Original Article

The use of positron emission tomography in thyroid cancer: a bibliometric analysis

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Background: Thyroid cancer is a common malignant tumor, and its incidence is rising. Positron emission tomography-computed tomography (PET-CT) is of great value in diagnosing and monitoring thyroid cancer. The purpose of this study is to analyze the current research status of the use of PET-CT in thyroid cancer.

Methods: We used the Science Citation Index-Expanded (SCI-E) database in the Web of Science Core Collection (WOSCC) as the data source for the literature search. The search was carried out with ("thyroid cancer" OR "thyroid carcinoma") AND "positron emission tomography", and the results were analyzed with the bibliometric R software package. The analysis included the number of documents published in this field by each country, the cooperative relationship between countries, the number of documents published by institutions, the cooperative relationship between institutions, the number of documents published by researchers, the cooperative relationship between researchers, the location of researchers being cited, the number of documents published in journals, and the use of keywords.

Results: One thousand and six hundred and seven papers were finally included, and the number of published papers each year showed a trend of fluctuating growth before reaching a peak in 2010, followed by a decreasing trend. The United States published the largest number of documents and was cited far more frequently than other countries. The research institute with the largest number of published articles was the Memorial Sloan Kettering Cancer Center in New York, USA. The cooperation relationship of authors presented a clustered distribution, and the authors in the same cluster often came from the same research institution or country. The professional journal "*Thyroid*" published the largest amount of studies in this field. According to Bradford's rules, nine core journals in this field were determined. The result of our keyword analysis showed that the most commonly used keyword was "positron emission tomography", followed by "cancer" and "carcinoma". The research in this field focused on follow-up and management of thyroid cancer, especially papillary thyroid cancer.

Conclusions: The number of studies in this field shows a decreasing trend, and PET is essential in the follow-up monitoring of thyroid cancer patients.

Keywords: Positron emission tomography (PET); thyroid cancer; thyroid carcinoma; bibliometrics analysis

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Introduction

Thyroid cancer is a common malignant tumor. The 2021 global cancer statistics report predicts that there will be 586,000 new cases of thyroid cancer worldwide in 2020, ranking it 11th among all malignant tumors, with 43,600 deaths per annum. The mortality of thyroid cancer is relatively low, ranking 26th among all malignant tumors and the lowest among common malignant tumors (1). In China, the 2016 cancer statistical study estimated that in 2015, there would be 90,000 new cases of thyroid cancer, ranking 10th among all malignant tumors, with 6,800 deaths, and 22nd among 25 malignant tumors (2). The statistical results of several epidemiological studies in the United States, Italy, and South Korea show that the incidence of thyroid cancer in many countries has increased significantly in the past 20–30 years (3,4). The statistical results in China also show that thyroid cancer incidence in Beijing increased by approximately fivefold between 1995 and 2010 (5). On the other hand, the rates in Tianjin increased nearly threefold from 1981 to 2001 (6).

In recent decades, ^{18}F-deoxyglucose (FDG) positron emission tomography-computed tomography (PET-CT) has been widely used in clinical practice (7), and ^{18}F-FDG PET-CT imaging has significantly improved the detection rate of thyroid cancer (8). In a previous study, approximately 1/3 of tumors detected by ^{18}F-FDG PET-CT were thyroid cancer (9). ^{18}F-FDG PET-CT can provide important information at the molecular level and plays a crucial role in the differential diagnosis of benign and malignant tumors (10). Bibliometrics is an important method of literature research nowadays. By statistical analysis of the relevant literature on a specific topic, the status quo of the relevant research on the subject can be presented, including national information, research institution information, researcher information, journal information, and the use of keywords in the relevant literature on the topic (11). To further investigate the current status of the use of ^{18}F-FDG PET-CT in thyroid cancer, we used bibliometric methods to statistically analyze the relevant literature.

Highlight box

Key findings

- The number of studies on the use of PET-CT in thyroid cancer shows a decreasing trend, and PET is essential in the follow-up monitoring of thyroid cancer patients.

What is known and what is new?

- Positron emission tomography-computed tomography (PET-CT) is of great value in diagnosing and monitoring thyroid cancer.
- The current research status of the use of PET-CT in thyroid cancer.

What is the implication, and what should change now?

- Future researchers can refer to the results of this study to carefully choose the research direction in this field.
- In future research efforts, we should pay attention to the research trends of important research institutions in the United States, South Korea, and other countries through the key journals summarized in this study.

Methods

Data source

We used the Science Citation Index Expanded (SCI-E) database in the Web of Science Core Collection (WOSCC) as the data source for our literature search. SCI-E is the primary data source for bibliometric research at present. It mainly includes English literature articles (including literature in other languages with English abstracts) and reflects the main achievements of scientific research worldwide.

Search strategy

We used the search topic terms “thyroid cancer” OR “thyroid carcinoma” AND “positron emission tomography”. The time range was from inception to 2022.08.23.

Analysis

All records and references of the search results were exported in plain text format and analyzed using the R software bibliometric package. The analysis contents included the number of documents published in this field by each country, the cooperation relationship between countries, the number of documents published by institutions, the cooperation relationship between institutions, the number of documents published in research, the cooperation relationship between researchers, the situation of researchers being cited, the number of documents published in journals, and the use of keywords.

Statistical analysis

Excel software was used to draw the trend chart of the number of published documents and the number of cited

Table 1 Search results by document type

Document types	Record count	% of 1,607
Original Articles	1,182	73.55
Review Articles	310	19.29
Editorial Materials	66	4.11
Proceedings Papers	15	0.93
Meeting Abstracts	16	1.00
Letters	13	0.81
Early Access	2	0.12
Book Chapters	2	0.12
Notes	1	0.06

Notes: in this table, when the conference papers, conference abstracts, corrections, advance publications, and other documents were duplicated with original articles or reviews, the corresponding records of the former were deleted.

papers in this field. Qualitative data are expressed in terms of quantity and percentage.

Results

General information

In this study, 1,675 relevant research literature records were retrieved, including 1,182 original articles, 310 reviews, 66 editorials, 59 conference papers, 32 conference abstracts, 13 letters, 7 online publications, 3 revisions, 2 book chapters, and 1 briefing. Among them, there were 68 duplicate records. After removing duplicate records, 1,607 articles were finally included (*Table 1*). The analysis results showed that the number of documents published each year had a fluctuating growth trend before 2010, while after reaching the peak in 2010, there was a decreasing trend (*Table 2*, *Figure 1*). However, the number of citations increased yearly (*Table 2*, *Figure 1*). These documents were cited 63,742 times, with an average of 39.67 times for each document and an h-index of 103.

Table 2 Annual changes in the number of publications and citations

Years	Publications	Citations
1995	4	0
1996	7	19
1997	8	37
1998	15	91
1999	21	164
2000	23	254
2001	37	457
2002	33	519
2003	47	732
2004	54	947
2005	36	814
2006	57	1,159
2007	88	1,877
2008	90	2,111
2009	70	2,186
2010	103	2,894
2011	99	3,346
2012	96	3,947
2013	72	3,682
2014	94	4,322
2015	84	4,196
2016	87	4,590
2017	78	4,506
2018	68	4,205
2019	71	4,568
2020	80	5,211
2021	75	5,813
2022	10	1,095

Distribution of source countries

The search results show that many countries have conducted relevant research (*Table 3*), but the United States has been cited far more than other countries (*Figure 2*). At the same time, the total number of published documents in various countries far exceeds the number of records retrieved in this study, indicating that many countries have cooperated in this field.

Distribution of research institutions

The greatest number of published articles were from the

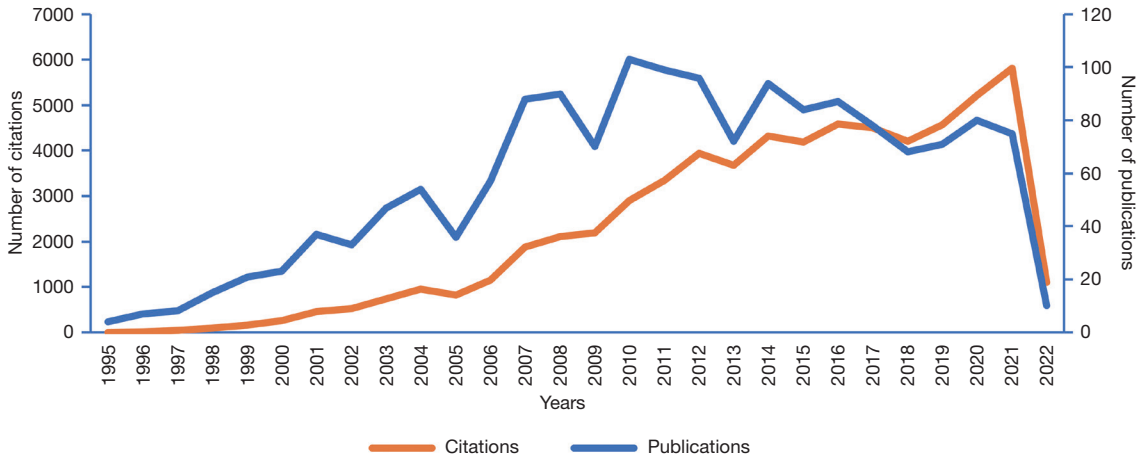

Figure 1 Annual changes in the number of publications and the number of citations.

Table 3 Ranking of countries with number of published documents (top 10)

Rank	Region	Frequency
1	United States of America	1,305
2	France	552
3	South Korea	535
4	Italy	469
5	Germany	415
6	China	394
7	Japan	276
8	The Netherlands	211
9	United Kingdom	181
10	Switzerland	177

Memorial Sloan Kettering Cancer Center (*Figure 3*) in New York, USA. Research institutions from The United States and South Korea headed the list of the top 20 research institutions that produced the largest number of published documents (*Figure 3*). Further analysis of the cooperation between institutions showed that they were clustered, and the research institutions in each cluster were from the same country. Among them, research institutions from the United States carried out extensive cooperation, mainly with the Memorial Sloan Kettering Cancer Center, followed by several research institutions from South Korea, which also demonstrated relatively close cooperative relationships (*Figure 4*).

Author analysis

In this field, there were 49 authors who published more than 10 articles, including eight authors who published more than 20 articles. L. Giovanella from Sweden published the largest number of articles, with 35 in total (*Figure 5*). In the visual atlas of the authors' co-authorship, we can see that the cooperation relationship of the authors presents a cluster distribution. Further analysis showed that authors in the same cluster were often from the same research institution or country (*Figure 6*). The citation analysis shows that S. M. Larson from the Memorial Sloan Caitlin Cancer Center in New York, USA, was cited 801 times (*Figure 7*). Moreover, these documents were often cited simultaneously in the same document (*Figure 8*).

Distribution of journals

The analysis of journals showed that the journal with the largest number of published studies in this field was "*Thyroid*", which published 107 articles in total, followed by the professional journal "*European Journal of Nuclear Medicine Molecular Imaging*" in the field of nuclear medicine, which published 89 studies in total (*Figure 9*). Four of the top five journals with the largest number of publications were nuclear medicine professional journals (*Figure 9*). According to Bradford's rules, nine core journals in this field were identified, namely: *Thyroid*, *European Journal of Nuclear Medicine Molecular Imaging*, *Clinical Nuclear Medicine*, *Journal of Nuclear Medicine*, *Nuclear Medicine Communication*, *Journal of Clinical Endocrinology & Metabolism*, *Quarterly*

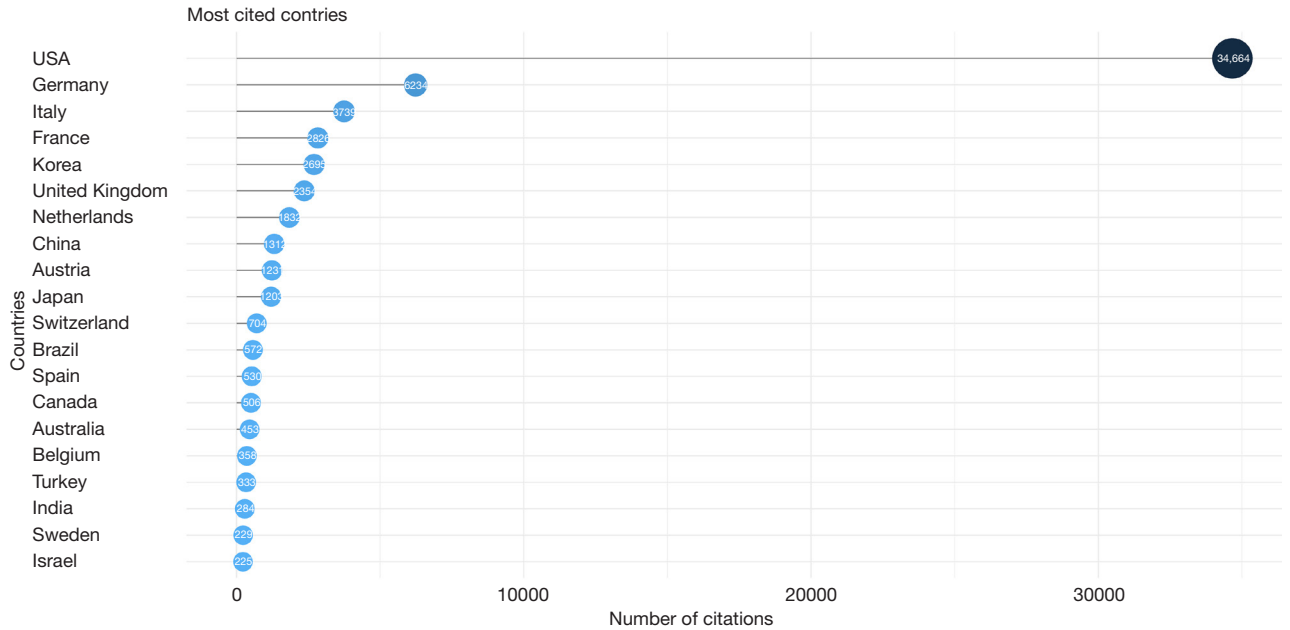

Figure 2 Visual atlas of the number of citations for studies published by various countries (top 20).

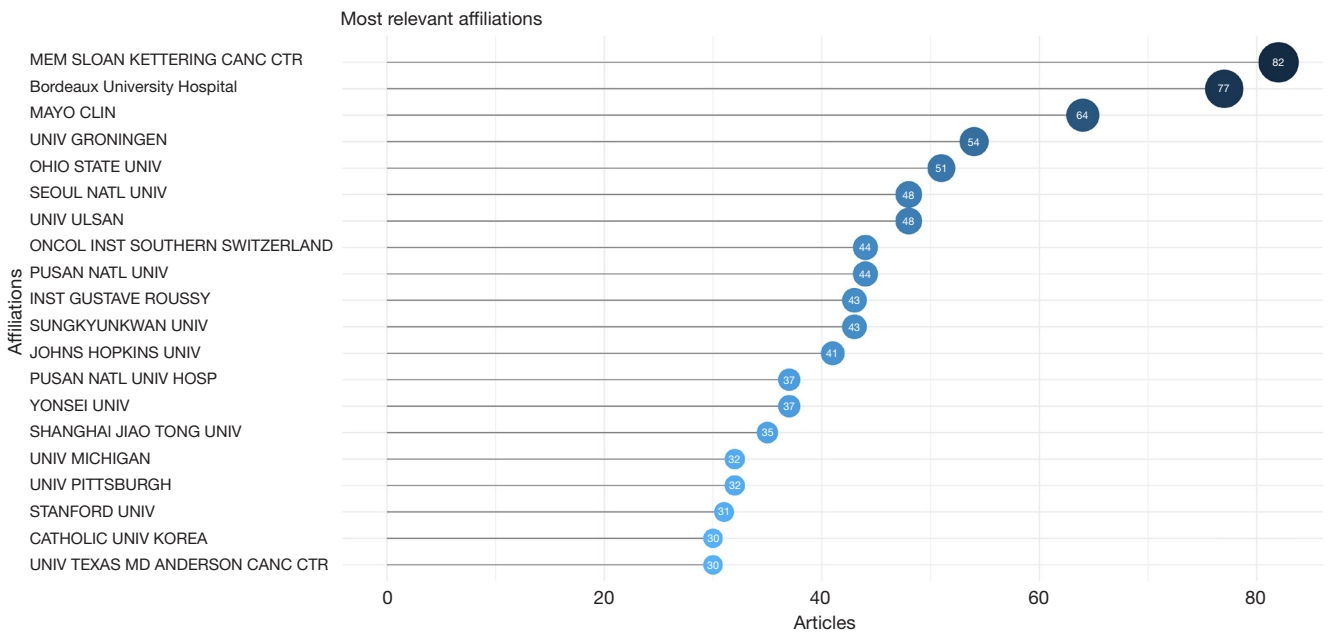

Figure 3 Ranking of number of documents published by institutions (top 20).

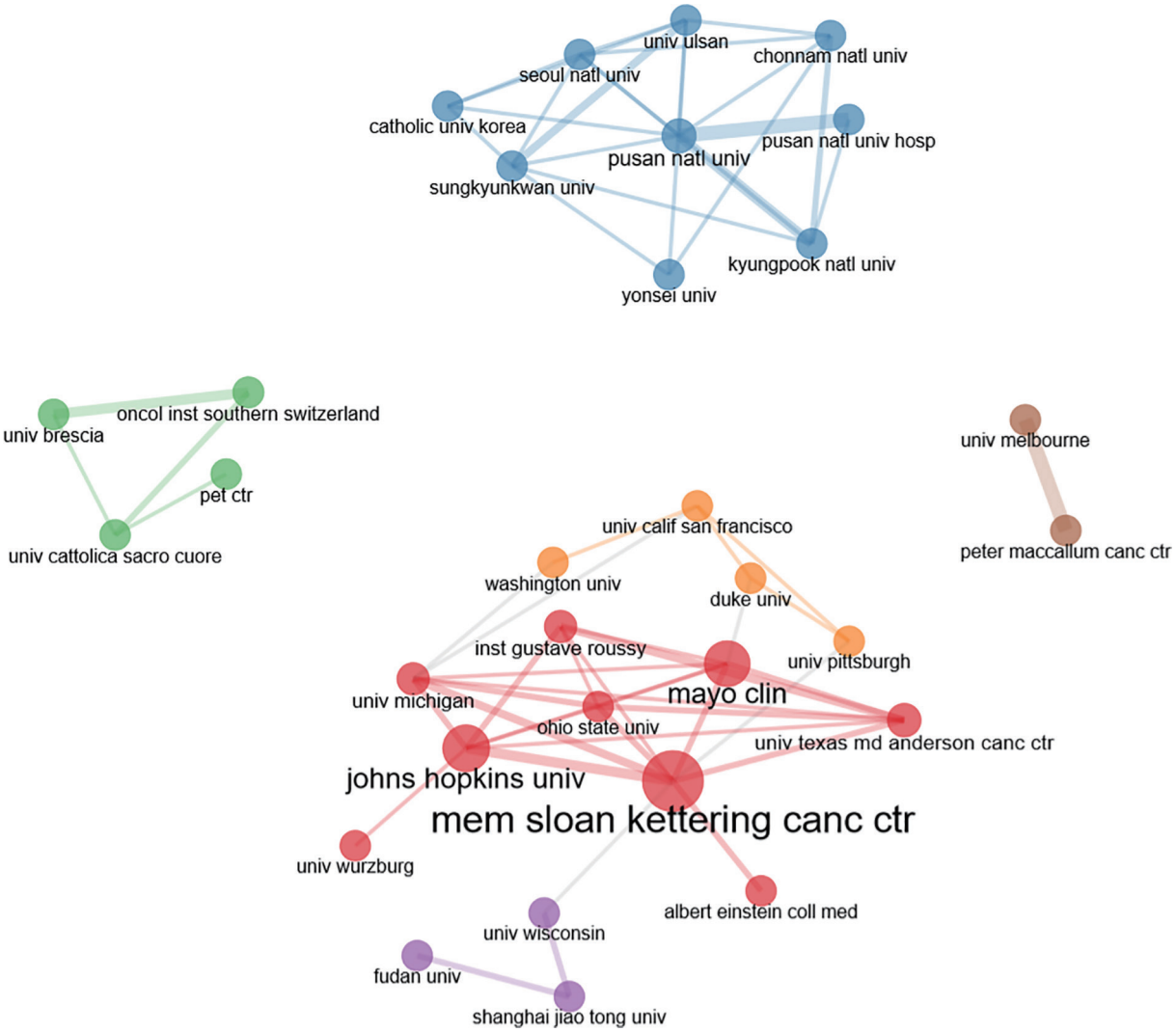

Figure 4 Visual atlas of institutional cooperation.

Journal of Nuclear Medicine and Molecula, *Annals of Nuclear Medicine*, and *Seminars in Nuclear Medicine* (*Figure 10*).

Keyword analysis

The results of the keyword analysis revealed that the most commonly used keywords were "positron emission tomography", followed by "cancer" and "carcinoma", which are the main keywords in this field. In addition, common keywords included "follow up", "management", "diagnosis", and "salary". It can be seen from the common keywords that research in this field was focused on follow-up and management of thyroid cancer, especially papillary thyroid cancer (*Figure 11*). The keyword co-occurrence map shows that "positron emission tomography" was often used together with "cancer", "carcinoma", and "follow-up" (*Figure 12*).

Discussion

In this study, 1,607 articles were retrieved according to the topic words. The analysis of these 1,607 articles showed that the number of PET-CT-related research articles regarding thyroid cancer patients had declined slowly after reaching a peak in 2010. Further analysis revealed that the country with the most research in this field was the United

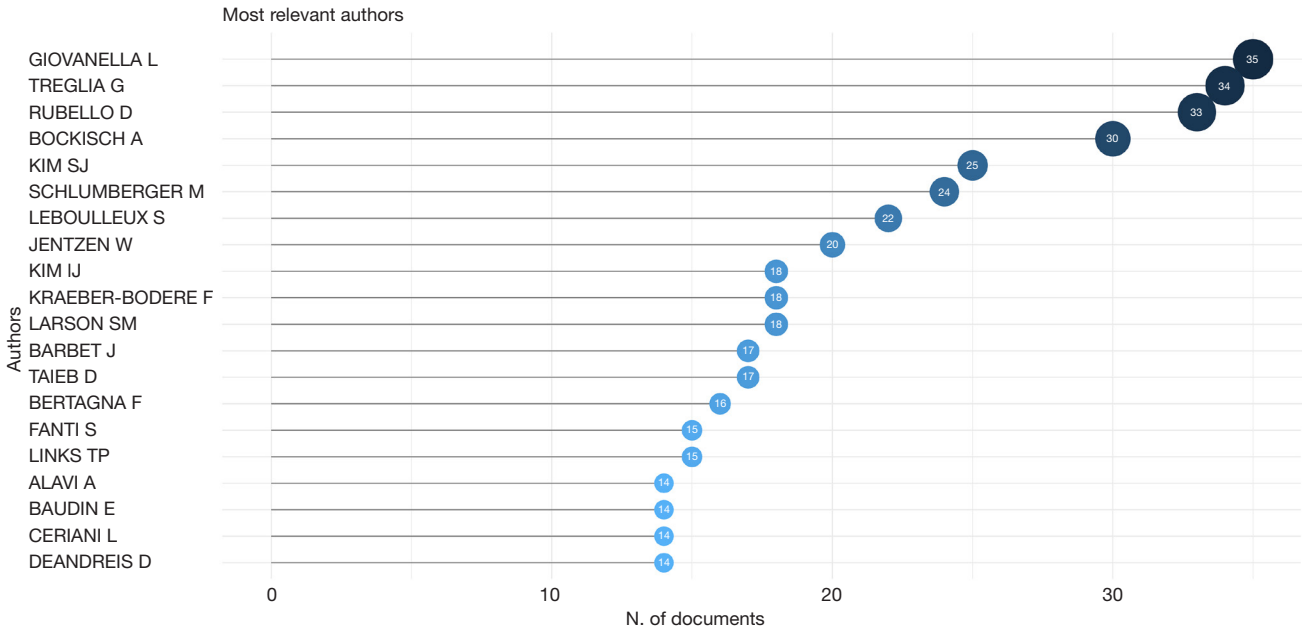

Figure 5 Ranking of number of articles published by authors (top 20).

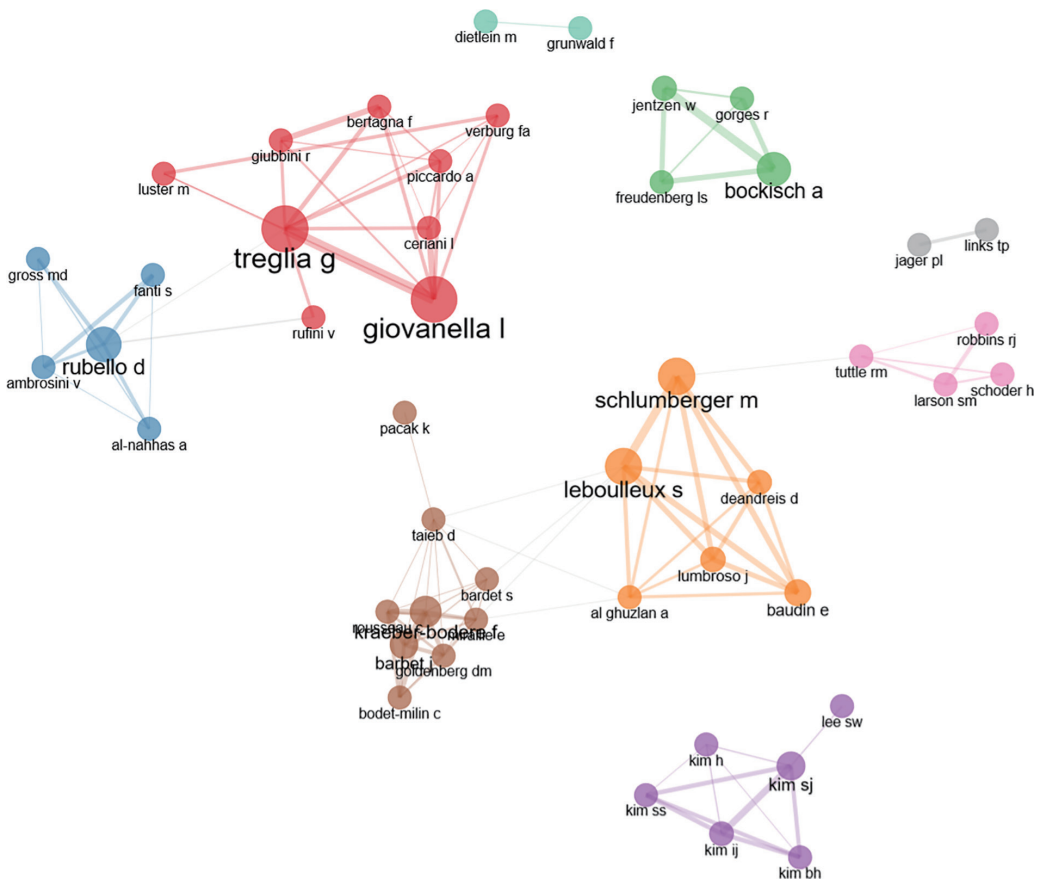

Figure 6 The visual atlas of cooperation.

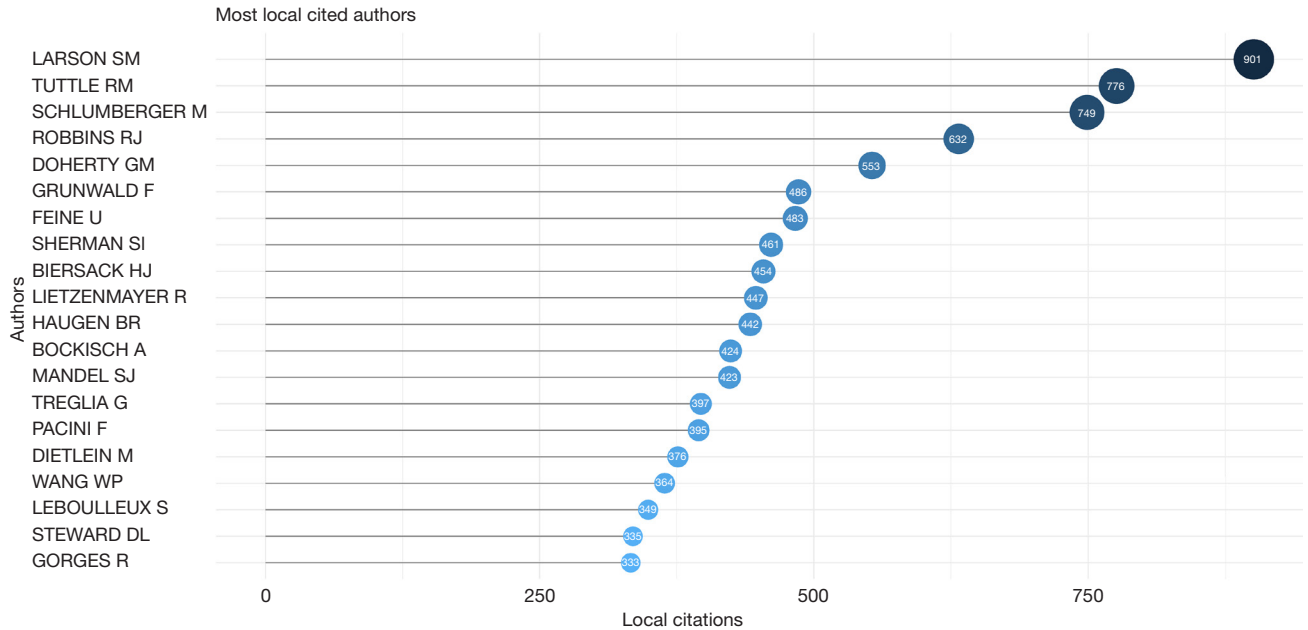

Figure 7 Ranking of authors with high citations (top 20).

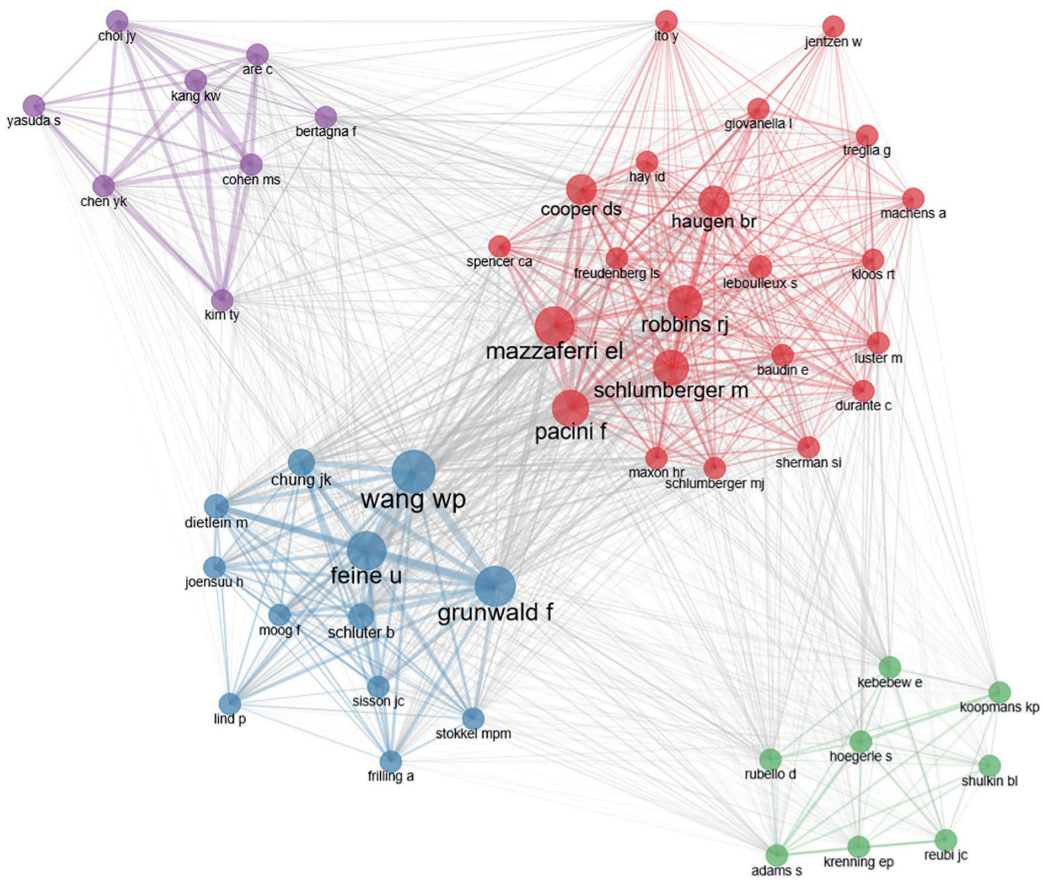

Figure 8 Visual atlas of co-citation.

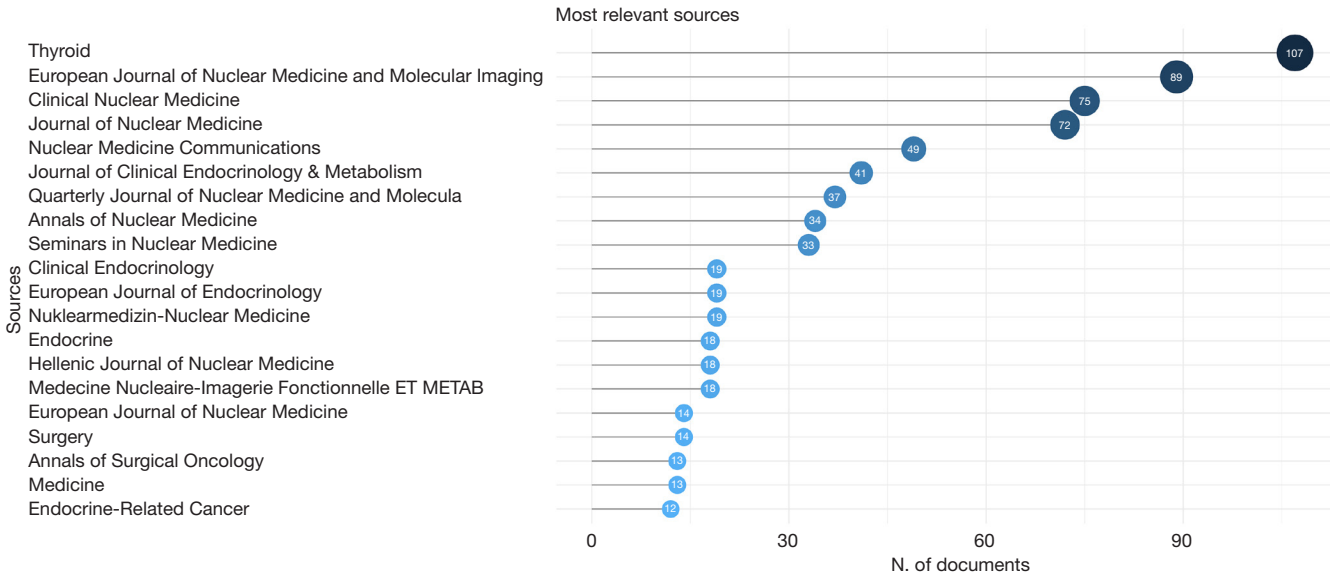

Figure 9 Ranking of the number of articles published in journals (top 20).

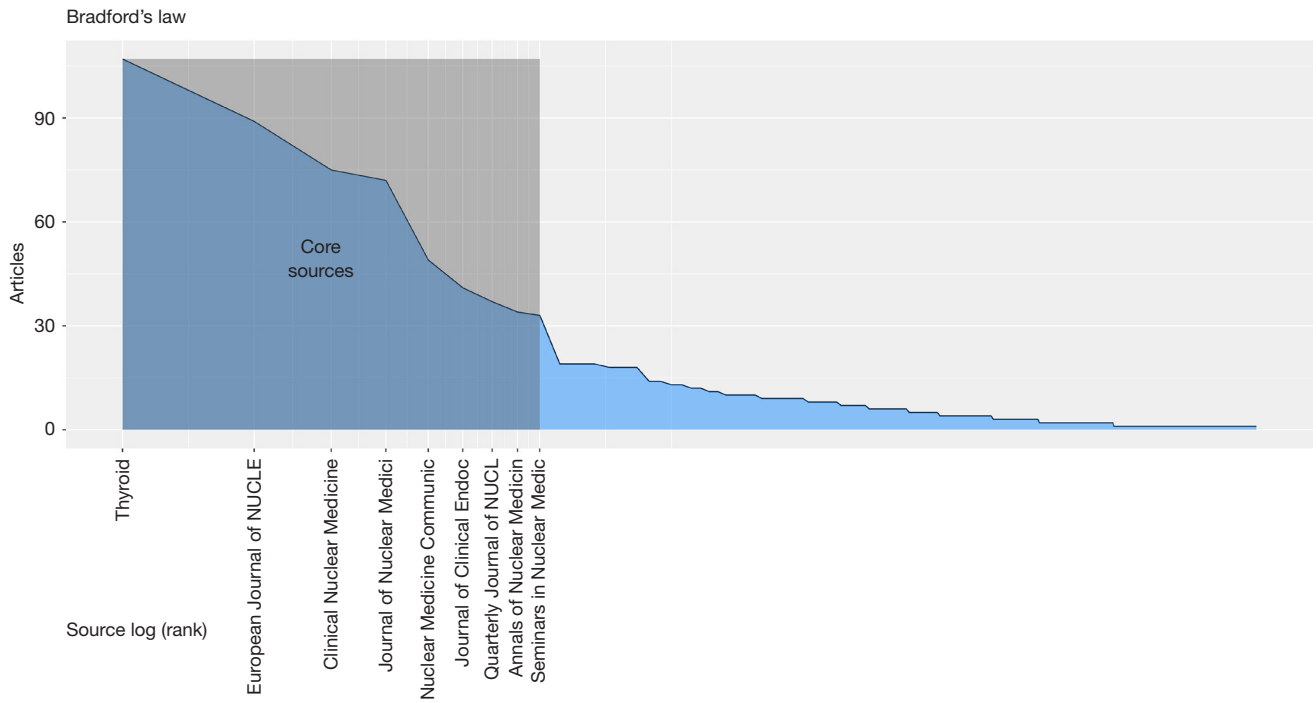

Figure 10 Bradford's law identifying the core journals.

States, and the institution with the most research was the Memorial Sloan Kettering Cancer Center in New York, USA. The cooperation between institutions was mainly limited to each country. Although the author with the most published literature was L. Giovanella from Sweden, the author with the most citations was S. M. Larson from the Memorial Sloan Kettering Cancer Center in New York, USA. The research papers in this field were mainly

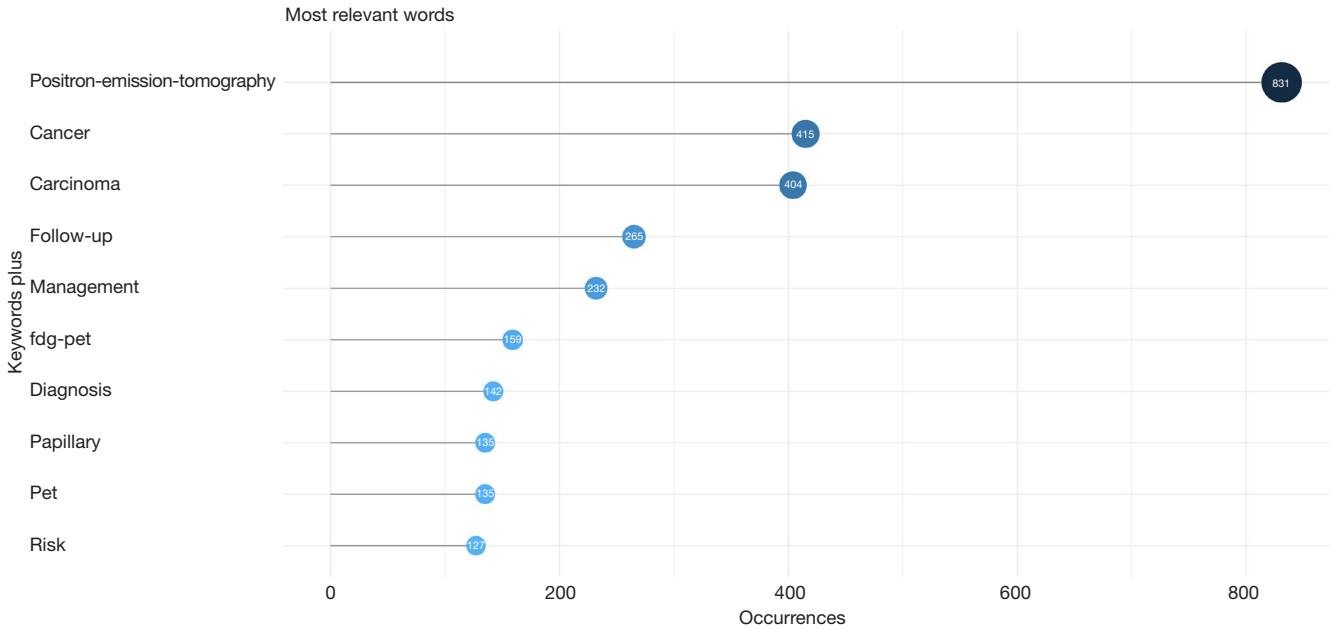

Figure 11 Frequency of keyword use (top 10).

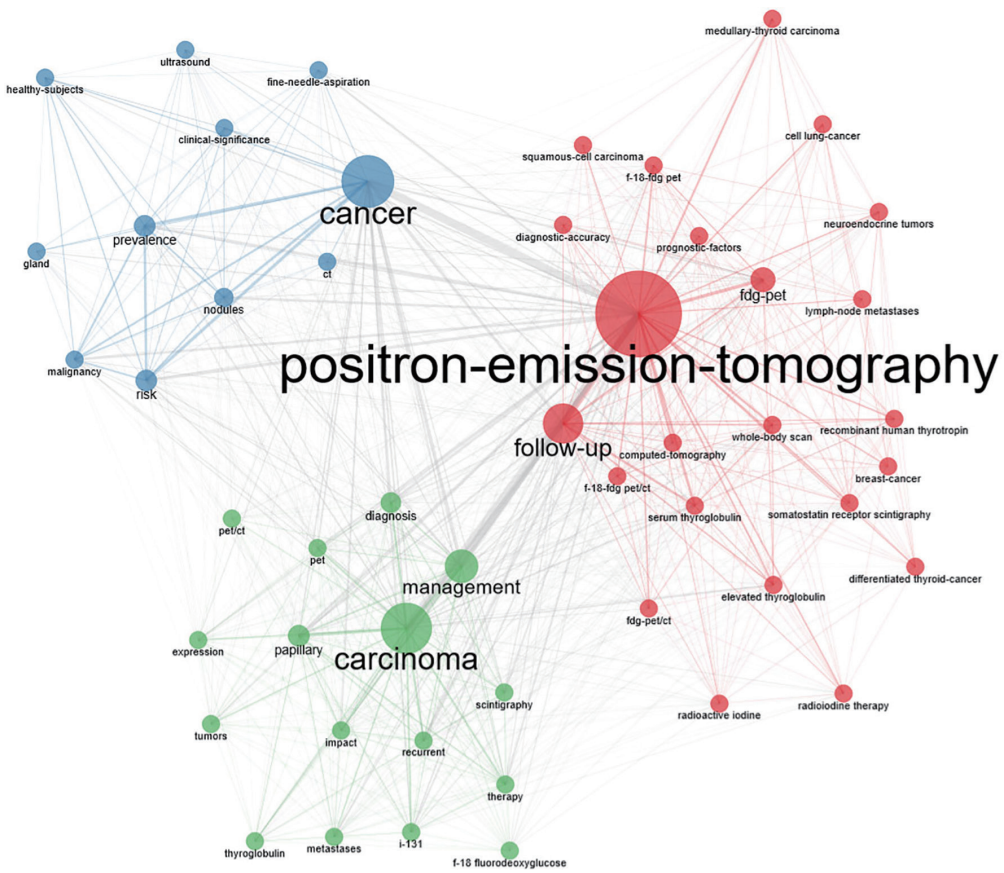

Figure 12 Keyword co-occurrence map.

published in the professional journals of thyroid diseases and nuclear medicine. We identified nine core journals in this field according to Bradford's rules. The keyword analysis demonstrated that PET was mainly used for patients' follow-up, management, and diagnosis, especially for papillary thyroid cancer.

The pathological classification of thyroid carcinoma includes papillary carcinoma, follicular carcinoma, Hürthle cell carcinoma, medullary carcinoma, and undifferentiated carcinoma. The most common is papillary thyroid carcinoma, accounting for 79~94% of all thyroid cancers (12). Due to the biological characteristics of thyroid cancer and the effectiveness of current treatment, the vast majority of patients with thyroid cancer can achieve long-term survival and even clinical or pathological cure (13). The type of thyroid cancer with the poorest prognosis is undifferentiated cancer with high malignancy, but it is relatively rare. To eradicate thyroid cancer, it is often necessary to perform a total thyroidectomy and administer patients lifelong thyroxine, and some patients need to be assisted by radioiodine ablation (14). Although these methods can cure thyroid cancer, particular surgical or therapeutic complications can occur, such as damage to the recurrent laryngeal nerve or low parathyroid function. The latter requires long-term use of thyroxine, which may also lead to adverse medication side effects (15). In addition, it should be noted that thyroid cancer is more likely to recur after treatment than other malignant tumors. A previous study has shown that about 20% of patients with thyroid cancer may need to undergo two or more operations because of recurrence (16). Therefore, monitoring before, during, and after treatment is critically important.

The clinical practice for diagnosing thyroid diseases mainly includes a physical examination, ultrasound, fine needle puncture, and ^{18}F-FDG PET-CT imaging. Physical examination, ultrasound, and fine needle puncture are used primarily to evaluate local nodules. ^{18}F-FDG PET-CT imaging can not only differentiate thyroid nodules but can also evaluate the general situation, especially when diagnosis with the previous methods proves challenging (17). Some researchers believe that using ^{18}F-FDG PET-CT in postoperative monitoring can promptly detect the recurrence and metastasis of thyroid cancer, providing an important reference for follow-up treatment (18). A previous study has shown that the iodine uptake ability of undifferentiated thyroid cancer tissues is reduced or even extinguished. At the same time, glucose metabolism activity is enhanced, and glucose transporter-1 (GLUT-1) expression is significantly increased (19). On the contrary, a low expression of GLUT-1 in differentiated thyroid carcinoma may lead to a decrease in glucose metabolism activity, thus achieving a relatively good prognosis (20). A previous study has shown that ^{18}F-FDG PET-CT has a vital reference value for the early diagnosis and prognosis of thyroid cancer (21). PET-CT has high sensitivity and accurate anatomical localization ability for diagnosing malignant tumors, especially in whole-body imaging, which can fully assess the possibility of diagnosis, staging, metastasis and recurrence (8,22,23). Some research results show that the ability of differentiated thyroid cancer tissue to ingest FDG is related to metastatic or recurrent tumor tissue. The lower the degree of differentiation of metastatic or recurrent lesions, the stronger the degree of glycolysis, and the higher the degree of differentiation of metastatic or recurrent lesions, the lower the intake of FDG, leading to a specific difference in the effective detection of ^{18}F-FDG PET-CT for postoperative metastasis and recurrence of differentiated thyroid cancer (24-27). Actually, based on previous researches, some guideline were established for clinical practice, especially for medullary thyroid carcinoma (28,29). The main limitation for the utility of PET-CT in thyroid cancer management is the high cost for patients, which make some low-income patients cannot afford it.

However, the results of this study indicated that the number of documents published every year in this field showed a downward trend after 2010, suggesting that research in this field may have been comprehensively evaluated and the issues of concern had gradually resolved. Future researchers can refer to the results of this study to carefully choose the research direction in this field. Furthermore, in future research efforts, we should pay attention to the research trends of important research institutions in the United States, South Korea, and other countries through the key journals summarized in this study.

There are some limitations to this study: this research is a literature analysis and does not analyze specific cases. The results and conclusions obtained are holistic and not focused on particular cases or studies. However, because some documents in other languages were not included in the database, some important papers may have been omitted. However, SCI-E is a globally recognized scientific literature database, and the literature it contains reflects the main achievements of current scientific development. Secondly, this study did not conduct an in-depth analysis of each piece of literature. Some of the literature may have

been repeated, but according to the amount of published literature identified and the number of papers cited, we believe this study accurately reflects the important research institutions and researchers in this field.

Conclusions

The number of studies in this field shows a decreasing trend, and PET is essential in the follow-up monitoring of thyroid cancer patients.

Acknowledgments

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-22-626/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Sung H, Ferlay J, Siegel RL, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. CA Cancer J Clin 2021;71:209-49.
2. Chen W, Zheng R, Baade PD, et al. Cancer statistics in China, 2015. CA Cancer J Clin 2016;66:115-32.
3. Lim H, Devesa SS, Sosa JA, et al. Trends in Thyroid Cancer Incidence and Mortality in the United States, 1974-2013. JAMA 2017;317:1338-48.
4. Miranda-Filho A, Lortet-Tieulent J, Bray F, et al. Thyroid cancer incidence trends by histology in 25 countries: a population-based study. Lancet Diabetes Endocrinol 2021;9:225-34.
5. Zhao L, Pang P, Zang L, et al. Features and trends of thyroid cancer in patients with thyroidectomies in Beijing, China between 1994 and 2015: a retrospective study. BMJ Open 2019;9:e023334.
6. Qian B, He M, Dong S, et al. Incidence and mortality of thyroid cancer in Tianjing from 1981 to 2001. Chin J Endocrinol Metab 2005;21:432-4.
7. Bal C, Chakraborty D, Khan D. Positron Emission Tomography/Computed Tomography in Thyroid Cancer. PET Clin 2022;17:265-83.
8. Schlumberger M, Leboulleux S. Current practice in patients with differentiated thyroid cancer. Nat Rev Endocrinol 2021;17:176-88.
9. Treglia G, Kroiss AS, Piccardo A, et al. Role of positron emission tomography in thyroid and neuroendocrine tumors. Minerva Endocrinol 2018;43:341-55.
10. Abraham T, Schoder H. Thyroid cancer--indications and opportunities for positron emission tomography/computed tomography imaging. Semin Nucl Med 2011;41:121-38.
11. Brandt JS, Hadaya O, Schuster M, et al. A Bibliometric Analysis of Top-Cited Journal Articles in Obstetrics and Gynecology. JAMA Netw Open 2019;2:e1918007.
12. Cabanillas ME, McFadden DG, Durante C. Thyroid cancer. Lancet 2016;388:2783-95.
13. Araque KA, Gubbi S, Klubo-Gwiezdzinska J. Updates on the Management of Thyroid Cancer. Horm Metab Res 2020;52:562-77.
14. Chmielik E, Rusinek D, Oczko-Wojciechowska M, et al. Heterogeneity of Thyroid Cancer. Pathobiology 2018;85:117-29.
15. Buttner M, Rimmele H, Bartes B, et al. Management of thyroid cancer: results from a German and French patient survey. Hormones (Athens) 2021;20:323-32.
16. Tuttle RM. Controversial Issues in Thyroid Cancer Management. J Nucl Med 2018;59:1187-94.
17. Treglia G, Giovanella L, Rufini V. PET and PET/CT imaging in thyroid and adrenal diseases: an update. Hormones (Athens) 2013;12:327-33.
18. Nanni C, Rubello D, Fanti S, et al. Role of 18F-FDG-PET and PET/CT imaging in thyroid cancer. Biomed Pharmacother 2006;60:409-13.
19. Choi SJ, Jung KP, Lee SS, et al. Clinical Usefulness of F-18 FDG PET/CT in Papillary Thyroid Cancer with Negative Radioiodine Scan and Elevated Thyroglobulin

Level or Positive Anti-thyroglobulin Antibody. Nucl Med Mol Imaging 2016;50:130-6.
20. Trivino Ibanez EM, Muros MA, Torres Vela E, et al. The role of early 18F-FDG PET/CT in therapeutic management and ongoing risk stratification of high/intermediate-risk thyroid carcinoma. Endocrine 2016;51:490-8.
21. Shen FC, Hsieh CJ, Huang IC, et al. Dynamic Risk Estimates of Outcome in Chinese Patients with Well-Differentiated Thyroid Cancer After Total Thyroidectomy and Radioactive Iodine Remnant Ablation. Thyroid 2017;27:531-6.
22. Yang JH, Maciel RMB, Nakabashi CCD, et al. Clinical utility of 18F-FDG PET/CT in the follow-up of a large cohort of patients with high-risk differentiated thyroid carcinoma. Arch Endocrinol Metab 2017;61:416-25.
23. Rizzo A, Perotti G, Zagaria L, et al. 18F-FDG PET/CT concurrent with first radioiodine post-therapeutic scan in high risk differentiated thyroid cancer: a useful tool or just an expensive diversion? Q J Nucl Med Mol Imaging 2022. [Epub ahead of print]. doi: 10.23736/S1824-4785.22.03364-7.
24. Piccardo A, Puntoni M, Dezzana M, et al. Indeterminate thyroid nodules. The role of (18)F-FDG PET/CT in the "era" of ultrasonography risk stratification systems and new thyroid cytology classifications. Endocrine 2020;69:553-61.
25. Nakajo M, Jinguji M, Shinaji T, et al. (18)F-FDG-PET/CT features of primary tumours for predicting the risk of recurrence in thyroid cancer after total thyroidectomy: potential usefulness of combination of the SUV-related, volumetric, and heterogeneous texture parameters. Br J Radiol 2019;92:20180620.
26. Lee JW, Lee SM, Lee DH, et al. Clinical utility of 18F-FDG PET/CT concurrent with 131I therapy in intermediate-to-high-risk patients with differentiated thyroid cancer: dual-center experience with 286 patients. J Nucl Med 2013;54:1230-6.
27. Zhu X, Wu S, Yuan X, et al. Progression free survival related to (18)F-FDG PET/CT uptake and (131)I uptake in lung metastases of differentiated thyroid cancer. Hell J Nucl Med 2019;22:123-30.
28. Giovanella L, Treglia G, Iakovou I, et al. EANM practice guideline for PET/CT imaging in medullary thyroid carcinoma. Eur J Nucl Med Mol Imaging 2020;47:61-77.
29. Bozkurt MF, Virgolini I, Balogova S, et al. Guideline for PET/CT imaging of neuroendocrine neoplasms with (68)Ga-DOTA-conjugated somatostatin receptor targeting peptides and (18)F-DOPA. Eur J Nucl Med Mol Imaging 2017;44:1588-601.

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