

Article

Not peer-reviewed version

The Future of Autoimmune Pancreatitis (AIP): Spotlight on Key Researchers and Emerging Global Networks

[Naruaki Ogasawara](#) *

Posted Date: 14 September 2024

doi: 10.20944/preprints202409.1120.v1

Keywords: gastroenterology; autoimmune pancreatitis; co-authorship network analysis; network analysis; research collaboration; research trend analysis; research trends; key researchers; research strategies; internal medicine; planning future collaborative studies



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

The Future of Autoimmune Pancreatitis (AIP): Spotlight on Key Researchers and Emerging Global Networks

Naruaki Ogasawara

Editorial Department, The Japanese Society of Internal Medicine, Tokyo 113-8433; n-ogasawara@naika.or.jp;
Phone: +81-0-3813-5991, Fax: +81-0-3813-5991

Abstract: **Aim:** This study aims to analyze the collaborative networks and identify key players in autoimmune pancreatitis (AIP) research from 2000 to 2023. Using data from the Web of Science (WoS) Core Collection, I assess the structure and evolution of co-authorship networks to understand collaboration trends and influential researchers in the field. **Method:** I conducted a network analysis of co-authorship patterns in AIP research using Python (Version 3.10.5) in the PyCharm development environment (Software Version 2022.1.3). The analysis included macro-level indicators: network density, clustering coefficient, components, and average distance, as well as micro-level indicators: degree centrality, closeness centrality, and betweenness centrality. These metrics were used to evaluate the connectivity, clustering, and key nodes within the network across three distinct periods: 2000-2009, 2010-2019, and 2020-2023. **Result:** The analysis revealed that the co-authorship network in AIP research evolved from a fragmented structure with limited collaboration in the early 2000s to a more interconnected but still dispersed network in recent years. Despite an increase in network density and a decrease in the number of disconnected components over time, the overall structure remains highly clustered, with many researchers operating within isolated groups. Key figures, such as Kazuichi Okazaki, Terumi Kamisawa, and Shigeyuki Kawa from Japan, consistently ranked high in centrality measures, highlighting their significant influence and leadership in the field. The findings suggest that while local collaborations are strong, broader international connections are still developing. **Conclusion:** This study provides a comprehensive overview of the collaborative landscape in AIP research, identifying central researchers and highlighting persistent fragmentation within the network. The prominent role of Japanese researchers in shaping the field underscores the importance of fostering greater international collaboration to bridge gaps between research clusters. Enhancing global partnerships could lead to more integrated and impactful research outcomes, ultimately advancing the understanding and management of autoimmune pancreatitis.

Keywords: gastroenterology; autoimmune pancreatitis; co-authorship network analysis; network analysis; research collaboration; research trend analysis; research trends; key researchers; research strategies; internal medicine; planning future collaborative studies

Introduction

Background and Objectives

Autoimmune pancreatitis (AIP) is a rare form of chronic pancreatitis characterized by an immune-mediated inflammatory process, which can lead to pancreatic and extra-pancreatic manifestations. Understanding the collaborative dynamics and the structural characteristics of research networks within this field is crucial for advancing knowledge and fostering international collaborations. AIP presents unique challenges in terms of diagnosis and management, often requiring multidisciplinary approaches that include gastroenterologists, radiologists, pathologists, and surgeons¹⁻².

Globally, the research landscape in AIP shows diverse trends. In Western countries, the focus has often been on understanding the pathophysiology, genetic predispositions, and long-term outcomes of AIP, with a strong emphasis on clinical trials and cohort studies. European and North

American researchers have been instrumental in developing diagnostic criteria and treatment guidelines, contributing significantly to the standardization of care ³.

In contrast, Asian research, particularly from Japan and South Korea, has been pivotal in identifying and characterizing AIP as a distinct clinical entity. Asian cohorts have also contributed to the global understanding of IgG4-related disease, with a significant portion of AIP research in these regions exploring the link between AIP and systemic involvement of IgG4. The high prevalence and unique presentations of AIP in Asia, especially in Japan, have led to region-specific research initiatives, often involving large-scale collaborations that cross national borders ⁴.

Given these regional variations and the growing volume of research output, analyzing the co-authorship networks in AIP can provide valuable insights into how researchers and institutions interact, collaborate, and influence the development of this field. By examining the structural properties of these networks, this study aims to identify key players, uncover collaboration trends, and map the evolution of research activities over the past two decades.

The purpose of this study is to analyze the collaborative structures within AIP research by examining co-authorship networks from 2000 to 2023 using data from the Web of Science (WoS) Core Collection database. Understanding these networks provides insights into the cooperative relationships between researchers, the evolution of research groups, and the overall impact of these collaborations on the field. Network analysis offers a powerful framework for uncovering the underlying structure of scientific collaboration and identifying key players and influential research clusters that drive the field forward.

Scope of the Study

This study examines publications related to AIP research indexed in the WoS Core Collection database between 2000 and 2023. A total of 4,217 articles were selected for analysis, providing a comprehensive overview of the collaborative landscape within this specialized field over the past two decades. The dataset ensures the inclusion of the most recent publications (as of September 2024). The analysis will focus on constructing and evaluating co-authorship networks using macro-level indicators such as network density (the ratio of actual to possible connections), clustering coefficient (the degree to which nodes tend to cluster together), number of components (distinct connected subgroups within the network), and average path length (the average distance between nodes). At the micro-level, I will assess degree centrality (the number of direct connections each node has), closeness centrality (how close a node is to all other nodes), and betweenness centrality (the extent to which a node lies on the shortest path between other nodes). These metrics will help illuminate the structure and dynamics of researcher collaborations in this field.

Significance of the Study

The findings of this study hold significant implications for the field of AIP research. By identifying key researchers and institutions, this analysis can highlight leading contributors and potential areas for strengthening collaborations. Understanding the evolution of international collaborative networks is essential for fostering global research partnerships, which are increasingly important in addressing the complex challenges in AIP prevention and treatment. This study also aims to assess the impact of these collaborations on scientific output and innovation within the field.

Moreover, the analysis of network structures and their changes over time can provide valuable insights into the dynamics of AIP research, revealing how collaborations have shifted and evolved in response to emerging trends and challenges. This understanding is crucial for guiding future research directions and enhancing the effectiveness of collaborative efforts. Additionally, by highlighting the importance of international cooperation, this study underscores the value of continued global engagement to advance the field of AIP and improve patient outcomes worldwide.

Material and methods

The present study investigates the co-authorship patterns in AIP research papers. I utilized the WoS Core Collection database, conducting a "Topic Search" with the keyword "autoimmune pancreatitis" to analyze a total of 4,217 articles published between 2000 and 2023 (as of September 2024). In this analysis, I examined who collaborated with whom in co-authoring these papers. I

conducted network analysis using the Python programming language (version 3.10.5) within the integrated development environment (IDE) PyCharm (software version 2022.1.3). This study employed methodology-established principles of social network analysis⁵. I carried out the analysis in two main parts:

Macro-level Metrics:

Network Density: Calculated as the ratio of the number of edges to the maximum possible edges Between all nodes.

Clustering Coefficient: Measured the extent to which nodes form clusters by considering the number of edges among neighboring nodes and calculating the average.

Components: Identified and counted the number of subgraphs (components) where nodes are mutually connected.

Average Path Length: Evaluated the average "distance" between nodes by calculating the overall average path length in the network⁶.

Micro-level Metrics:

Degree Centrality: Measured the importance of each node by counting the number of edges it has in the network.

Closeness Centrality: Defined as the inverse of the sum of the shortest path lengths from a node to all other nodes, measuring how close each node is to others in the network.

Betweenness Centrality: Assessed the extent to which a node lies on the shortest paths between other nodes, indicating its importance in information transmission within the network⁶⁻⁷.

The significance of these macro-level metrics in understanding the structure of scientific collaboration networks and these micro-level centrality measures in scientific collaboration networks has been well documented and used⁶⁻⁷. Through these analyses, I can identify collaborative relationships and influential researchers in AIP research. This information may be useful for understanding research trends and planning future collaborative studies.

Results-

The study analyzed the co-authorship network of researchers in AIP research, focusing on the periods from 2000 to 2023. The analysis was conducted using data from the WoS Core Collection and utilized both macro and micro-level network metrics to understand the evolution of collaborative networks in this field.

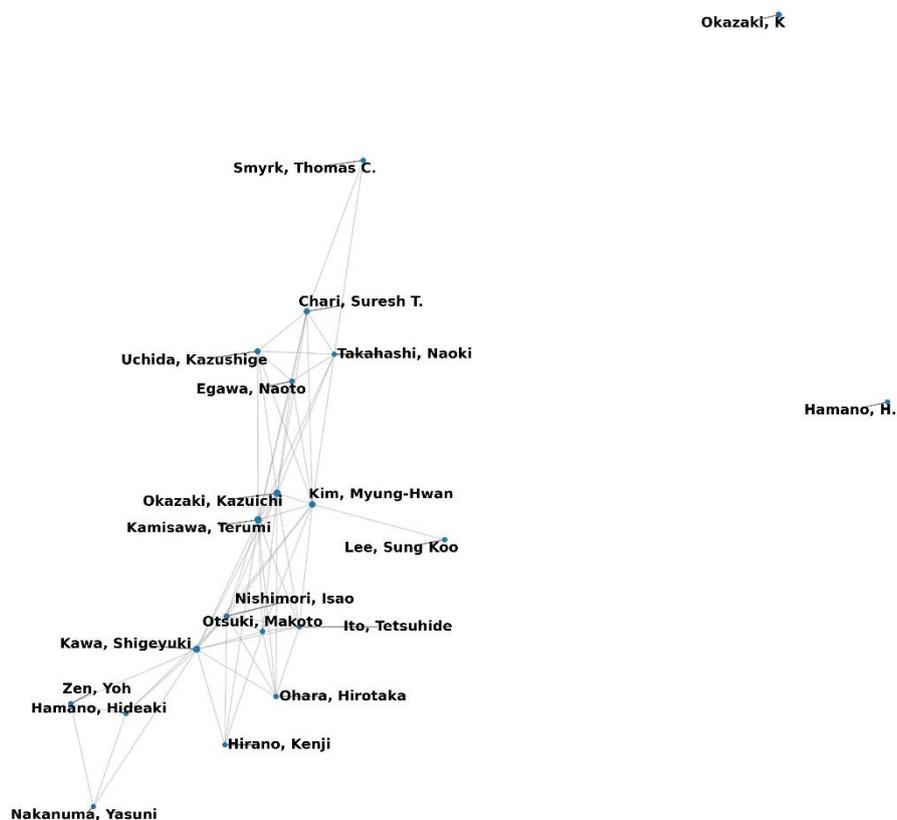
2000-2009 Network Analysis

During the period from 2000 to 2009, the network of co-authorship in AIP research exhibited a relatively sparse structure, with a network density of 0.0022 (Table 1), indicating that collaborative ties between researchers were limited during this early phase of AIP studies (Figure 1). The average clustering coefficient was remarkably high at 0.912 (Table 1), suggesting that while overall connections were sparse, researchers who collaborated tended to form tight-knit clusters (Figure 1). The network was highly fragmented, with 373 components (Table 1), which implies that many researchers operated within small, disconnected groups (Figure 1). The average distance between nodes was infinite, indicating that the network was not fully connected, and numerous researchers were isolated from the main collaborative components⁸.

Table 1. Network Metrics.

Metric	2000 - 2009	2010 - 2019	2020 - 2023
Network Density	0.0022	0.0011	0.0024
Average Clustering Coefficient	0.912	0.918	0.940
Number of Components	373	848	515
Average Distance	infinite	infinite	infinite

Top 20 Autoimmune Pancreatitis Researcher Network from 2000 to 2009

**Figure 1.** Top 20 Autoimmune Pancreatitis Researcher Network from 2000 to 2009.

At the micro-level, key players in this period, identified by degree centrality, included Kamisawa, Terumi (Japan) (0.0296), Okazaki, Kazuichi (Japan) (0.0283), and Kawa, Shigeyuki (Japan) (0.0254) (Table 2), who emerged as central figures in connecting different research clusters. Kamisawa (Japan) also ranked highest in closeness centrality (0.0863) (Table 3), underscoring his central position within the connected component of the network. Lauwers, GY (France) led in betweenness centrality (0.0135) (Table 4), indicating a pivotal role in bridging disparate subgroups within the research network.

Table 2. Top 20 Nodes by Degree Centrality.

Node	2000 - 2009	Degree Centrality	2010 - 2019	Degree Centrality	2020 - 2023	Degree Centrality
1	Kamisawa, Terumi	0.0296	Okazaki, Kazuichi	0.0357	Okazaki, Kazuichi	0.0417
2	Okazaki, Kazuichi	0.0283	Kamisawa, Terumi	0.0349	Ikeura, Tsukasa	0.0394
3	Kawa, Shigeyuki	0.0254	Kawa, Shigeyuki	0.0307	Kubota, Kensuke	0.0341
4	Kim, Myung-Hwan	0.0206	Zen, Yoh	0.0291	Kamisawa, Terumi	0.0325
5	Chari, Suresh T.	0.0189	Kawano, Mitsuhiro	0.0279	Naitoh, Itaru	0.0315
6	Okazaki, K	0.0179	Notohara, Kenji	0.0265	Uchida, Kazushige	0.0299
7	Uchida, Kazushige	0.0172	Chiba, Tsutomu	0.0231	Kanno, Atsushi	0.0297
8	Hamano, Hideaki	0.0149	Yamamoto, Motohisa	0.0229	Nishino, Takayoshi	0.0288

9	Egawa, Naoto	0.0149	Frulloni, Luca	0.0223	Masamune, Atsushi	0.0283
10	Nishimori, Isao	0.0147	Uchida, Kazushige	0.0213	Shimizu, Kyoko	0.0274
11	Otsuki, Makoto	0.0132	Shimosegawa, Tooru	0.0207	Sakagami, Junichi	0.0260
12	Smyrk, Thomas C.	0.0132	Saeki, Takako	0.0197	Iwasaki, Eisuke	0.0260
13	Hamano, H.	0.0129	Matsui, Shoko	0.0197	Schleinitz, Nicolas	0.0253
14	Zen, Yoh	0.0129	Umehara, Hisanori	0.0192	Notohara, Kenji	0.0244
15	Ohara, Hirotaka	0.0127	Kodama, Yuzo	0.0187	Frulloni, Luca	0.0241
16	Lee, Sung Koo	0.0127	Chari, Suresh T.	0.0185	Hashimoto, Shinichi	0.0241
17	Ito, Tetsuhide	0.0122	Takahashi, Naoki	0.0184	Shimosegawa, Tooru	0.0239
18	Nakanuma, Yasuni	0.0117	Masaki, Yasufumi	0.0181	Hamada, Shin	0.0223
19	Takahashi, Naoki	0.0114	Lerch, Markus M.	0.0177	Inui, Kazuo	0.0223
20	Hirano, Kenji	0.0114	Takahashi, Hiroki	0.0174	Watanabe, Takayuki	0.0221

Table 3. Top 20 Nodes by Closeness Centrality.

Node	2000 - 2009	Closeness Centrality	2010 - 2019	Closeness Centrality	2020 - 2023	Closeness Centrality
1	Kamisawa, Terumi	0.0863	Okazaki, Kazuichi	0.1843	Okazaki, Kazuichi	0.1513
2	Okazaki, Kazuichi	0.0847	Kamisawa, Terumi	0.1839	Ikeura, Tsukasa	0.1422
3	Kim, Myung-Hwan	0.0803	Frulloni, Luca	0.1761	Kubota, Kensuke	0.1408
4	Kawa, Shigeyuki	0.0802	Zen, Yoh	0.1758	Kamisawa, Terumi	0.1395
5	Notohara, Kenji	0.0792	Kawa, Shigeyuki	0.1751	Naitoh, Itaru	0.1360
6	Chari, Suresh T.	0.0760	Lerch, Markus M.	0.1741	Frulloni, Luca	0.1299
7	Nishimori, Isao	0.0757	Notohara, Kenji	0.1727	Vujasinovic, Miroslav	0.1293
8	Otsuki, Makoto	0.0750	Shimosegawa, Tooru	0.1722	Shimosegawa, Tooru	0.1283
9	Ito, Tetsuhide	0.0739	Webster, George	0.1716	Uchida, Kazushige	0.1277
10	Naruse, Satoru	0.0728	Lohr, Matthias	0.1715	Nishino, Takayoshi	0.1276
11	Shimosegawa, Tooru	0.0723	Takahashi, Naoki	0.1707	Kitano, Masayuki	0.1276
12	Uchida, Kazushige	0.0722	Chari, Suresh	0.1696	Shimizu, Kyoko	0.1271
13	Sugumar, Aravind	0.0720	Kawano, Mitsuhiro	0.1693	Schleinitz, Nicolas	0.1264
14	Zen, Yoh	0.0129	Umehara, Hisanori	0.0192	Notohara, Kenji	0.0244
15	Ohara, Hirotaka	0.0127	Kodama, Yuzo	0.0187	Frulloni, Luca	0.0241
16	Lee, Sung Koo	0.0127	Chari, Suresh T.	0.0185	Hashimoto, Shinichi	0.0241
17	Ito, Tetsuhide	0.0122	Takahashi, Naoki	0.0184	Shimosegawa, Tooru	0.0239

18	Nakanuma, Yasuni	0.0117	Masaki, Yasufumi	0.0181	Hamada, Shin	0.0223
19	Takahashi, Naoki	0.0114	Lerch, Markus M.	0.0177	Inui, Kazuo	0.0223
20	Hirano, Kenji	0.0114	Takahashi, Hiroki	0.0174	Watanabe, Takayuki	0.0221

Table 4. Top 20 Nodes by Betweenness Centrality.

Node	2000 - 2009	Betweenness Centrality	2010 - 2019	Betweenness Centrality	2020 - 2023	Betweenness Centrality
1	Lauwers, GY	0.0135	Webster, George J. M.	0.0469	Okazaki, Kazuichi	0.0301
2	Kawa, Shigeyuki	0.0130	Zhang, Wen	0.0451	Frulloni, Luca	0.0115
3	Klöppel, G	0.0125	Rodriguez-Justo, M.	0.0298	Zhang, Wen	0.0113
4	Deshpande, V	0.0120	Zen, Yoh	0.0280	Vujasinovic, Miroslav	0.0104
5	Mino-Kenudson, M.	0.0117	Okazaki, Kazuichi	0.0242	Schleinitz, Nicolas	0.0103
6	Kamisawa, Terumi	0.0109	Kamisawa, Terumi	0.0236	Shimosegawa, Tooru	0.0102
7	Chari, Suresh T.	0.0101	Webster, G. J.	0.0220	Ikeura, Tsukasa	0.0100
8	Okazaki, Kazuichi	0.0090	Frulloni, Luca	0.0192	Kubota, Kensuke	0.0094
9	Frulloni, L	0.0072	Kawa, Shigeyuki	0.0145	Kawano, Mitsuhiro	0.0079
10	Cavallini, G	0.0072	Lerch, Markus M.	0.0144	Chari, Suresh T.	0.0066
11	Kim, Myung-Hwan	0.0070	Shimosegawa, Tooru	0.0127	Stone, John H.	0.0064
12	Nishimori, I	0.0067	Culver, Emma L.	0.0122	Hanada, Keiji	0.0057
13	Okazaki, K	0.0065	Chari, Suresh	0.0120	Culver, Emma L.	0.0056
14	Kloppel, Guenter	0.0058	Notohara, K.	0.0118	Naitoh, Itaru	0.0054
15	Hamano, H.	0.0053	Notohara, Kenji	0.0117	Kamisawa, Terumi	0.0052
16	Hirano, Kenji	0.0041	Kim, Myung-Hwan	0.0110	Notohara, Kenji	0.0050
17	Cornell, Lynn D.	0.0039	Chari, Suresh T.	0.0102	Kitano, Masayuki	0.0044
18	Smyrk, T. C.	0.0037	Takahashi, Naoki	0.0100	Oracz, Grzegorz	0.0043
19	Zen, Yoh	0.0037	Yang, Aiming	0.0094	Adsay, Volkan	0.0042
20	Hayashi, Y	0.0036	Kubota, Kensuke	0.0091	Della-Torre, Emanuel	0.0038

2010-2019 Network Analysis

During the period from 2010 to 2019, the co-authorship network of AIP research became more complex and fragmented, with an increased number of components (848) (Table 1), suggesting that the field expanded, leading to more isolated research clusters (Figure 2). The network density decreased to 0.0011 (Table 1), reflecting a broader but less interconnected research landscape. The average clustering coefficient slightly increased to 0.918 (Table 1), indicating strong local collaboration within clusters despite the overall sparsity (Figure 2). The average distance remained infinite, highlighting persistent disconnectedness within the broader network⁸.

Top 20 Autoimmune Pancreatitis Researcher Network from 2010 to 2019

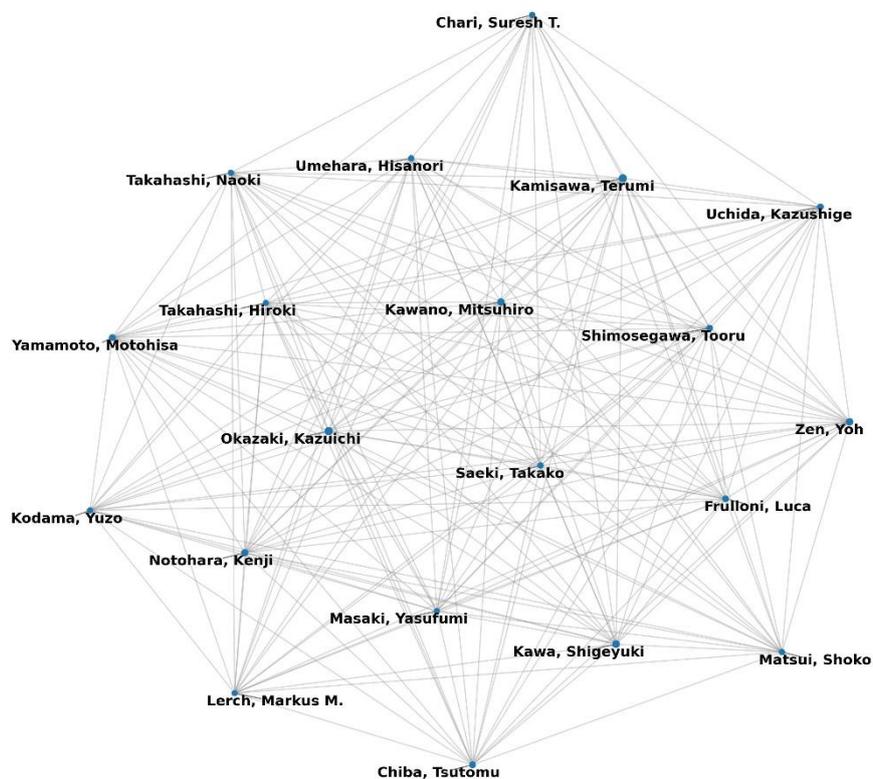


Figure 2. Top 20 Autoimmune Pancreatitis Researcher Network from 2010 to 2019.

On the micro-level, the analysis identified Okazaki, Kazuichi (Japan) (0.0357), Kamisawa, Terumi (Japan) (0.0349), and Kawa, Shigeyuki (Japan) (0.0307) continued to hold top positions in degree centrality, maintaining their influential roles in the field (Table 2). Okazaki (Japan) also dominated in closeness centrality (0.1843) (Table 3), reinforcing his position at the core of the research community. George J. M. Webster (UK) emerged as a critical connector in the network with the highest betweenness centrality (0.0469) (Table 4), highlighting his significant influence in facilitating collaborations across different research clusters.

2020-2023 Network Analysis

During the 2020-2023 period, the co-authorship network for AIP research showed signs of increasing connectivity and collaboration. The network density improved to 0.0024 (Table 1), indicating a slight increase in researcher interconnectivity (Figure 3). The average clustering coefficient further increased to 0.940 (Table 1), suggesting a robust tendency for researchers to collaborate within tight-knit clusters (Figure 3). The number of components decreased to 515 (Table 1), showing that the network, while still fragmented, became somewhat more cohesive. However, the average distance remained infinite, indicating ongoing challenges in connecting the entire research community⁸.

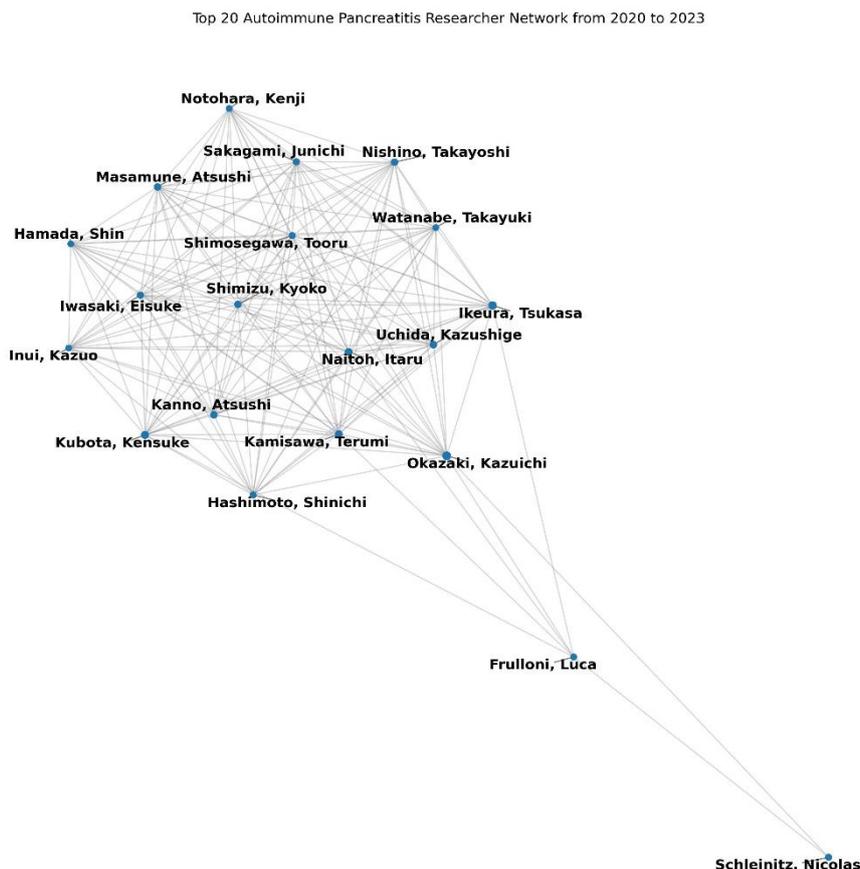


Figure 3. Top 20 Autoimmune Pancreatitis Researcher Network from 2020 to 2023.

At the micro-level, degree centrality analysis identified Okazaki, Kazuichi (Japan) (0.0417), Ikeura, Tsukasa (Japan) (0.0394), and Kubota, Kensuke (Japan) (0.0341) (Table 2), who were the most central figures by degree centrality. Okazaki (Japan) also led in closeness centrality (0.1513) (Table 3), solidifying his role as a central figure in the network. Okazaki (Japan) was also the top node in betweenness centrality (0.0301) (Table 4), indicating his critical position in linking various research clusters. Other notable researchers such as Frulloni, Luca (Italy) and Vujasinovic, Miroslav (Sweden) played significant roles in maintaining the network's connectivity, as evidenced by their high centrality scores across various metrics.

Summary

The network analysis of AIP research from 2000 to 2023 reveals a dynamic evolution in collaborative patterns and key players within the field. Across all three periods, the network was characterized by high clustering coefficients, indicating strong local collaboration among researchers. However, the persistent high number of components and infinite average distance highlight a major challenge: the overall disconnectedness of the broader research network.

Prominent figures such as Okazaki, Kazuichi, Kamisawa, Terumi, and Kawa, Shigeyuki (Japan) consistently emerged as central nodes, signifying their influential roles in shaping the field through extensive collaboration. Notably, Okazaki's prominence in both degree and betweenness centrality across all periods underscores his pivotal role in fostering connections between otherwise isolated research clusters. The progression of the network over time reflects a growing, albeit still fragmented, collaborative community, with key players driving the integration and expansion of autoimmune pancreatitis research.

Discussion

The network analysis of AIP research from 2000 to 2023 provides valuable insights into the evolving landscape of collaboration and influence among researchers in this specialized field. The findings highlight significant trends, key players, and structural characteristics of the co-authorship networks, offering a comprehensive understanding of how scientific collaboration has shaped the development of AIP research over the past two decades.

Evolution of Collaboration Networks

The analysis reveals a clear progression in the structure of AIP research networks across the three studied periods: 2000-2009, 2010-2019, and 2020-2023. During the early period (2000-2009), the co-authorship network was relatively sparse, characterized by a low network density (0.0022) and a high number of disconnected components (373). This fragmentation indicates that many researchers operated within isolated groups with limited interaction between clusters, reflecting the nascent stage of international collaboration in AIP research.

As the field matured in the 2010-2019 period, the number of components increased significantly (848), suggesting an expansion of the research landscape with more isolated clusters. However, despite the network's growth, the overall connectivity remained low, as evidenced by the decreased network density (0.0011). The high clustering coefficient (0.918) in this period suggests that, while collaborations within clusters were strong, there was still a lack of broader inter-cluster connections.

In the most recent period (2020-2023), there were signs of increasing connectivity within the AIP research community. The network density improved slightly to 0.0024, and the number of components decreased to 515, indicating a trend toward greater cohesiveness and collaboration among researchers. However, the persistence of an infinite average distance across all periods highlights a continuing challenge: the overall disconnectedness of the broader research network. This underscores the need for further efforts to bridge gaps between disparate research clusters to foster a more integrated and collaborative global research environment.

Key Players and Regional Dynamics

Throughout the analysis, certain key players consistently emerged as central figures within the AIP research network. Notably, Japanese researchers such as Kazuichi Okazaki, Terumi Kamisawa, and Shigeyuki Kawa were identified as highly influential across all periods, with high scores in degree, closeness, and betweenness centrality. Okazaki, in particular, was a prominent figure in both degree and betweenness centrality, underscoring his pivotal role in connecting otherwise isolated clusters and facilitating broader collaboration within the network.

The prominence of Japanese researchers in AIP research is not surprising, given the unique regional context. A significant portion of AIP research in Asia, particularly in Japan and South Korea, has focused on exploring the relationship between AIP and systemic involvement of IgG4. The high prevalence of AIP and its distinctive clinical presentations in Japan have driven region-specific research initiatives, often involving large-scale, cross-border collaborations. This regional focus has positioned Japan as a leader in AIP research, a trend that aligns with findings from previous studies, including my own research on the future and trends in immunity-related research in Japan, the U.S., and the U.K. (2000-2023), which identified Japan as a global leader in the field of autoimmune pancreatitis⁹⁻¹⁰.

The analysis also highlights the contributions of researchers from other regions. For example, in the 2010-2019 period, George J. M. Webster from the UK emerged as a key connector in the network, demonstrating significant influence in bridging research clusters across national boundaries. Similarly, in the 2020-2023 period, researchers like Luca Frulloni (Italy) and Miroslav Vujasinovic (Sweden) played important roles in maintaining network connectivity, as indicated by their high centrality scores.

Implications for Future Research and Collaboration

The findings of this study have several implications for the future of AIP research. First, the identification of key players and influential research clusters provides a roadmap for strengthening existing collaborations and forging new partnerships. By understanding the current collaborative

dynamics, researchers and institutions can better strategize their engagement in global research networks, potentially leading to more cohesive and impactful research outcomes.

Second, the analysis underscores the importance of fostering international collaboration, particularly in bridging the gaps between isolated research clusters. While local collaborations within regions are strong, as evidenced by high clustering coefficients, the overall disconnectedness of the network suggests that opportunities for broader, cross-regional partnerships are not fully realized. Enhancing international cooperation could help address the complex challenges in AIP diagnosis, management, and treatment, ultimately leading to improved patient outcomes worldwide.

Finally, the study highlights the evolving nature of collaborative networks in response to emerging trends and challenges in AIP research. As the field continues to grow, it will be essential to monitor these changes and adapt strategies to foster more integrated and effective collaborations. This will involve not only identifying and supporting key players but also encouraging participation from a diverse array of researchers and institutions, particularly those from underrepresented regions or disciplines.

Conclusion

This study provides a comprehensive analysis of the evolution of co-authorship networks in AIP research from 2000 to 2023. By examining both macro-level and micro-level network metrics, the findings reveal significant trends and key players that have shaped the collaborative landscape of AIP research over the past two decades.

The analysis demonstrates that while the AIP research network has gradually become more interconnected, it remains characterized by a high degree of fragmentation and localized clustering. Across all periods, the network showed high clustering coefficients, reflecting strong local collaboration within research clusters. However, the persistently high number of components and infinite average distances suggest ongoing challenges in achieving broader connectivity and integration within the global research community.

Prominent figures such as Japan's researchers Kazuichi Okazaki, Terumi Kamisawa, and Shigeyuki Kawa consistently emerged as central nodes in the network, underscoring their influential roles in driving collaboration and shaping the field of AIP research. Okazaki was notable for his high scores in both degree and betweenness centrality, highlighting his pivotal role in linking otherwise isolated research clusters. This prominence of the Japanese researchers aligns with the strong regional focus on AIP in Asia, particularly in Japan, where distinct clinical presentations and a higher prevalence of the disease have fueled significant research efforts.

The progression of the network over time reflects a dynamic but still fragmented collaborative environment, with some improvements in connectivity observed in the most recent period (2020-2023). However, the persistence of isolated research clusters indicates that there remains substantial room for enhancing global collaboration.

To address these challenges, future efforts should focus on fostering greater international collaboration and bridging the gaps between disconnected research groups. This could involve strategic initiatives to promote cross-regional partnerships and support the participation of diverse researchers and institutions. By doing so, the AIP research community can work towards a more integrated network that not only advances scientific knowledge but also improves clinical outcomes for patients worldwide.

Overall, this study highlights the critical role of key players and the evolving structure of collaboration in AIP research. Understanding these dynamics provides valuable insights for researchers, institutions, and policymakers aiming to strengthen the global research landscape in this specialized field. By building on these findings, future research can further enhance collaborative efforts, ultimately contributing to the advancement of AIP diagnosis, management, and treatment.

Through this study, Japanese researchers are leading the world in AIP research, as my previous study showed⁹⁻¹⁰. I hope Japanese AIP researchers will continue to lead AIP research and play a key role in promoting large-scale international collaborations. And I hope that the results of this research will lead to a better understanding of AIP research.

Funding: none.

Conflict of Interest Disclosure Statement: none.

Ethics approval statement: not applicable for this article.

Abbreviations

WoS, Web of Science; IDE, Integrated Development Environment

References

1. Zhang L, Smyrk TC. Autoimmune pancreatitis and IgG4-related systemic diseases. *Int J Clin Exp Pathol*. 2010 May 25;3(5):491-504.
2. O'Reilly DA, Malde DJ, Duncan T, Rao M, Filobos R. Review of the diagnosis, classification and management of autoimmune pancreatitis. *World J Gastrointest Pathophysiol*. 2014 May 15;5(2):71-81.
3. Cai O, Tan S. From Pathogenesis, Clinical Manifestation, and Diagnosis to Treatment: An Overview on Autoimmune Pancreatitis. *Gastroenterol Res Pract*. 2017;2017:3246459.
4. Kamisawa T, Ryu JK, Kim MH, Okazaki K, Shimosegawa T, Chung JB. Recent advances in the diagnosis and management of autoimmune pancreatitis: similarities and differences in Japan and Korea. *Gut Liver*. 2013 Jul;7(4):394-400.
5. Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511815478>.
6. Newman, M. (2001), 'Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality', *Phys. Rev. E* 64 (1), 016132.
7. Newman ME. The structure of scientific collaboration networks. *Proc Natl Acad Sci USA*. 2001 Jan 16;98(2):404-9
8. Barabasi AL, Albert R. Emergence of scaling in random networks. *Science*. 1999 Oct 15;286(5439):509-12.
9. Naruaki Ogasawara. *Research Trends in Internal Medicine - A Text Mining Analysis of Internal Medicine Journal in the Japan - Jxiv*, doi: <https://doi.org/10.51094/jxiv.673>, version 1
10. Naruaki Ogasawara. *Future and Trends in Immunity-Related Research in Japan, the U.S., and the U.K. - Research and Future Directions in 2000-2023 - Jxiv*, doi: <https://doi.org/10.51094/jxiv.778>, version 1

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.