ORIGINAL ARTICLE Head and neck Imaging

A Review on Application of Image Processing in Thyroid Cancer

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SUBMISSION: 19/12/2023 - ACCEPTANCE: 22/08/2024

ABSTRACT

The image processing plays a significant role in the early detection and diagnosis of thyroid cancer. Many researchers are trying to develop and implement image-processing models for cancer detection. This article reviews and discusses the literature on image processing and thyroid cancer. The bibliometric and structured literature review methods assess the existing literature. The study indicates that the prevalence of thyroid cancer has been increasing in recent years. Numerous factors, such as raised detection through screening programs, changes in investigative criteria, and environmental and lifestyle aspects, have contributed to this trend. Furthermore, the literature finds various diagnostic and treatment methods available for patients with thyroid cancer, as well as the difficulties associated with overdiagnosis and overtreatment. Furthermore, the role of image processing techniques in the analysis and diagnosis of thyroid cancer focuses on their possible advantages and disadvantages.

KEY WORDS: Image Processing, Thyroid Cancer, Bibliometric, Deep Learning

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Introduction

Image processing is a crucial process for diagnosing and preventing thyroid cancer. Thyroid cancer is a typical malignancy, and medical imaging techniques are essential for its early detection, judgment, and treatment planning [1]. We can identify the small thyroid nodule using an image processing algorithm, which will improve the quality of images. Early detection is necessary to improve the survival of thyroid cancer patients [2]. Image processing tools can distinguish between benign and malignant thyroid nodules. Features such as size, shape, texture, and vascularity can be analyzed for more accurate results. We can identify the stage and extent of thyroid cancer using images of the thyroid gland. In order to plan surgical procedures and radiation therapy, accurate 3D reconstruction and volume measurements are necessary [3]. We can monitor the changes in thyroid nodules over time using image processing techniques. Serial imaging allows physicians to determine the size and characteristics of nodules and assess treatment response [4]. Ultrasound and other imaging techniques utilize fine needle aspiration biopsies to locate and target suspicious areas for biopsy, increasing the accuracy of the procedure. Image-guided surgery is becoming increasingly common in the treatment of thyroid cancer **[5]**. It allows for smaller incisions, reduced damage to surrounding tissues, and more rapid recovery times. Image processing helps surgeons locate tumours during these procedures. Advanced image processing techniques are used to identify high-risk features [1]. Various imaging techniques, such as ultrasound, CT, MRI, and nuclear medicine scans, can be combined to provide a more comprehensive view of thyroid nodules. Image fusion and integration techniques can assist in the interpretation of complex cases.

The thyroid gland is a small butterfly-shaped gland located in the neck, which produces the hormones that regulate metabolism. Thyroid cancer causes that gland to be affected. There has been an increase in the incidence of thyroid cancer due to various factors, such as increasing detection rates through screening programs, diagnostic criteria, and environmental and lifestyle factors. We will explore the numerous factors that contribute to the rise in thyroid cancer incidence and the latest diagnostic and treatment options available for patients with this disease. Image processing plays a significant role in analyzing and managing thyroid cancer.

Artificial intelligence (AI) has emerged as an effective tool in medical imaging. It has been proven to have greater accuracy and efficiency in diagnosing ultrasound images of thyroid cancer, as evidenced by[6].

T-CALOS (Thyroid Cancer Longitudinal Study) by [7] helps to study and understand the patterns and dynamics of thyroid cancer in specific populations, such as the Korean population and justify the importance of comprehensive, long-term clinical and epidemiological studies

Moreover, researchers like [8] and [9] have discovered advanced methods for discriminating and managing high-risk thyroid nodules [8] and propose a modified TI-RADS classification. At the same time, [9] delves into the value of circulating miRNA expression profiling in conjunction with sonographic TI-RADS classification, enhancing the precision of thyroid nodule diagnoses.

Technological advances have also revolutionized the landscape of thyroid nodule evaluation. Studies like that of [10] explore the clinical value of Shear Wave Elastography Color Scores in classifying thyroid nodules, shedding light on applying cutting-edge techniques for diagnosis and risk stratification.

Furthermore, [11] presents a retrospective study on the features and trends of thyroid cancer in patients undergoing thyroidectomies in Beijing, China, highlighting the evolving nature of thyroid cancer and the need for continuous research.

Thus, the following research questions (RQs) are explored in this review:

RQ1. What is the publication trend (number of articles by year)?

RQ2. Where are the most influential publications (outlets, articles)?

RQ3. Who are the most prolific contributors (authors, countries, and institutions)?

RQ4. What does existing research (themes, topics) convey?

RQ5. Where can future research be explored to enrich our understanding of Image processing techniques in cancer detection?

The search for articles was initiated in early 2023. Our search for articles to include in this review followed a four-stage search strategy. The first stage involved a database search, for which we selected Scopus. We chose

Scopus for two key reasons: first, it boasts comprehensive coverage of publications that meet stringent indexing requirements, ensuring they are scientifically and scholarly relevant. Second, Scopus provides extensive bibliometric information for the publications it indexes. Indeed, Scopus is well-suited for projects aiming to compile a substantial corpus for review [12]. It is a preferred choice in the scientific community for bibliometric reviews [13].

Furthermore, Scopus has earned recognition as a high-quality source of bibliometric data [14], and its measures exhibit an "extremely high" correlation with those found in alternative scientific databases like the Web of Science [15]. While Web of Science offers slightly narrower coverage, Scopus emerges as a more comprehensive yet equally high-quality data source for our review. Our search keywords were "image processing" and "thyroid cancer," chosen for their central importance to the review. The database search yielded a total of 238 articles.

Stage 2 is scholarly filtration. We chose to include only journal articles and conference proceedings, as they are usually (1) evaluated on the grounds of novelty and (2) subjected to rigorous peer review, both of which are essential criteria to (1) unpack knowledge diversity, and (2) report insights of the highest quality, respectively. We did not include other articles, such as books and book chapters, as they usually fall short of these criteria. The criteria here are in line with the recommendations by [12]. The scholarly filtration excluded five articles and, thus, included 232 articles only. Stage 3 is language filtration. We chose to include articles written in English retained in Stage 2 only. This filtration was required as (1) we are native English speakers, and (2) translation works are impractical for reviews with large datasets (e.g., bibliometric reviews). The criteria here align with the recommendations by Donthu, Kumar, Mukherjee and others [16]. The language filtration excluded 82 articles and, thus, included 189 articles only.

Table 1 Descriptive Analysis of the Data

Description	Results
Timespan	1991:2023
Sources (Journals, Books, etc)	110
Documents	189
Average years from publication	8.58
Average citations per documents	30.93
Average citations per year per doc	3.319
Document Types	
Article	189
Document Contents	
Keywords Plus (ID)	2071
Author's Keywords (DE)	475
Authors	
Authors	1115
Author Appearances	1265
Authors of single-authored documents	6
Authors of multi-authored documents	1109
Authors Collaboration	
Single-authored documents	6
Documents per Author	0.17
Authors per Document	5.9
Co-Authors per Documents	6.69
Collaboration Index	6.06

2. Discussions

2.1 Analysis of Academic Research Trends

The analysis covers a significant period, from 1991 to 2023, providing a comprehensive overview of research development over the last three decades. Table 1 shows that 110 sources, including journals, books and other scholarly materials, were used to compile 189 documents, indicating a wide range of academic resources were referenced. 189 documents in the dataset are articles. The research documents contain 2,071 Keywords Plus (ID), indicating a rich diversity of keywords used to index the content. There are 475 Author Keywords (DE), highlighting the importance of author-provided keywords for content categorization. There are 1,115 unique authors associated with the 189 documents, suggesting a large and diverse pool of researchers contributing to this work. The authors collectively make 1,265 appearances in the dataset, indicating that many researchers have multiple contributions. Most documents are multi-authored, and six are single-authored, as shown in Table 1, indicating a relatively low percentage of solo-authored research. There are six single-au-

Table no. 2: Publication Trend

Particulars	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2023	Overall
Total articles	5	3	18	22	30	79	32	189
No. of contributing Authors	19	12	109	166	192	521	246	1265
average no. of authors	3.80	4.00	6.06	7.55	6.40	6.59	7.69	6.69
collaboration index	0.21	0.25	0.16	0.13	0.15	0.15	0.13	0.14
Sole authored Articles	1	0	1	1	1	2	0	6
Co-Authored Articles	4	3	17	21	29	77	32	183
No. of cited publications	4	2	17	21	29	77	21	171
% of cited publication	0.8	0.67	0.94	0.96	0.97	0.98	0.6563	0.90
Total Citations	30	76	1131	1834	802	1814	159	5846
Citations per cited publications	7.50	38	66.53	87.33	27.66	23.56	7.57	34.19
Citations per contributing authors	1.57	6.33	10.38	11.05	4.18	3.49	0.65	4.62
h-index	2	4	8	10	14	24	8	70
g index	2	6	8	10	15	25	8	74
Number of active years	5	2	5	5	5	5	3	30
Productivity per active year	1	1.5	3.6	4.4	6	15.8	10.67	6.3

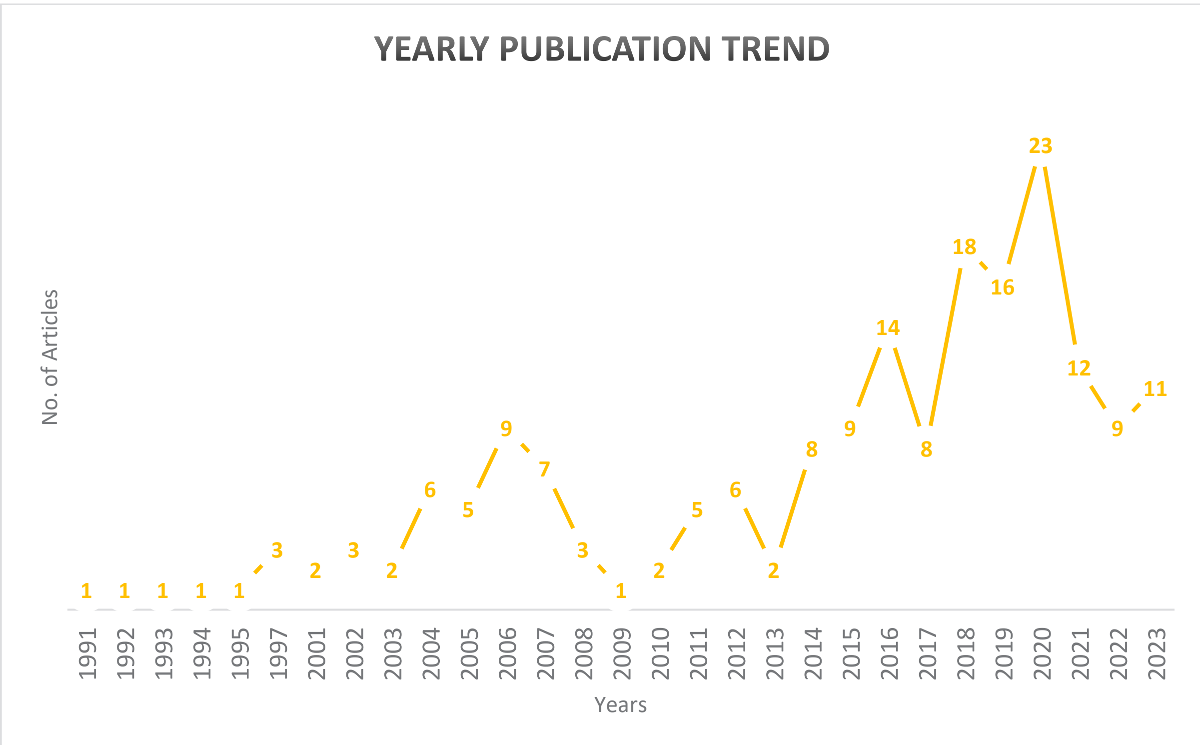


Fig 2.1 Yearly publication trend

Table No. 3: Most Prominent Articles

Sl. No	Author	Title	Year	Source Title	TC	Citable Years	CPY
1	BAEK JH	Computer-Aided Diagnosis for Classifying Benign Versus Malignant Thyroid Nodules Based on Ultra-sound Images: A Comparison with Radiologist-Based Assessments	2016	MEDICAL PHYSICS	97	8	12.125
2	CHOI YJ	Computer-Aided Diagnosis for Classifying Benign Versus Malignant Thyroid Nodules Based on Ultra-sound Images: A Comparison with Radiologist-Based Assessments	2016	MEDICAL PHYSICS	97	8	12.125
3	LEE JH	Application Of Deep Learning to The Diagnosis of Cervical Lymph Node Metastasis from Thyroid Cancer with Ct	2019	EUROPEAN RADIOLOGY	67	5	13.4
4	LEE JH	Deep Convolutional Neural Network for The Diagnosis of Thyroid Nodules on Ultrasound	2019	HEAD AND NECK	65	5	13
5	KIM E-K	Deep Convolutional Neural Network for The Diagnosis of Thyroid Nodules on Ultrasound	2019	HEAD AND NECK	65	5	13
6	KWAK JY	Deep Convolutional Neural Network for The Diagnosis of Thyroid Nodules on Ultrasound	2019	HEAD AND NECK	65	5	13
7	MOON HJ	Deep Convolutional Neural Network for The Diagnosis of Thyroid Nodules on Ultrasound	2019	HEAD AND NECK	65	5	13
8	YOON JH	Deep Convolutional Neural Network for The Diagnosis of Thyroid Nodules on Ultrasound	2019	HEAD AND NECK	65	5	13
9	JENTZEN W	Assessment Of Lesion Response in The Initial Radioiodine Treatment of Differentiated Thyroid Cancer Using 124i Pet Imaging	2014	JOURNAL OF NUCLEAR MEDICINE	64	10	6.4
10	JENTZEN W	Dose-Response Relationship in Dif-ferentiated Thyroid Cancer Patients Undergoing Radioiodine Treatment Assessed by Means Of 124i Pet/Ct	2016	JOURNAL OF NUCLEAR MEDICINE	56	8	7
11	ZHANG Y	Differentiation Of Spinal Metastases Originated from Lung and Other Cancers Using Radiomics and Deep Learning Based on Dce-Mri	2019	MAGNETIC RESONANCE IMAGING	53	5	10.6
12	ZHANG J	Differentiation Of Spinal Metastases Originated from Lung and Other Cancers Using Radiomics and Deep Learning Based on Dce-Mri	2019	MAGNETIC RESONANCE IMAGING	53	5	10.6
13	ZHANG J	Detection Of Metastatic Breast and Thyroid Cancer In Lymph Nodes By Desorption Electrospray Ionization Mass Spectrometry Imaging	2017	JOURNAL OF THE AMERI-CAN SOCIETY FOR MASS SPECTROME-TRY	47	7	6.714

14	ZHANG Y	Machine Learning-Based Multiparametric Mri Radiomics for Predicting the Aggressiveness of Papillary Thyroid Carcinoma	2020	EUROPEAN JOURNAL OF RADIOLOGY	41	4	10.25
15	WANG H	Machine Learning-Based Multiparametric Mri Radiomics for Predicting the Aggressiveness of Papillary Thyroid Carcinoma	2020	EUROPEAN JOURNAL OF RADIOLOGY	41	4	10.25

Table No. 4: Most Prominent Sources

Sources	TA	NCA	ANA	CI	SA	CA	PCP	TC	C/CP	NAY	PAY	CP
JOURNAL OF NUCLEAR MEDICINE	18	153	8.50	0.12	0	18	1.00	1496	83.11	12	1.5	18
ULTRASOUND IN MEDICINE AND BIOLOGY	7	45	6.43	0.16	0	7	0.86	122	20.33	6	1	6
ANALYTICAL AND QUANTITATIVE CYTOLOGY AND HISTOLOGY	6	24	4.00	0.25	0	6	1.00	65	10.83	6	1	6
PLOS ONE	5	31	6.20	0.16	0	5	1.00	89	17.80	4	1.25	5
ANNALS OF NUCLEAR MEDICINE	4	34	8.50	0.12	0	4	1.00	90	22.50	3	1.33	4
MEDICAL PHYSICS	4	20	5.00	0.20	0	4	0.75	138	46.00	4	0.75	3
NUCLEAR MEDICINE COMMUNICATIONS	4	32	8.00	0.13	0	4	0.75	27	9.00	4	0.75	3
SCIENTIFIC REPORTS	4	30	7.50	0.13	0	4	1.00	191	47.75	4	1	4
AMERICAN JOURNAL OF ROENTGENOLOGY	3	16	5.33	0.19	0	3	1.00	186	62.00	3	1	3
COMPUTERS IN BIOLOGY AND MEDICINE	3	25	8.33	0.12	0	3	1.00	48	16.00	2	1.5	3
EUROPEAN JOURNAL OF RADIOLOGY	3	16	5.33	0.19	0	3	1.00	103	34.33	2	1.5	3
EUROPEAN RADIOLOGY	3	15	5.00	0.20	0	3	1.00	125	41.67	3	1	3
HELLENIC JOURNAL OF NUCLEAR MEDICINE	3	9	3.00	0.33	0	3	0.67	8	4.00	2	1	2
KOREAN JOURNAL OF RADIOLOGY	3	26	8.67	0.12	0	3	1.00	54	18.00	1	3	3
RADIOLOGY	3	26	8.67	0.12	0	3	1.00	885	295.00	2	1.5	3
REVISTA ESPANOLA DE MEDICINA NUCLEAR E IMAGEN MOLECULAR	3	17	5.67	0.18	0	3	1.00	17	5.67	3	1	3
BMC CANCER	2	12	6.00	0.17	0	2	1.00	399	199.50	2	1	2
CANCER RESEARCH	2	35	17.50	0.06	0	2	1.00	113	56.50	2	1	2
CANCERS	2	12	6.00	0.17	0	2	1.00	7	3.50	2	1.00	2
CLINICAL NUCLEAR MEDICINE	2	13	6.50	0.15	0	2	1.00	9	4.50	1	2	2

TA = Total Articles, NCA = NO. of Contributing Authors, ANA= Average No. of Authors, CI= Collaboration Index, SA= Sole Authored Articles, CA= Co-authored Article, PCP= Production per Cited Publications, TC= Total Citation, C/CP= Citation by Cited Publication, NAY= No. of Active Years, PAY= Productivity per Active Years, CP = Citable Publications thored documents. The average number of authors per document is 5.9, indicating that multi-authored papers are the norm in this research domain. On average, each document has 6.69 co-authors, highlighting the collaborative nature of the research. The collaboration index 6.06 implies that researchers in this field frequently collaborate on their work.

This analysis provides insight into the trend, topic, and collaboration in the field of research. It suggests that collaboration and interdisciplinary work is necessary to address complex issues.

2.2 Publication and Citation Trend

Table 2 outlines the publication and citation trends during the study period. There are 189 articles, with the highest of 79 from 2016 to 2020 and 32 from 2021 to 2023. In 1996 and 2000, the majority of articles were published.

The number of contributing authors has increased and reached the highest point between the 2016 to 2020 period, with 521 authors. The lowest number of authors was during 1996-2000, with 12. Overall, there are 1,265 authors contributing to this area. The average number of authors per article varies, ranging from 7.69 in 2021-2023. This signifies the increased collaborative research. The collaboration index ranges from 0.13 to 0.25, identifying the authors' collaboration degree. We observed that most articles were co-authored, and only 6 papers during the study period were single-authored. Single articles were authored during the 1996-2000 and 2021-2023 periods. Co-authored articles constitute most of the dataset, with 183 out of 189 articles. This demonstrates the collaborative nature of research in the field. The number of cited publications was highest (77) in the 2016-2020. As Table 2 demonstrates, 171 publications have been cited across all times. Compared to the total number of articles, the percentage of cited publications ranges from 0.6563 to 0.98. The total number of citations also increases over time, with the highest number (1,834) in 2006-2010. There is a total of 5846 citations; from 2006 to 2010, citations were maximum. The citations per cited publication range from 7.50 to 87.33, with the highest impact in 2006-2010. The average number of citations per contributing author was highest from 2006 to 2010, with a value of 11.05, and the lowest during 2021-2023, with a value of 0.65. The research spans a total of 30 years. The h-index and g-index, which measure research influence and efficiency, increase over time. As indicated in Table 2, the overall h-index is 70, and the g-index is 74. The productivity per active year increases over time, with the highest (15.8) in 2016-2020, indicating increased research output during the past few years.

2.3 Prominent Articles Analysis

The prominent article analysis focuses on a series of 15 research publications from various authors and years involving topics related to medical imaging, machine learning, and cancer diagnosis. The analysis will examine critical aspects such as the titles, publication years, source titles, total citations (TC), citable years (Citable Years), and citations per year.

The analyzed publications provide a range of topics in medical imaging and cancer diagnosis, with multiple authors contributing to numerous papers. Nevertheless, some papers have similar titles and authors, indicating collaborative efforts within the research community.

In 2019, most papers were published, indicating that a significant research effort was made. Most notable articles span from 2014 to 2020, as shown in Table 3.

The publications are distributed across various source titles, including "Medical Physics," "European Radiology," "Head and Neck," "Journal of Nuclear Medicine," "Magnetic Resonance Imaging," "Journal of the American Society for Mass Spectrometry," and "European Journal of Radiology." This diversity in source titles signifies the interdisciplinary nature of the research.

The total number of citation values is varied from 41 to 97. The paper "Computer-Aided Diagnosis for Classifying Benign Versus Malignant Thyroid Nodules Based on Ultrasound Images" has the highest TC, and this article was cited 97 times, which indicates its substantial impact and relevance in the field.

Most publications have been cited between 4 and 10 years, indicating that they are relatively recent and remain relevant for publication.

The CPY metric differs from the publications by values ranging from 6.4 to 13.4. Higher CPY values indicate that the research remains influential and is frequently cited annually.

As indicated in Table 3, the prominent articles include 15 research publications in medical imaging, machine learning, and cancer diagnosis. The publications from

Table No. 5: Most Prominent Authors

Authors	TA	NCA	ANA	CI	SA	CA	TC	C/CP	NAY	PAY	CP
LEE JH	7	62	8.858	0.11	0	7	221	31.574	5	1.4	7
JENTZEN W	6	48	8	0.10	1	5	177	29.5	4	1.5	6
ZHANG Y	6	50	8.34	0.10	1	5	150	25	4	1.25	5
BAEK JH	5	46	9.2	0.11	0	5	165	33	4	1.25	5
CHOI YJ	4	37	9.25	0.11	0	4	154	38.5	3	1.3333	4
KIM E-K	4	34	8.5	0.12	0	4	137	34.25	3	1.3333	4
KWAK JY	4	34	8.50	0.12	0	4	137	34.25	3	1.3333	4
MOON HJ	4	34	8.50	0.12	0	4	137	34.25	3	1.3333	4
WANG H	4	26	6.5	0.15	0	4	64	16.00	4	1	4
YOON JH	4	34	8.50	0.12	0	4	137	34.25	3	1.3333	4
ZHANG J	4	35	8.75	0.11	0	4	252	63	4	1	4
BABA S	3	18	6.00	0.17	0	3	136	45.33	3	0.6667	2
BACKES WH	3	29	9.67	0.10	0	3	65	21.67	2	1.5	3
BINSE I	3	25	8.33	0.12	0	3	59	19.67	2	1.5	3
BOCKISCH A	3	25	8.33	0.12	0	3	120	40.00	2	1.5	3
CHEN S	3	32	10.67	0.09	0	3	11	3.67	2	1	2
CHEN Y	3	34	11.33	0.09	0	3	69	23.00	3	1	3
CHUNG SR	3	27	9	0.11	0	3	57	19	2	1.5	3
HA EJ	3	17	5.67	0.18	0	3	174	58	3	1	3
HAN K	3	29	9.67	0.10	0	3	107	35.67	2	1.5	3

TA = Total Articles, NCA = NO. of Contributing Authors, ANA= Average No. of Authors, CI= Collaboration Index, SA= Sole Authored Articles, CA= Co-authored Article, PCP= Production per Cited Publications, TC= Total Citation, C/CP= Citation by Cited Publication, NAY= No. of Active Years, PAY= Productivity per Active Years, CP = Citable Publications

2019 have significantly impacted ongoing research, with the highest citation count and CPY values.

2.4 Prominent Sources Analysis

Based on several key metrics such as Total Articles (TA), Non-Cited Articles (NCA), Articles with No Authors (ANA), Collaboration Index (CI), Sole-Authored Articles (SA), Co-Authored Articles (CA), Papers per Citable Publication (PCP), Total Citations (TC), Citations per Citable Publication (C/CP), Number of Articles in a Year (NAY), Papers per Author in a Year (PAY), and Citations per Publication (CP), the analysis focuses on evaluating scientific journals within the field of nuclear medicine and medical imaging. These metrics provide insights into the publications, research collaboration, and impact of journals in this field.

JOURNAL OF NUCLEAR MEDICINE has 1496 citations and the highest number of articles (18), displaying significant work and a significant impact in the field. It also has a high Citations per Citable Publication (C/CP) value of 83.11, suggesting the quality and impact of its publications.

ULTRASOUND IN MEDICINE AND BIOLOGY journal has fewer total articles (7) than others. It has a relatively high Citations per Publication (CP) value of 20.33, indicating the influence of its research in medical ultrasound.

ANALYTICAL AND QUANTITATIVE CYTOLOGY AND HISTOLOGY This journal has a comprehensive Collaboration Index (CI) of 1.00, indicating that all articles are published. It also has a high C/CP value of 10.83, demonstrating the impact of its research in cytology and histology.

RADIOLOGY journal has only three total articles, with a remarkably high number of total citations (885), making it one of the most influential journals regarding citation impact. It also has a high CP value of 295.00.

KOREAN JOURNAL OF RADIOLOGY This journal exhibits a high Papers per Author in a Year (PAY) value of 3, indicating productive authorship within its pages.

CANCER RESEARCH has only two total articles. The journal has a high Collaboration Index (CI) and Citations per Publication (CP) value, suggesting that its research significantly impacts cancer research.

This analysis provides valuable insights into the characteristics and impact of scientific journals in nuclear medicine and medical imaging. JOURNAL OF NUCLEAR MEDICINE is a prominent journal with many articles and citations. However, journals like ULTRASOUND IN MEDICINE AND BIOLOGY, ANALYTICAL AND QUANTITATIVE CYTOLOGY AND HISTOLOGY, and RADIOLOGY demonstrate significant impact and relevance in their respective subfields.

2.5 Author Analysis

The authors' analysis assesses their effectiveness and impact on nuclear medicine and medical imaging. The metrics Total Articles (TA), Non-Cited Articles (NCA), Articles with No Authors (ANA), Collaboration Index (CI), Sole-Authored Articles (SA), Co-Authored Articles (CA), Total Citations (TC), Citations per Citable Publication (C/CP), Number of Articles in a Year (NAY), Papers per Author in a Year (PAY), and Citations per Publication (CP) are considered for the analysis. This analysis reveals the publication patterns, research collaboration, and impact of authors in this research area.

The author, LEE JH, has a substantial number of Total Articles (7) and a high Total Citations (221), resulting in an impressive Citations per Publication (CP) of 31.574. Additionally, the Collaboration Index (CI) suggests a moderate level of research collaboration.

JENTZEN W With 6 Total Articles and a high Citations per Publication (CP) of 29.5, JENTZEN W demonstrates a significant research impact. Notably, one of their articles is Sole-Authored (SA), contributing to the diverse collaboration patterns among authors.

Like JENTZEN W, ZHANG Y has 6 Total Articles and a high Citations per Publication (CP) of 25, indicating a robust research impact. This author also has one Sole-Authored (SA) article.

BAEK JH and CHOI YJ These authors have 5 and 4 Total Articles, respectively, and both exhibit high Citations per Publication (CP) values (33 and 38.5, respectively). BAEK JH has a slightly higher Collaboration Index (CI).

WANG H While having only 4 Total Articles, WANG H achieves a notable Citations per Publication (CP) of 16.00. This author's research consists of a lower Collaboration Index (CI).

BABA S, BACKES WH, BINSE I, and BOCKISCH A These authors have moderate numbers of Total Articles (3) and diverse Citations per Publication (CP) values. BACKES WH and BINSE I have high Collaboration Index (CI) values, suggesting extensive research collaboration.

CHEN S and CHEN Y These authors have 3 Total Articles and exhibit high Citations per Publication (CP) values (11 and 23, respectively). CHEN Y has a higher Collaboration Index (CI).

HA EJ, HAN K, and CHUNG SR These authors have 3 Total Articles each, with varied Citations per Publication (CP) values. HA EJ stands out with a high Citations per Publication (CP) of 58. The analysis provides insights into the productivity and impact of authors in nuclear medicine and medical imaging. Authors like LEE JH, JENTZEN W, and ZHANG Y demonstrate significant research impact with high Citations per Publication (CP) values. The diversity in collaboration patterns, ranging from Sole-Authored (SA) to Co-Authored (CA) articles, highlights researchers' varied approaches in this field.

2.6 Keyword Analysis

The keyword "Thyroid Cancer" has a relatively high number of total articles (114), a moderate number of co-occurring articles (844), and a high number of citations (3888). It also has a high co-occurrence index (1.00), suggesting a strong association with other keywords. The citation per publication (C/CP) is also relatively high at 36.68.

The "Deep Learning" keyword has a moderate number of total articles (78) but a lower number of co-occurring articles (528). It has 2198 citations and a co-occurrences index of 1.00, indicating strong associations with other keywords.

The term "Thyroid Carcinoma" has a high number of citations (3802) and a high number of total articles (81).

Table No. 6: Most Prominent Keywords

Key Words	TA	NCA	CI	SA	CA	PCP	TC	C/CP	NAY	PAY	CP
Thyroid Cancer	114	844	1.00	1	843	0.93	3888	36.68	16	6.625	106
Ultrasonography	118	885	1.00	1	884	0.93	4016	36.51	25	4.4	110
Thyroid Nodule	177	1216	1.00	6	1210	0.94	5801	34.95	29	5.72	166
Thyroid Neoplasms	103	776	1.00	1	775	0.93	3917	40.80	25	3.84	96
Image Processing	168	1137	0.99	6	1131	0.93	5579	35.54	29	5.41	157
Ultrasound	177	1198	0.99	6	1192	0.93	5783	35.26	29	5.66	164
Diagnosis	177	1198	0.99	6	1192	0.93	5783	35.26	29	5.66	164
Thyroid	51	361	1.00	1	360	0.91	1489	32.36	18	2.55	46
Thyroid Carcinoma	81	549	1.00	0	549	0.98	3802	47.52	23	3.48	80
Deep Learning	78	528	1.00	2	526	0.94	2198	30.11	24	3.04	73

It has a co-occurrence index of 1.00, indicating a strong connection with other words. The citation per publication (C/CP) is also slightly higher at 47.52.

These analyses provide insights into the dataset's prevalence, associations, and impact of various keywords. Researchers can use this information to identify important topics, understand their relationships, and gauge their significance in the field.

2.7 Prominent Countries

The United States has 24 articles and 1,526 citations, making it an impressive average of 63.58 citations per article. Japan has only 9 articles, with a remarkable average of 112.67 citations per article. This suggests that Japanese research tends to contribute significantly to its respective fields. Germany has 13 articles with a respectable average of 26.08 citations per article. This indicates a consistent quality and impact in its scientific output. Italy and Korea have a good average number of citations per article, with Italy at 38.71 and Korea at 32.75. This indicates that research from these countries is highly valued and influential. China has the highest number of articles (31) on the list, but its average citations per article (17.16) are lower than some of the other countries. This could indicate a preference for quantity over citation impact in its research output. Several countries, like India, Greece, Turkey, and Belarus, have relatively low average article citations.

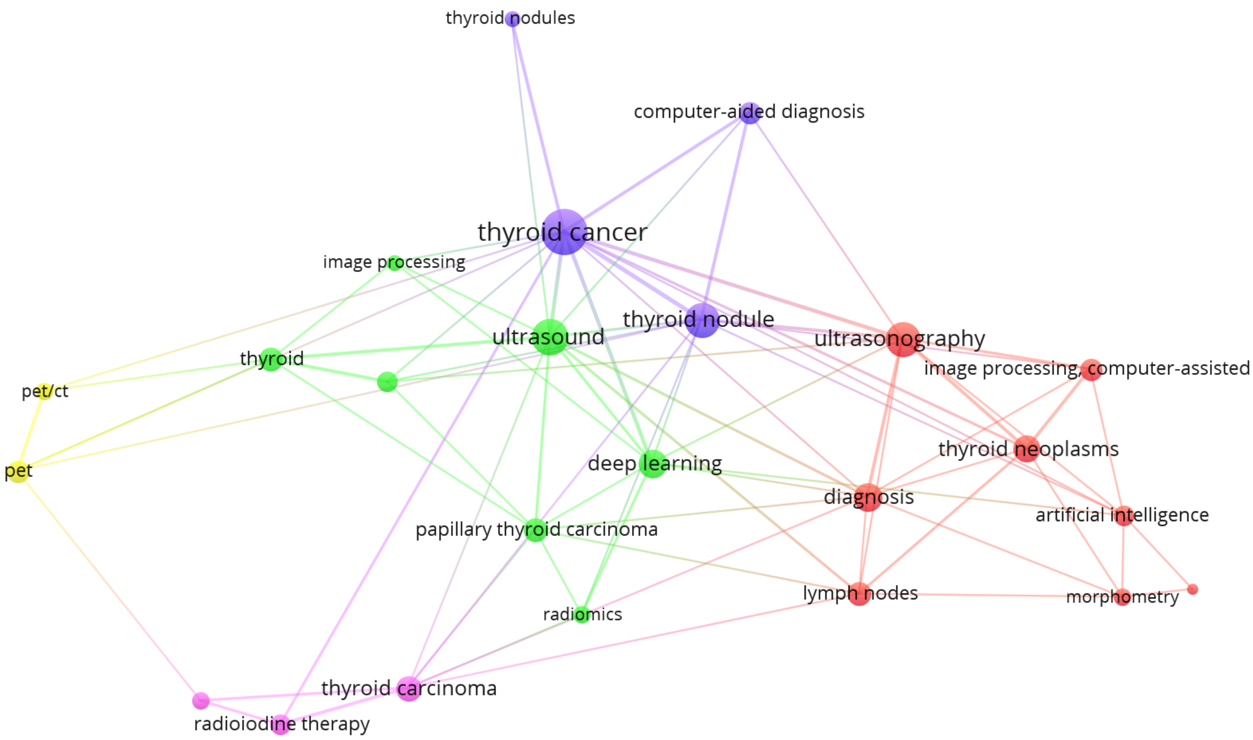
The United Kingdom and Israel have a relatively small number of articles (2 each) but very high average citations per article (86.50 and 80.50, respectively), indicating that their research tends to have a significant impact. Austria has one article but has not received any citations, resulting in an average of 0.00 per article. This analysis provides insights into the research output and impact of different countries. The USA, Japan, and the United Kingdom have few articles but receive a high average number of citations, indicating highly influential research. Conversely, China and India have more articles, but the average citation per article is moderate.

2.8. Thematic Analysis

2.8.1. Cluster 1: Factors influencing Thyroid cancer.

Thyroid cancer, originating from thyroid follicular or parathyroid epithelial cells, has become the most common malignancy in the head and neck region [17]. In recent decades, its incidence has notably surged, with Thailand reporting an annual increase of 1,500 new cases. This rise is attributed to advanced detection techniques, such as thyroid ultrasonography, which have proven highly beneficial.

The escalation in thyroid cancer incidence since the 1980s has underscored the importance of image-processing techniques in its diagnosis and monitoring. Although improved diagnostic tools like fine-needle as-



piration biopsy have played a role, hormonal changes, dietary habits, and genetic/environmental factors may also contribute [10].

Diagnostic advancements have significantly improved the detection of minute thyroid abnormalities, a vital driver of the rising incidence. Innovations in medical imaging, like thyroid sonography, have aided early identification [7]. The introduction of thyroid cancer screening programs in countries like South Korea and the increasing obesity rates in China have also raised incidence rates. Future research might involve leveraging advanced data analytics and AI techniques to analyze the extensive longitudinal data, leading to nuanced understandings of thyroid cancer trends and potential interventions [7]

In summary, the burgeoning thyroid cancer incidence stems from multiple factors, including advanced diagnostic imaging, screening programs, hormonal changes, dietary shifts, and genetic/environmental elements [8]. Balancing early detection and avoiding unnecessary treatments is crucial.

A significant concern is the detection of clinically insignificant thyroid tumours, leading to unwarranted interventions and risks. Researchers are exploring image processing techniques, such as computer-aided diagnosis, to distinguish benign from malignant nodules accurately. [9]. Future advancements might involve exploring emerging miRNA profiling technologies and AI-driven analysis tools to refine the diagnostic process [9] further.

Socioeconomic factors such as healthcare access, education, and environmental exposure must also be considered when analyzing the increased incidence of thyroid cancer. Accurate diagnosis is essential, but overdiagnosis and overtreatment must be avoided. Research is needed for effective early differential diagnoses of thyroid nodules. Imaging techniques, like ultrasound, CT, MRI, and PET scans, have aided the detection of small thyroid nodules [10]. However, concerns about overdiagnosis persist. Simple and accurate methods are required to differentiate benign from malignant thyroid nodules. Future advancements might involve refining elastography techniques, considering real-time data analysis, and integrating the technology into routine ultrasound practices for enhanced thyroid nodule characterization [10].

Technological advances like artificial intelligence (AI) have improved the accuracy of thyroid cancer diagnosis. AI can identify abnormalities and characterize tissues, potentially reducing misdiagnoses and unnecessary biopsies [6]. Future advancements might involve refining AI algorithms, incorporating more extensive datasets, and integrating AI tools into routine clinical practices for widespread use [6].

Differentiating benign from malignant lesions is crucial. Ultrasonography, the primary imaging method, is sensitive but struggles with accurate differentiation [9]

Ultrasound elastography measures tissue stiffness and shows promise in identifying malignant and benign nodules[10]. However, it has limitations and cannot provide definitive diagnoses in all cases. Rarely, thyroid tuberculosis can mimic thyroid cancer on ultrasound, necessitating alternate diagnoses. Therefore, ultrasound elastography should complement other methods to ensure accurate diagnosis.

Recent studies, such as the one by Rago et al., have highlighted the sensitivity and specificity of ultrasound elastography in detecting malignant thyroid nodules. These findings suggest that ultrasound elastography has the potential to enhance the accuracy of thyroid cancer diagnosis.

Future research may involve collaborative international studies to compare thyroid cancer trends across regions and explore common risk factors. Additionally, investigating the molecular and genetic underpinnings of evolving thyroid cancer subtypes could be a promising direction for future research, as demonstrated in the study by [11]Top of Form

Cluster 2.8.2: Diagnosis of Thyroid Cancer

The increasing use of advanced medical imaging technologies has led to the widespread adoption of sensitive screening methods, contributing to a steady rise in thyroid cancer cases. Unfortunately, this trend has also resulted in overdiagnosis and overtreatment. The primary drivers behind this surge are the identification of indolent and well-differentiated papillary carcinomas and early-stage thyroid cancers. However, there is a silver lining in the form of a slight decrease in thyroid cancer mortality over the past decade.

A promising solution has emerged to enhance the detection of papillary thyroid carcinoma: a convolutional neural network with an added spatial constrained layer (Komatsu et al., 2021). The increase in the incidence of thyroid cancer can be attributed to enhanced diagnostic precision and improved imaging techniques employed in screening. Future advancements may involve optimizing AI algorithms, conducting prospective clinical trials, and streamlining AI integration with existing healthcare systems [18].

Recent advancements in imaging and molecular pathology detection have led to an annual increase of over 10% in thyroid cancer detection rates. This surge is not limited to tiny papillary thyroid cancers but also encompasses middle and advanced thyroid cancers. These innovations have enabled the better identification of small papillary carcinomas, resulting in a higher incidence of thyroid cancer diagnoses [19]. Future research might involve collaborative multicentre studies and molecular analyses to understand the underlying factors driving these patterns [19].

However, the widespread use of sensitive imaging methods for thyroid cancer screening has also brought about the issues of overdiagnosis and overtreatment [19]. Overdiagnosis occurs when cancer is detected that would not have caused harm or required treatment in the absence of screening. This is particularly relevant for slow-growing, indolent, well-differentiated papillary carcinomas, which may not progress to a harmful stage [20].

Overtreatment refers to the unnecessary or excessive treatment of patients diagnosed with thyroid cancer who may not require aggressive interventions. This overdiagnosis and overtreatment can have negative consequences for patients, including unnecessary surgeries and radiation therapies. Addressing these challenges, especially in diagnosing thyroid carcinomas like papillary thyroid tumours, is essential[21]. Future research might involve exploring targeted therapies for this particular thyroid tumour subtype and assessing its clinical behaviour[21].

To tackle the issue of overdiagnosis and overtreatment in thyroid cancer management, improving the detection method for papillary thyroid carcinoma is crucial[18]. A proposed solution involves implementing a detection method that utilizes a convolutional neural network with an added spatial constrained layer. This approach aims to enhance the accuracy and specificity of diagnosing papillary thyroid carcinoma in ultrasound imaging.

The increased incidence of thyroid cancer is primarily due to the widespread use of thyroid ultrasound, which increases the detection of papillary thyroid cancers. To mitigate the problem of overdiagnosis and overtreatment, developing prediction models to identify individuals who would most benefit from a thyroid examination can help avoid unnecessary diagnostic tests and procedures.

In recent years, artificial intelligence techniques, including convolutional neural networks, have gained attention to improve the detection and diagnosis of thyroid cancer. While using artificial intelligence algorithms in medical diagnostics offers significant advantages, careful considerations must be made, including integration with clinical expertise and the impact on workload and efficiency[22][20]. Future advancements may entail refining the algorithm, integrating it with electronic health records, and conducting prospective studies to assess its long-term impact on patient care[20]

Cluster 2.8.3:Role of Image Processing Techniques in Thyroid Cancer Diagnosis

Advancements in medical technology, particularly in image processing, have profoundly impacted the diagnosis and treatment of thyroid cancer. This paper examines the relationship between image-processing techniques and thyroid cancer, highlighting their potential advantages and weaknesses.

The analysis and diagnosis of thyroid cancer has been facilitated by image processing. One approach involves digital image analysis, which employs template machine techniques and automated defect detection to enhance classification accuracy rapidly[23]. A recent study employed digital image analysis to classify thyroid cancer, utilizing data mining and decision tree algorithms for prediction. Future work in this area could involve refining the ensemble model, considering additional data sources, and conducting validation studies to assess the model's real-world performance[23].

Image processing plays a crucial role in thyroid cancer diagnosis and treatment. Accurate classification facilitates early detection and tailored treatment plans, enabling the characterization and quantification of molecular components within tumour tissues. These techniques are essential for multimodality-based treatment options and for developing novel therapeutic or diagnostic tracers.

Analyzing input image features such as shape, image edge, and composition is critical to accurate thyroid cancer classification via image processing. These features provide valuable insights into the likelihood of thyroid cancer occurrence.

Digital image analysis enhances diagnosis accuracy by incorporating techniques like template matching and machine learning algorithms. A study used the DENSENET algorithm with Augmentation on SPECT, Ultrasound, and CT images for thyroid disease diagnosis [24]. Integrating these techniques with various imaging modalities offers a comprehensive approach, allowing for in-depth analysis of thyroid tumour tissue molecular components, resulting in precise diagnoses and personalized treatment plans.

Machine learning and deep learning techniques are gaining prominence in medical image analysis for their ability to extract meaningful patterns and features from raw image data, outperforming traditional algorithms. Deep learning has revolutionized thyroid cancer diagnosis by accurately identifying benign and malignant thyroid nodules in medical images [24].

Advancements in medical technology, particularly in image processing, have profoundly impacted the diagnosis and treatment of thyroid cancer. This paper delves into the relationship between image-processing techniques and thyroid cancer, shedding light on their potential advantages and challenges.

Image processing has been instrumental in the analysis and diagnosis of thyroid cancer. One approach involves digital image analysis, which employs template machine techniques and automated defect detection to enhance classification accuracy rapidly[23]. A recent study employed digital image analysis to classify thyroid cancer, utilizing data mining and decision tree algorithms for prediction.

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Deep convolutional neural networks (CNNs) are employed to diagnose thyroid nodules with ambiguous cytology results. The findings likely include the development of a CNN-based diagnostic tool that can enhance the accuracy of diagnosing thyroid nodules, particularly those with atypical or unclear characteristics [25]. Future research could involve refining the deep CNN model, conducting clinical trials, and integrating the tool into routine clinical practice for more accurate and efficient thyroid nodule diagnoses.

Conclusion

Image processing is crucial in early cancer detection, including thyroid cancer. The paper summarises image processing and thyroid cancer research, covering publications from 1991 to 2023. This indicates a wide range of studies, likely highlighting the evolution of technology and understanding of thyroid cancer over this period. The paper employs bibliometric and structured literature review techniques. Bibliometrics involves quantitative analysis of research output, while structured literature review is a systematic approach to reviewing and summarizing existing literature. This combination of methods should provide a robust overview of the research in the field. The analysis found that most articles were published between 2016 and 2020 (79), followed by 2006-2010 (22). The author, LEE JH, has a substantial number of Total Articles (7) and a high Total Citations (221), resulting in an impressive Citations per Publication (CP) of 31.574. The United States stands out as the leader in scientific research with 24 articles and 1,526 citations, resulting in an impressive average of 63.58 citations per article. The analysis reveals an increasing incidence of thyroid cancer in recent years. Several factors are mentioned, including increased detection through screening programs, changes in diagnostic criteria, and environmental and lifestyle factors. This indicates that there may be both actual increases in cases and changes in how they are identified. The paper likely discusses various diagnostic and treatment options for thyroid cancer patients.

The paper highlights the role of image-processing techniques in analyzing and diagnosing thyroid cancer. Image processing can enhance the accuracy of diagnosis by providing detailed and visual information from medical images, such as ultrasound, CT scans, or MRI. Overdiagnosis and overtreatment are essential issues in cancer care. Overdiagnosis occurs when cancers are detected that would not have caused harm, resulting in unnecessary treatments. The paper may explore these challenges in the context of thyroid cancer. The paper likely discusses the advantages and challenges of using image processing techniques. Advantages may include early detection and improved accuracy, while challenges could involve the need for specialized expertise and advanced technology.

From our study, we have identified the following future research scope.

In conclusion, integrating AI with ultrasound technology shows promise for thyroid cancer diagnosis, warranting further validation studies on diverse populations. The T-CALOS study can offer insights into thyroid cancer's natural history and risk factors, with potential for personalized treatment plans. Collaboration with international studies can provide a global perspective. Refining TI-RADS and exploring machine learning can enhance risk assessment and reduce unnecessary surgeries. Integrating miRNA profiling can improve diagnostic accuracy while addressing socioeconomic disparities remains crucial. Shear wave elastography holds potential, and ongoing Beijing thyroid cancer trend analysis informs regional strategies. These research directions have the potential to advance global thyroid cancer management.

Future research should refine AI algorithms for diverse thyroid disease management, integrating real-time patient data for personalized treatment plans. Collaboration with healthcare systems is crucial for implementing AI in routine practice and assessing its long-term impact. Investigate evolving trends, genetic, and environmental factors in thyroid malignancy, refine AI for ultrasound imaging in remote care, explore molecular mechanisms for novel thyroid tumour subtype, and expand the TNAPP algorithm for comprehensive thyroid nodule management.Top of Form

Future research involves refining ensemble models and deep learning for enhanced thyroid prediction accuracy. Collaboration with healthcare institutions for real-world assessments and potential telemedicine applications. Further advancements in deep learning, validation in clinical settings, and integration with other diagnostic methods to improve overall accuracy. **R**

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Ready - Made Citation

Pavithra S, Naveen Kumar J R. A Review on Application of Image Processing in Thyroid Cancer. Hell J Radiol 2024; 9(3): 2-17.