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Key Researchers: Structural Evolution of Co-Author Networks in Single-Balloon Enteroscopy (2000-2023)

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Article

Key Researchers: Structural Evolution of Co-Author Networks in Single-Balloon Enteroscopy (2000-2023)

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Abstract: Aim: This study aims to analyze the evolution of co-author networks in Single-Balloon Enteroscope (SBE) research from 2000 to 2023, using data from the Web of Science (WoS) Core Collection. The objective is to provide a structural overview of researcher collaborations in this specialized field, highlighting key contributors and the impact of international cooperation. **Method:** I conducted a co-author network analysis on 149 SBE-related articles indexed in the WoS Core Collection between 2000 and 2023. Using Python (Version 3.10.5) within the PyCharm development environment (Software Version 2022.1.3), I assessed macro-level indicators including network density, clustering coefficient, number of components, and average distance. Micro-level indicators such as degree centrality, closeness centrality, and betweenness centrality were also evaluated to understand the roles of individual researchers in the network. **Result:** The analysis revealed that the co-author networks in SBE research have evolved over the studied period, with varying degrees of connectivity and collaboration. From 2000 to 2009, the network showed moderate clustering but high fragmentation, with a few key researchers like Nista, Enrico C., and Spada, Cristiano playing central roles. In the 2010-2019 period, network density decreased, indicating expansion in the author pool but less frequent co-authorships. However, the clustering coefficient remained high, suggesting localized collaboration. Central figures such as Itoi, Takao emerged as influential in bridging network gaps. In the most recent period (2020-2023), network density moderately increased, reflecting improved collaboration. Key contributors included Tanisaka, Yuki, and Ryozawa, Shomei, who enhanced connectivity within the network. Despite these advancements, the network remained fragmented with isolated components throughout all periods. **Conclusion:** The co-author networks in SBE research have shown an overall increase in collaboration over the past two decades, with key contributors playing pivotal roles in connecting disparate groups. However, the persistent fragmentation suggests a need for more integrated efforts to enhance international collaboration. Understanding these network dynamics can inform future strategies for fostering global cooperation and advancing SBE research.

Keywords: Single-Balloon Enteroscope; single balloon enteroscopy technique; Single balloon enteroscopy; co-authorship network analysis; network analysis; research collaboration; research trend analysis; research trends; key researchers; research strategies; internal medicine; planning future collaborative studies

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Introduction

Background and Objectives

Single balloon enteroscopy (SBE) is a vital endoscopic technique primarily used for diagnosing and treating small bowel disorders [1]. Since its introduction, SBE has offered a less invasive alternative to traditional surgical methods, significantly enhancing the ability to explore and intervene in the small intestine [1]. However, the field faces several challenges, including enhanced diagnostic accuracy, improved procedural safety, and more efficient operator training [1]. Furthermore, technological advancements and increased collaboration among researchers are essential to overcome these limitations.

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Globally, SBE has been widely adopted, with numerous studies and clinical trials conducted to improve its efficacy and safety [2]. International collaboration has played a crucial role in advancing the technology and sharing best practices across borders. The integration of SBE into routine clinical practice varies by region and is influenced by healthcare infrastructure and access to advanced medical technologies [2].

Japan has been at the forefront of SBE research and clinical application. Japanese researchers and clinicians have pioneered several advancements in the field, contributing to the global body of knowledge [3,4]. In Japan, SBE is covered by national health insurance. The country's health insurance system has facilitated the widespread use of SBE. Additionally, Japan's research environment has fostered strong partnerships between academic institutions, hospitals, and industry, driving continuous improvements in SBE technology and practice.

Network analysis, particularly co-author network analysis, has emerged as a powerful tool to examine collaborative relationships among researchers. Understanding these networks provides insights into the dissemination of knowledge, the formation of influential research groups, and the evolution of scientific fields. This study aims to analyze the co-author networks in the field of SBE, providing a structural overview of the collaborations from 2000 to 2023. By examining these networks, I aim to elucidate the trends and dynamics of research in this domain, highlighting key contributors and the impact of international collaboration.

Scope of the Study

This study examines publications related to SBE research indexed in the Web of Science (WoS) Core Collection database between 2000 and 2023. A total of 149 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

This study aims to provide a comprehensive overview of the collaborative landscape in SBE research, identifying key researchers, influential collaborations, and evolving trends over time. By elucidating the roles and connections of central figures within the network, the findings can guide targeted efforts to enhance collaboration, such as forming strategic alliances and prioritizing underrepresented research areas. For instance, understanding which researchers or groups are central to the network can help in designing initiatives to foster interdisciplinary collaboration, share resources, and integrate diverse expertise. Moreover, the insights from this study could be applied to optimize research strategies, funding allocation, and policymaking, ultimately improving the global effectiveness of SBE technique.

Material and Methods

The present study investigates the co-authorship patterns in SBE research papers. I utilized the WoS Core Collection database, conducting a "Topic Search" with the keyword "SINGLE-BALLOON ENTEROSCOPE" to analyze a total of 149 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 analysis [5]. 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 network [6].

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 network [6,7].

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 used [6,7]. Through these analyses, I can identify collaborative relationships and influential researchers in SBE 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 the field of SBE 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

In the 2000–2009 period, the co-authorship network exhibited a network density of 0.0739 (Table 1), indicating that approximately 7.39% of the potential connections between authors were realized. The average clustering coefficient was 0.9099 (Table 1), suggesting a high tendency for authors who collaborate with the same co-author to also collaborate with each other (Figure 1). The network consisted of 13 components (Table 1), indicating a fragmented structure with multiple disconnected sub-networks (Figure 1). The average distance within the network was infinite, reflecting the presence of isolated components or sparse connections among certain groups of authors [8].

Table 1. Network Metrics.

Metric	2000 - 2009	2010 - 2019	2020 - 2023
Network Density	0.0739	0.0208	0.0467
Average Clustering Coefficient	0.9099	0.948	0.9739
Number of Components	13	48	24
Average Distance	infinite	infinite	infinite

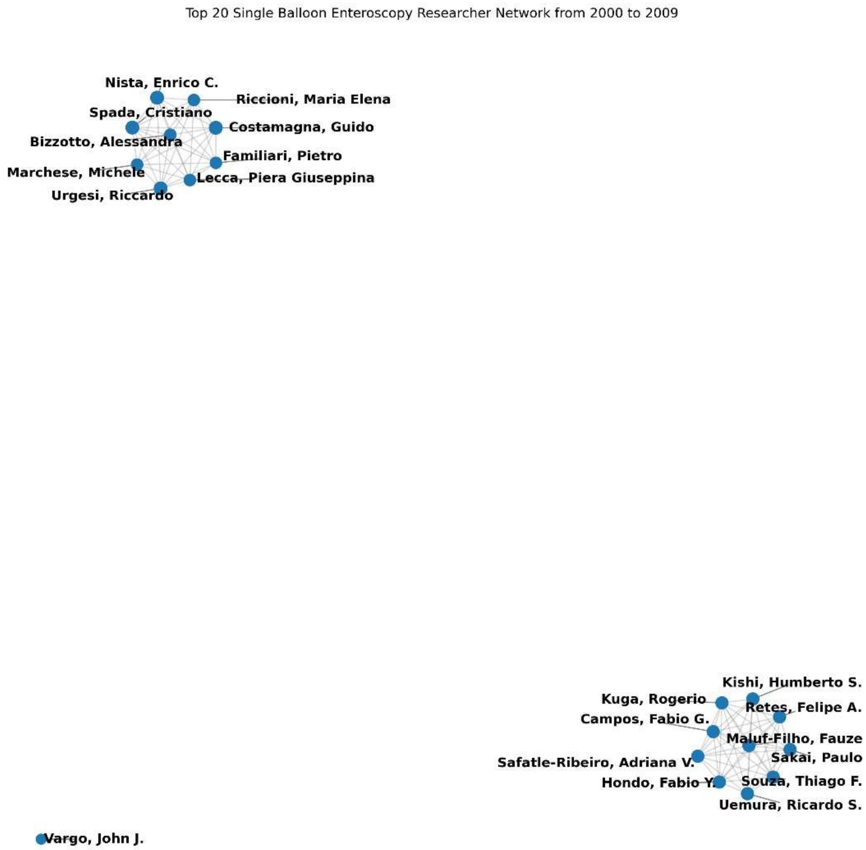

Figure 1. Top 20 Single-Balloon Enteroscopy Researcher Network from 2000 to 2009.

At the micro level, in terms of degree centrality, key contributors such as Nista, Enrico C., Spada, Cristiano, Urgesi, Riccardo, and Costamagna, Guido emerged as the most connected authors, each having a degree centrality of 0.1351. These authors were prominent in bridging collaborative gaps and maintaining network cohesiveness (Table 2). Closeness centrality mirrored these findings, with the same set of authors demonstrating high proximity to other nodes, highlighting their roles as central figures in facilitating communication within the network (Table 3). Betweenness centrality, however, was relatively low across the board, with Moenkemueller, Klaus (0.0030) and Vargo, John J. (0.0019) leading, indicating a limited number of authors acting as crucial intermediaries in the network (Table 4).

Table 2. Top 20 Nodes by Degree Centrality.

Node	2000 - 2009	Degree Centrality	2010 - 2019	Degree Centrality	2020 - 2023	Degree Centrality
1	Nista, Enrico C.	0.1351	Itoi, Takao	0.0934	Tanisaka, Yuki	0.0859
2	Spada, Cristiano	0.1351	Baron, Todd H.	0.0722	Ryozawa, Shomei	0.0859
3	Urgesi, Riccardo	0.1351	Maple, John T.	0.0637	Mizuide, Masafumi	0.0859

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4	Costamagna, Guido	0.1351	Katanuma, Akio	0.0573	Fujita, Akashi	0.0859
5	Kuga, Rogerio	0.1216	Yane, Kei	0.0552	Ogawa, Tomoya	0.0859
6	Maluf-Filho, Fauze	0.1216	Kin, Toshifumi	0.0552	Tashima, Tomoaki	0.0808
7	Souza, Thiago F.	0.1216	Takahashi, Kuniyuki	0.0552	Katsuda, Hiromune	0.0808
8	Uemura, Ricardo S.	0.1216	Matsumoto, Kazuyuki	0.0488	Sugimoto, Mitsuru	0.0707
9	Campos, Fabio G.	0.1216	Mukai, Shuntaro	0.0488	Takagi, Tadayuki	0.0707
10	Hondo, Fabio Y.	0.1216	Takada, Tadahiro	0.0488	Suzuki, Rei	0.0707
11	Safatle-Ribeiro, Adriana V.	0.1216	Strasberg, Steven M.	0.0488	Konno, Naoki	0.0707
12	Kishi, Humberto S.	0.1216	Pitt, Henry A.	0.0488	Asama, Hiroyuki	0.0707
13	Retes, Felipe A.	0.1216	Ukai, Tomohiko	0.0488	Sato, Yuki	0.0707
14	Sakai, Paulo	0.1216	Shikata, Satoru	0.0488	Irie, Hiroki	0.0707
15	Riccioni, Maria Elena	0.1081	Teoh, Anthony Yuen Bun	0.0488	Watanabe, Ko	0.0707
16	Bizzotto, Alessandra	0.1081	Kim, Myung-Hwan	0.0488	Nakamura, Jun	0.0707
17	Familiari, Pietro	0.1081	Kiriyama, Seiki	0.0488	Kikuchi, Hitomi	0.0707
18	Lecca, Piera Giuseppina	0.1081	Mori, Yasuhisa	0.0488	Takasumi, Mika	0.0707
19	Marchese, Michele	0.1081	Miura, Fumihiko	0.0488	Hashimoto, Minami	0.0707
20	Vargo, John J.	0.0811	Chen, Miin-Fu	0.0488	Kato, Tsunetaka	0.0707

Table 3. Top 20 Nodes by Closeness Centrality.

Node	2000 - 2009	Closeness Centrality	2010 - 2019	Closeness Centrality	2020 - 2023	Closeness Centrality
1	Nista, Enrico C.	0.1351	Itoi, Takao	0.0959	Tanisaka, Yuki	0.0859
2	Spada, Cristiano	0.1351	Isayama, Hiroyuki	0.0941	Ryozawa, Shomei	0.0859
3	Urgesi, Riccardo	0.1351	Katanuma, Akio	0.0877	Mizuide, Masafumi	0.0859
4	Costamagna, Guido	0.1351	Kogure, Hirofumi	0.0773	Fujita, Akashi	0.0859
5	Kuga, Rogerio	0.1216	Watabe, Hirotsugu	0.0773	Ogawa, Tomoya	0.0859
6	Maluf-Filho, Fauze	0.1216	Yamada, Atsuo	0.0773	Tashima, Tomoaki	0.0811
7	Souza, Thiago F.	0.1216	Yamaji, Yutaka	0.0773	Katsuda, Hiromune	0.0811
8	Uemura, Ricardo S.	0.1216	Koike, Kazuhiko	0.0773	Miyaguchi, Kazuya	0.073
9	Campos, Fabio G.	0.1216	Iwashita, Takuji	0.077	Mashimo, Yumi	0.073
10	Hondo, Fabio Y.	0.1216	Nakai, Yousuke	0.077	Sugimoto, Mitsuru	0.0707
11	Safatle-Ribeiro, Adriana V.	0.1216	Hara, Kazuo	0.077	Takagi, Tadayuki	0.0707
12	Kishi, Humberto S.	0.1216	Park, Do Hyun	0.077	Suzuki, Rei	0.0707
13	Retes, Felipe A.	0.1216	Baron, Todd H.	0.0767	Konno, Naoki	0.0707
14	Sakai, Paulo	0.1216	Mukai, Shuntaro	0.0736	Asama, Hiroyuki	0.0707
15	Riccioni, Maria Elena	0.1126	Takada, Tadahiro	0.0736	Sato, Yuki	0.0707
16	Bizzotto, Alessandra	0.1126	Strasberg, Steven M.	0.0736	Irie, Hiroki	0.0707
17	Familiari, Pietro	0.1126	Pitt, Henry A.	0.0736	Watanabe, Ko	0.0707
18	Lecca, Piera Giuseppina	0.1126	Ukai, Tomohiko	0.0736	Nakamura, Jun	0.0707
19	Marchese, Michele	0.1126	Shikata, Satoru	0.0736	Kikuchi, Hitomi	0.0707
20	Riccioni, Maria Flena	0.0901	Teoh, Anthony Yuen Bun	0.0736	Takasumi, Mika	0.0707

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Table 4. Top 20 Nodes by Betweenness Centrality.

Node	2000 - 2009	Betweenness Centrality	2010 - 2019	Betweenness Centrality	2020 - 2023	Betweenness Centrality
1	Moenkemueller, Klaus	0.0030	Itoi, Takao	0.0242	Moreels, Tom G.	0.0003
2	Vargo, John J.	0.0019	Katanuma, Akio	0.0210	Tanisaka, Yuki	0.0002
3	Nista, Enrico C.	0.0009	Isayama, Hiroyuki	0.0205	Ryozawa, Shomei	0.0002
4	Spada, Cristiano	0.0009	Matsumoto, Kazuyuki	0.0104	Mizuide, Masafumi	0.0002
5	Urgesi, Riccardo	0.0009	Baron, Todd H.	0.0085	Fujita, Akashi	0.0002
6	Costamagna, Guido	0.0009	Maple, John T.	0.0019	Ogawa, Tomoya	0.0002
7	Riccioni, Maria Elena	0.0000	Yane, Kei	0.0007	Tashima, Tomoaki	0.0001
8	Bizzotto, Alessandra	0.0000	Kin, Toshifumi	0.0007	Katsuda, Hiromune	0.0001
9	Familiari, Pietro	0.0000	Takahashi, Kuniyuki	0.0007	Suzuki, Masahiro	0.0001
10	Lecca, Piera Giuseppina	0.0000	Kato, Hironari	0.0006	Miyaguchi, Kazuya	0.0000
11	Marchese, Michele	0.0000	Tsutsumi, Koichiro	0.0006	Mashimo, Yumi	0.0000
12	Upchurch, Bennie	0.0000	Okada, Hiroyuki	0.0006	Noguchi, Tatsuya	0.0000
13	Dumot, John A.	0.0000	Ohtsuka, Kazuo	0.0003	Araki, Ryuichiro	0.0000
14	Zuccaro, Gregory	0.0000	Kudo, Shin-Ei	0.0003	Harada, Maiko	0.0000
15	Stevens, Tyler	0.0000	Maguchi, Hiroyuki	0.0003	Eduardo Zamora-Nava, Luis	0.0000
16	Santisi, Janice A.	0.0000	Moreels, Tom G.	0.0002	Mier y Teran-Ellis, Santiago	0.0000
17	Koornstra, Jan J.	0.0000	Ito, Kei	0.0002	Zepeda-Gomez, Sergio	0.0000
18	Fry, Lucia	0.0000	Kanno, Yoshihide	0.0002	Perez-Cuadrado-Robles, Enrique	0.0000
19	Kobayashi, Kiyonori	0.0000	Masu, Kaori	0.0002	Liliana Miranda-Lora, America	0.0000
20	Katsumata, Tomoe	0.0000	Koshita, Shinsuke	0.0001	Valdovinos-Andraca, Francisco	0.0000

2010-2019. Network Analysis

From 2010 to 2019, the co-authorship network a marked decrease in network density to 0.0208 (Table 1), with only 2.08% of potential collaborations being realized, reflecting an expansion of the author pool but with less frequent co-authorships between them (Figure 2). The average clustering coefficient increased to 0.9480 (Table 1), further emphasizing strong local clustering tendencies (Figure 2). The number of components grew to 48 (Table 1), suggesting increased fragmentation or the emergence of numerous independent research clusters (Figure 2). The average distance remained infinite, indicating persistent disconnection among various groups of authors [8].

Figure 2. Top 20 Single-Balloon Enteroscopy Researcher Network from 2010 to 2019.

At the micro level during this period, Itoi, Takao emerged as a central figure, leading in degree centrality (0.0934), closeness centrality (0.0959), and betweenness centrality (0.0242), signifying his extensive collaboration and influence across the network. Other significant contributors included Baron, Todd H., Maple, John T., and Katanuma, Akio, who also ranked highly in both degree and closeness centralities, indicating their central roles in the network (Table 2-3). Betweenness centrality analysis highlighted Itoi, Takao, Katanuma, Akio, and Isayama, Hiroyuki as critical nodes, suggesting that these authors frequently acted as key intermediaries, connecting otherwise disparate parts of the network (Table 4).

2020-2023. Network Analysis

During the 2020–2023 period, the co-authorship network for SBE research exhibited a network density of 0.0467 (Table 1), indicating that 4.67% of the potential connections between authors were realized. This represents a moderate level of connectivity within the network, suggesting an increase in collaboration compared to previous periods (Figure 3). The average clustering coefficient was 0.9739 (Table 1), which indicates a very high tendency for authors collaborating with the same co-author to also collaborate (Figure 3). The network was composed of 24 components (Table 1),

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demonstrating a structure with multiple distinct sub-networks, yet showing improved integration compared to earlier periods. The average distance remained infinite, reflecting the existence of isolated components and indicating that not all authors are reachable from others, further highlighting the fragmented nature of the network [8].

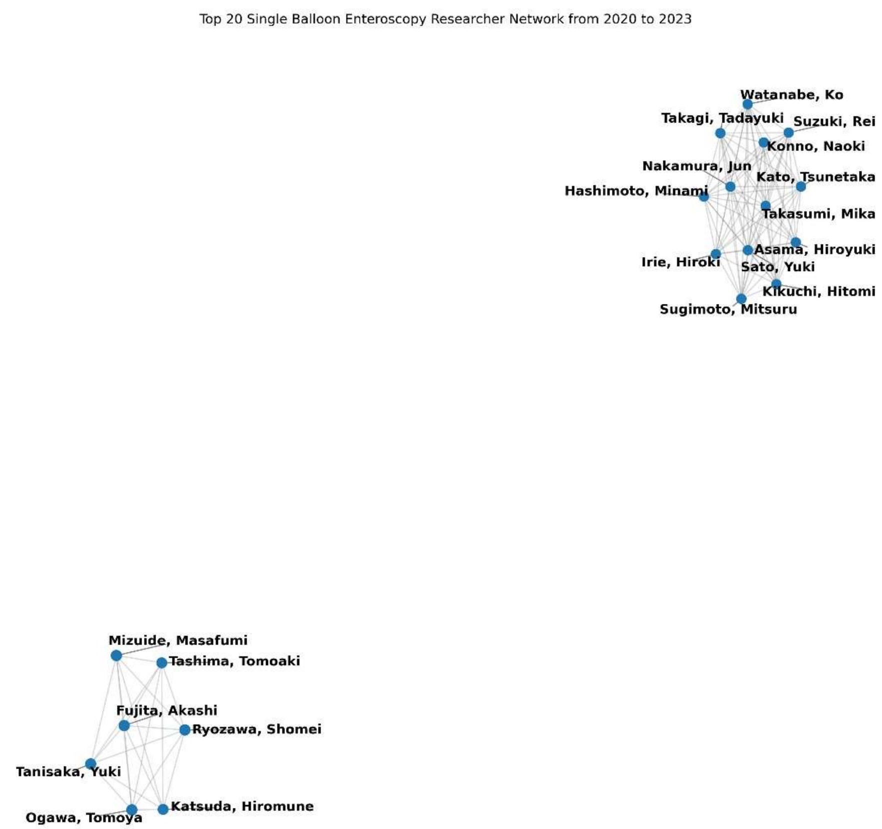

Figure 3. Top 20 Single-Balloon Enteroscopy Researcher Network from 2020 to 2023.

At the micro level, key contributors such as Tanisaka, Yuki, Ryozawa, Shomei, Mizuide, Masafumi, Fujita, Akashi, and Ogawa, Tomoya emerged as the most connected authors, each having a degree centrality of 0.0859 (Table 2). These authors played significant roles in enhancing network connectivity and cohesiveness by bridging collaborative gaps. The findings of closeness centrality closely mirrored those of degree centrality, with the same set of authors demonstrating high proximity to other nodes, highlighting their positions as central figures within the network who facilitate communication and collaboration (Table 3). Betweenness centrality was generally low across the network, indicating a limited number of authors acting as critical intermediaries. However, Moreels, Tom G. led with a betweenness centrality of 0.0003, followed by Tanisaka, Yuki, Ryozawa, Shomei, Mizuide, Masafumi, Fujita, Akashi and Ogawa, Tomoya with 0.0002 each (Table 4). These authors occupied strategic positions within the network, albeit to a lesser extent, serving as key

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connectors among otherwise disconnected groups. Their roles were crucial in enabling pathways that facilitated indirect collaborations within the network.

Discussion

The present study examined the evolution of co-author networks in SBE research from 2000 to 2023 using data from the WoS Core Collection. Our analysis utilized both macro and micro-level network metrics to explore the collaborative landscape in this specialized field. The findings highlight the dynamics of SBE research collaborations and the key contributors who have shaped the development of this endoscopic technique.

During the 2000-2009 period, the co-authorship network exhibited a relatively low network density of 0.0739, indicating that only 7.39% of potential connections between authors were realized. This suggests that while there was a moderate level of collaboration, the network was not densely interconnected. The clustering coefficient was high at 0.9099, reflecting a strong propensity for authors working with the same co-author to also collaborate, which is typical of closely-knit research clusters. However, the network was highly fragmented, consisting of 13 components, suggesting that many subgroups of researchers operated independently without extensive cross-group interactions. The average distance within the network was infinite, signifying the presence of isolated components or sparse connections, which could hinder the flow of information across the network.

Key contributors in this period, such as Nista, Enrico C., Spada, Cristiano, Urgesi, Riccardo, and Costamagna, Guido, emerged as central figures in the network with a degree centrality of 0.1351. Their high degree and closeness centrality values suggest that these authors played pivotal roles in maintaining network cohesion and facilitating collaborations among researchers. Betweenness centrality was relatively low, indicating that few authors acted as crucial intermediaries in the network. Notably, Moenkemueller, Klaus, and Vargo, John J. demonstrated higher betweenness centrality values, albeit still modest, highlighting their roles in bridging otherwise disconnected groups of researchers.

In the subsequent decade (2010-2019), the network exhibited a marked decrease in density to 0.0208, reflecting an expanded author pool but with less frequent co-authorship. This period saw an increase in the number of components, further emphasizing the fragmentation and decentralization of the network. The high clustering coefficient persisted, suggesting that while broader collaborations were limited, localized clusters of intense cooperation remained prevalent. The average path length remained relatively high, indicative of the extended distances required to connect disparate authors within the network.

The roles of central authors became more pronounced in this period, with figures such as Itoi, Takao, Katanuma, Akio, and Isayama, Hiroyuki emerging with significant degree and closeness centrality values. Itoi, Takao had the highest degree centrality (0.0934) and closeness centrality (0.0959), making him a pivotal figure in connecting other researchers within the network and facilitating broader dissemination of knowledge and fostering international collaborations. However, the overall low betweenness centrality values (e.g., Itoi, Takao at 0.0242 and Katanuma, Akio at 0.0210) suggest that while key authors were well connected within their local clusters, the network's structural properties limited the overall connectivity and integration of more peripheral researchers.

In the most recent period (2020-2023), the network exhibited an increase in density to 0.0467, indicating an improvement in the realization of potential collaborations among researchers. The average clustering coefficient remained high at 0.9739, which suggests that although the network is becoming slightly more connected, tight-knit local clusters still dominate. The network consisted of 24 components, reflecting a trend towards greater integration among researchers compared to previous periods. However, the average distance remained infinite, indicating the presence of isolated groups or individuals not connected to the main network.

Prominent researchers in this period, including Tanisaka, Yuki and Ryozawa, Shomei, displayed the highest degree and closeness centrality values (both at 0.0859), highlighting their influential roles within the network. Despite their high connectivity, the overall betweenness centrality values remained very low, with Tanisaka, Yuki at 0.0002 and Ryozawa, Shomei at 0.0002, indicating that even key researchers were not acting as major intermediaries in the network. This suggests that while collaboration increased, the network still lacked strong bridging figures who connect disparate parts of the research community. This ongoing structural characteristic could limit the overall flow of information and collaborative opportunities across the entire network.

Overall, the findings of this study underscore the dynamic nature of co-authorship networks in SBE research over the past two decades. The evolution from a fragmented network with isolated clusters towards a more integrated structure reflects the growing importance of collaboration in advancing the field. Identifying key contributors and understanding their roles within the network provides valuable insights for fostering future collaborations, optimizing research strategies, and enhancing the global impact of SBE research. By leveraging these insights, stakeholders can develop targeted initiatives to strengthen the collaborative fabric of the research community, ensuring continued advancements in SBE technology and practice.

Conclusion

The analysis of the co-authorship network in SBE research from 2000 to 2023 reveals evolving patterns of collaboration and highlights the influential roles of key researchers. Over the years, the co-authorship network has demonstrated varying degrees of connectivity, clustering, and fragmentation, reflecting the dynamic nature of research collaboration in this field.

In the initial period from 2000 to 2009, the network density was relatively low at 0.0739, with only 7.39% of potential connections realized, indicating moderate collaboration among researchers. The high clustering coefficient of 0.9099 suggests that collaborations tended to occur within tight-knit groups, although the overall structure was fragmented into 13 components, with limited interaction across these sub-networks. The presence of isolated components and sparse connections hindered the efficient dissemination of information across the network. Key figures like Nista, Enrico C., Spada, Cristiano, Urgesi, Riccardo, and Costamagna, Guido emerged as central nodes, playing significant roles in bridging gaps and maintaining network cohesion.

The 2010-2019 period saw a decline in network density to 0.0208, with only 2.08% of potential collaborations realized, reflecting an expanded author pool but reduced co-authorship frequency. The clustering coefficient increased to 0.9480, indicating stronger local clustering, while the number of components rose to 48, pointing to greater fragmentation and the emergence of numerous independent research clusters. Itoi, Takao stood out as a pivotal figure, leading in degree, closeness, and betweenness centrality, underscoring his broad collaborative reach and influence within the network. Other notable contributors included Baron, Todd H., Maple, John T., and Katanuma, Akio, who also held central positions, facilitating communication and collaboration across the network.

In the most recent period of 2020-2023, the network density slightly improved to 0.0467, with 4.67% of potential connections realized, indicating a moderate increase in collaboration. The clustering coefficient remained high at 0.9739, reflecting a strong tendency for authors to form collaborative clusters. The network comprised 24 components, showing some improvement in integration compared to earlier periods, yet the average distance remained infinite, highlighting persistent disconnection among certain groups of authors. Key contributors such as Tanisaka, Yuki, Ryozawa, Shomei, Mizuide, Masafumi, Fujita, Akashi, and Ogawa, Tomoya emerged as central figures, significantly enhancing network connectivity and cohesiveness. Although betweenness centrality was generally low, authors like Moreels, Tom G., Tanisaka, Yuki, Ryozawa, Shomei, Mizuide, Masafumi, Fujita, Akashi, and Ogawa, Tomoya held strategic positions as key connectors, facilitating indirect collaborations within the network.

Overall, this study provides a comprehensive overview of the evolution of co-authorship networks in SBE research, highlighting key contributors and the impact of their collaborations. The findings suggest that while collaboration has increased over time, there remain opportunities for further enhancing connectivity and reducing fragmentation within the network. By fostering stronger international partnerships and encouraging cross-group interactions, the field of SBE research can continue to advance, promoting the dissemination of knowledge and the development of innovative approaches to small bowel endoscopy.

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Abbreviations

SBE, Single-Balloon Enteroscope; WoS, Web of Science; IDE, Integrated Development Environment

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