutions and authors within the overall framework of AIS research: the analysis shows that many North American and Asian institutions (such as Nanjing University and Columbia University Medical Center, etc.) are in an important position in AIS research output and citation, and multiple authors form a stable cooperative network, which is in line with the AI focus in this study. The cooperation pattern between the core institutions and authors in the application sub-field is consistent [20].

At the author level, Lou, Edmond, Wong, Jason, Labelle, Hubert and other high-output authors form a cooperation center to drive multi-team transnational collaboration. In the quantitative review of AIS enema treatment, Hubert Labelle was identified as one of the most productive authors. His research involves clinical and scientific research topics such as evaluation methods and conservative treatment effects of AIS, and has a co-authorship relationship with many international authors. It shows strong cross-team collaboration characteristics [21].

On the whole, AIS research presents a pattern of concentration of core countries and institutions, close collaboration between the author team, and multi-centralization of international cooperation, reflecting the high internationalization and interdisciplinary characteristics of this field. AI research in the field of AIS not only shows the rapid iteration and application expansion of technical

methods, but also through global cooperation and multi-center clinical data verification, it is developing in the practical direction of improving the accuracy of clinical diagnosis, automated image analysis and curve progress prediction model.

4.2. Research Hotspots

High-frequency keyword analysis shows that the core theme of AIS research revolves around the ontology of adolescent idiopathic scoliosis, image evaluation, AI algorithms and clinical diagnosis methods, which has been verified. A literature review of AIS diagnostic and image evaluation methods shows that although traditional diagnosis mainly relies on X-ray images, with the emergence of new non-invasive imaging technologies and automated processing methods, technological evolution in this field is being combined with AI algorithms and advanced image analysis, which shows that The cross-application between image evaluation, diagnostic methods and calculation tools has become an important part of AIS research [22]. In addition, at the specific application level of machine learning and AI algorithms, studies on automated diagnosis of spinal imaging have shown that algorithms combined with deep learning and image feature extraction can automatically estimate spinal alignment and Cobb angle from Moiré images. It shows the important role of AI in image evaluation and clinical diagnosis methods, which reflects the core position of topics such as "artificial intelligence" and "image technology" in keyword analysis [23].

Cluster analysis shows that research hotspots can be subdivided into Radiography, Artificial Intelligence, Vertebra Modelling, Automat Ic Segmentation and other technical directions. Research shows that automatic Cobb angle measurement and three-dimensional image analysis technology based on deep learning have made remarkable progress in these directions. For example, the latest instance segmentation method further verifies the advantages of automated measurement in eliminating manual errors and improving efficiency by detecting the vertebra and calculating the Cobb angle [24]. For example, the deep learning architecture proposed by Caesarendra *et al.* can automatically detect the vertebrae and accurately measure the Cobb angle from AIS X-ray images. Its automation method shows high reliability in comparison with the measurements of clinicians, proving the advantages of automatic algorithms in reducing subjective errors and improving efficiency [25]. In addition, Dong *et al.* used U-Net semantic segmentation technology to realize automatic Cobb angle measurement and Lenke classification of multi-angle full-spine images. The results are significantly superior to manual measurement in many classification consistency indicators, further proving that automatic segmentation and classification are combined in A The potential of IS image analysis [26].

Keyword burst analysis reflects the time evolution of research focuses: early research mainly focuses on algorithm development and basic feature extraction, and medium-term deep learning methods and structural evaluation began to rise. Recently, the focus of research has further shifted to clinical predictive models, ac-

curacy evaluation and AI-based advanced clinical auxiliary tools. Move. The systematic review also points out these trends, such as automated Cobb angle measurement and curve progress prediction, which has gradually become the mainstream application direction of AI in AIS research, but clinical implementation, verification and model transparency still need to be strengthened [27].

In summary, these empirical literature evidence supports the trend revealed by keyword analysis and cluster structure, that is, AIS research is evolving from method development and image automation to higher-level clinical applications and predictive models, and the diversified application of AI technology is pushing this field to multimodal and Development in the direction of clinical integration.

4.3. Research Trends

In the future, AIS research will present the following development trends: First, the deepening of multidisciplinary integration: With the application of AI technology, image analysis, clinical diagnosis, surgical planning and functional evaluation are gradually integrated, and the research has developed from a single algorithm method to a multi-modal comprehensive analysis. For example, the review of Sungwon Lee and others pointed out that AI not only improves image automation evaluation, but also can be combined with clinical data to achieve personalized prediction and treatment planning, which reflects the potential of multidisciplinary collaborative applications such as image analysis, clinical diagnosis and prediction models [28]. Second, international cooperation is enhanced: core countries and institutions still dominate research, but the participation of regional and emerging countries is gradually increasing, and transnational cooperation networks show a trend of multi-centralization and multi-leveling, providing support for high-quality scientific research. Although there is less quantitative analysis of specific international cooperation for AIS, the global overview of AI and spinal surgery shows that the output of AI research is mainly concentrated in many different countries/regions, and data sharing, algorithm verification, etc. require multi-center collaboration, which means that international cooperation is more diverse. Ben and diversity data are very important [29].

Third, clinical application orientation: the research focus is expanding from algorithm and image analysis to clinical operability, including diagnostic accuracy, surgical assistance and predictive model application, emphasizing the interpretability and clinical feasibility of AI methods. The AIS + AI review clearly points out that automatic image analysis, curve classification and curve progress prediction are the most common applications of AI in AIS [9]. Fourth, technical method iteration: Convolutional Neural Network, Random Forest, Support Vector Machine (SVM), Convolution and automatic segmentation technology are still Continuous optimization, three-dimensional reconstruction and multimodal analysis have gradually become the mainstream of research, providing a technical basis for accurate evaluation and individualized intervention. An independent deep learning review shows that DL is widely used in spinal image analysis [30].

Fifth, data sharing and multi-center research: With the enhancement of international cooperation and cross-institutional cooperation, the construction of multi-center databases and shared image resources is conducive to improving the ability of model generalization and the value of clinical promotion. For example, a multi-center study covering 3899 cases of whole spine X-ray images in 7 hospitals has developed a deep learning model based on real-time data transformation [31].

In summary, AIS research is in a period of rapid development driven by AI technology. The research hotspots have gradually extended from basic algorithms to clinical applications. The leading role of international cooperation and core institutions continues to be highlighted, and the trend of multidisciplinary cross-cutting and technological iteration is obvious. In the future, AI will play a more important role in automatic image analysis, individualized prediction, surgical assistance and interdisciplinary collaboration, providing solid support for the accurate diagnosis and treatment of adolescent idiopathic scoliosis.

5. Conclusion

This study analyzes the application of AI in adolescent idiopathic scoliosis (AIS) research based on biometrics. The results show that China and the United States occupy a central position in literature production and international cooperation, and core institutions and authors promote multi-center cooperation. The research hotspots focus on disease characteristics, image evaluation, AI methods, spine modeling, automatic segmentation and clinical prediction models, and present the transformation trend from algorithm development to clinical application. Empirical research shows that automatic Cobb angle measurement, three-dimensional modeling and curve progress prediction models perform well in multi-center verification, reflecting multidisciplinary integration, technical iteration and clinical application orientation. In general, AI is developing rapidly in AIS research, providing support for accurate diagnosis, individualized intervention and clinical decision-making, and also providing direction for future multi-center cooperation and technical optimization.

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Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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