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Machine Learning for Thyroid Cancer Detection, Presence of Metastasis, and Recurrence Predictions - A Scoping Review

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ADMINISTRATIVE INFORMATION

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Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 27 February 2025 and was last updated on 27 February 2025.

INTRODUCTION

Review question / Objective This scoping review aims to evaluate machine learning (ML) applications in thyroid cancer diagnosis, metastasis detection, and recurrence prediction. Specifically, the review identifies methodologies, challenges, and clinical implications of integrating ML models into thyroid cancer management, improving diagnosis, treatment, and patient care.

Rationale Over the past years, thyroid cancer has seen a steady rise in incidence worldwide, with the peak incidence in the 5th-6th decades of life and a higher probability when more risk factors are present. Therefore, it is recognized as the most common malignant lesion of the endocrine glands. Moreover, ML is evolving rapidly, and the potential of Artificial Intelligence (AI)-based systems is increasingly recognized in the medical field. Therefore, this paper surveys the existing related literature and assesses the role of ML models in areas such as thyroid cancer diagnostic and prognostic, focusing on predicting malignancy for improved early detection or recurrence for improved treatment and quality of life. It highlights the ML methods used, discusses their performance, and compares them with traditional statistical and diagnostic methods. Additionally, it emphasizes the advantages while addressing limitations, challenges, ethical considerations, and future directions toward personalized medicine.

Condition being studied Thyroid cancer, including its different histological types: (a) Papillary Thyroid Carcinoma (PTC), (b) Follicular Thyroid Carcinoma (FTC), (c) Anaplastic Thyroid Carcinoma (ATC). We

also focus on metastases related to thyroid cancer and its recurrence prediction.

METHODS

Search strategy The study reviewed all original research articles and conference papers at the intersections between medicine and informatics to analyze the current ML methods for thyroid cancer management using actual medical data and electronic medical records (EMRs) as a systematic data retrieval approach. The scoping analysis followed a previously established scoping review methodology, the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews Statement) guideline. A comprehensive literature search was conducted to identify scientific studies that analyzed the connection between the term thyroid gland and information science. To identify relevant documents, on 7 November 2024, we constructed queries that searched for relevant word sequences (e.g., machine learning, thyroid cancer) in the titles, abstracts, and keywords to look for the papers that presented ML methods applied to thyroid cancer-related tasks (e.g., prediction, evaluation, or prognostic thyroid cancer disease) in six electronic databases (Scopus, Web of Science (WOS), Nature, Science Direct, Google Scholar, and PubMed). Scopus and WOS were relatively similar in terms of the search queries utilized.
For Scopus we applied the following query: (TITLE-ABS-KEY("deep learning") OR TITLE-ABS-KEY("machine learning")) AND (TITLE-ABS-KEY("thyroid cancer") OR TITLE-ABS-KEY("thyroid carcinoma") OR TITLE-ABS-KEY("thyroid sarcoma") OR TITLE-ABS-KEY("thyroid lymphoma")). Similarly, for WOS, the corresponding query was: (TS=("deep learning") OR TS=("machine learning")) AND (TS=("thyroid cancer") OR TS=("thyroid carcinoma") OR TS=("thyroid sarcoma") OR TS=("thyroid lymphoma")). For ScienceDirect, the search interface did not provide a specific keyword mapping for title, abstract, and keywords. However, it allowed searches restricted to these fields. Consequently, the following query was employed within the "Title, Abstract, or Author-Specified Keywords" search textbox: (("deep learning") OR ("machine learning")) AND (("thyroid cancer") OR ("thyroid carcinoma") OR ("thyroid sarcoma") OR ("thyroid lymphoma")). PubMed offered slightly less specificity, as the query could be applied only to the title and abstract fields. Nature and Google Scholar were the least specific among the sources analyzed, as they did not allow for precise field-based searching.

Participant or population Patients diagnosed with thyroid cancer or under suspicion, including both adult and pediatric populations, in studies that used actual medical data or electronic medical files of patients admitted to different hospitals or from known repositories.

Intervention This is not applicable to our review.

Comparator This is not applicable to our review.

Study designs to be included This is not applicable to our review.

Eligibility criteria Inclusion criteria: 1. Research articles and conference papers written in English that are fully available online; 2. Published in Scopus, WOS, Nature, Science Direct, Google Scholar, or Pubmed between 2014-2024 with more than 10 citations between 2014-2022 and at least 1 between 2023-2024; 3. Adults and children with current thyroid cancer diagnosis or just suspicions; 4. Patients undergoing blood analyses, testing, and other imaging tests, features in hospitals or input data from repositories for detecting disease progression; 5. Machine Learning applied to medical data to make predictions and prognostics for thyroid cancer; 6. Feature thyroid cancer management integrating ML tools into routine clinical workflows
Exclusion criteria: 1. Review articles, study protocols, book chapters, notes, brief reports, letters, editorials, or case studies written in any language; 2. Articles focusing on thyroid biomarkers, gene expressions, hypothyroidism or hyperthyroidism; 3. Articles using ultrasound images or radiomics generated from images.

Information sources The Scopus, Web of Science, Nature, Science Direct, Google Scholar, and PubMed databases, as they existed on November 7, 2024, in their state from 7 November 2024.

Main outcome(s) We evaluated the accuracy and effectiveness of machine learning models in diagnosing thyroid cancer, predicting metastasis, and forecasting recurrence and survival. We investigated how ML models improve diagnostic precision, enhance risk stratification, and contribute to personalized treatment planning. Additionally, we assessed the predictive performance of ML models compared to other used traditional diagnostic approaches, reporting metrics such as accuracy, F1-score, and AUROC. We also explored the impact of ML on early detection and prognosis, provided insights on whether these models can effectively reduce

human error, misdiagnosis rates, and overtreatment in thyroid cancer management.

Additional outcome(s) We identified the most used ML methods in thyroid cancer research and evaluated their applicability across different thyroid cancer subtypes. We discussed challenges related to data quality, interpretability, and clinical integration, particularly in terms of bias and generalizability. Our study explores the potential of ML-driven decision-support tools in routine endocrinology workflows, examining their role in refining prognostic models, improving long-term patient monitoring, and facilitating personalized treatment approaches. We discussed ethical considerations (e.g., transparency, explainability, and regulatory compliance) to ensure responsible AI implementation in healthcare. Finally, we outlined future directions, emphasizing the need for larger datasets, multimodal data integration, and the refinement of ML models to enhance their clinical impact in thyroid cancer diagnosis, prognosis, and patient outcome.

Data management This is not applicable to our review.

Quality assessment / Risk of bias analysis This is not applicable to our review.

Strategy of data synthesis This is not applicable to our review.

Subgroup analysis This is not applicable to our review.

Sensitivity analysis This is not applicable to our review.

Language restriction English.

Country(ies) involved Romania.

Keywords Thyroid Cancer; Machine Learning; Clinical Data; Prediction.

Dissemination plans Publication in Journal.

Contributions of each author

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