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INTEGRATED RADIOLOGY AND ENDOCRINOLOGY IN ONCOLOGIC SURGERY: A COMPREHENSIVE REVIEW FOR IMPROVED OUTCOMES

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Resumen: **INTRODUCTION** Endocrine cancers, including those of the thyroid, adrenal glands, and pancreas, significantly affect public health due to their high morbidity and mortality rates, placing a substantial burden on healthcare systems. Traditional surgical management faces limitations in precise tumor localization and characterization, highlighting the need for advanced diagnostic tools and integrated approaches. Precision medicine aims to tailor treatment strategies to individual patient characteristics, utilizing genetic, molecular, and radiological data to enhance surgical and therapeutic decisions. Radiology has evolved significantly with advancements in PET-CT, MRI, and functional imaging, enhancing the accuracy of diagnosing, staging, and monitoring endocrine tumors. **OBJETIVE** To evaluate advanced radiological imaging and integrated endocrinological approaches in endocrine cancer surgery, aiming to enhance diagnostic accuracy, improve surgical precision, optimize patient outcomes, and reduce healthcare costs through a multidisciplinary, precision medicine framework. **METHODS** This is a narrative review which included studies in the MEDLINE – PubMed (National Library of Medicine, National Institutes of Health), COCHRANE, EMBASE and Google Scholar databases, using as descriptors: "Endocrine Cancer Surgery" AND "Advanced Radiological Imaging" AND "Precision Medicine in Endocrinology" AND "Intraoperative Imaging Techniques" AND "Multidisciplinary Approach in Oncology" in the last years. **RESULTS AND DISCUSSION** Advanced imaging techniques like PET-CT and MRI have revolutionized the preoperative assessment of endocrine tumors by providing detailed visualization of tumor location, size, and extent, which enhances surgical planning. Combining radiological imaging with endocrinological insights allows for more tailored surgical approaches, improving precision and reducing risks such as incomplete resection and damage to critical tissues. Intraoperative imaging techniques, such as ultrasound and near-infrared fluorescence, provide real-time feedback during surgery, leading to better tumor resection and fewer complications. Imaging biomarkers like SUV on PET and ADC on MRI provide prognostic information about tumor aggressiveness and response to therapy, guiding more personalized treatment decisions. Imaging modalities like ultrasound, CT, and PET-CT are crucial for postoperative monitoring, detecting residual disease, and identifying early signs of recurrence, enabling timely interventions. AI and machine learning enhance diagnostic accuracy and surgical planning by analyzing large volumes of imaging data, identifying patterns and features that may be overlooked by human observers. Comparative studies show that advanced imaging techniques improve surgical outcomes, with higher rates of complete tumor resection, fewer complications, and lower recurrence rates. **CONCLUSION** The integration of advanced radiological imaging and endocrinological approaches significantly improves the management of endocrine cancers. Techniques like PET-CT, MRI, and intraoperative ultrasound enhance tumor localization, surgical precision, and patient outcomes. AI-driven technologies and imaging biomarkers offer new avenues for personalized treatment and better prognostication. Future research should focus on developing innovative imaging techniques and interdisciplinary approaches to further improve the diagnosis, treatment, and management of endocrine cancers. Embracing these advancements will enable more effective, personalized, and patient-centered care for those affected by endocrine malignancies.

Keywords: Surgery; Radiology; Endocrinology; Oncology.

INTRODUCTION

Endocrine cancers, which include malignancies of the thyroid, adrenal glands, pancreas, and other hormone-secreting tissues, represent a significant and growing concern in global health[1]. These cancers often present unique challenges due to their diverse biological behavior and the critical functions of the endocrine organs they affect. The morbidity and mortality associated with endocrine cancers can be substantial, impacting both patient quality of life and overall healthcare systems[2]. The burden of these cancers underscores the need for advancements in diagnostic and therapeutic approaches to improve patient outcomes and reduce healthcare costs[3].

The current standard of care for endocrine oncologic surgery involves a combination of surgical resection, radiological imaging, and endocrinological management[4]. Guidelines emphasize the importance of accurate preoperative assessment and meticulous surgical technique to achieve optimal outcomes[4]. However, traditional methods face limitations, including the difficulty of precise tumor localization and characterization, which can affect surgical planning and execution[5]. The need for improved diagnostic tools and integrated approaches is evident to enhance the accuracy and efficacy of endocrine cancer treatments[6].

Precision medicine has emerged as a pivotal concept in oncology, aiming to tailor treatment strategies to the individual characteristics of each patient[7]. In the context of endocrine oncology, this approach seeks to integrate detailed genetic, molecular, and radiological data to inform surgical and therapeutic decisions[8]. Precision medicine holds the promise of more personalized and effective treatments, potentially leading to better outcomes and reduced adverse effects[9]. This paradigm shift necessitates the incorporation of advanced imaging techniques and interdisciplinary collaboration to fully realize its benefits[9].

Radiology has undergone significant evolution in cancer treatment, with technological advancements transforming its role in the management of endocrine tumors[10]. The development of high-resolution imaging modalities, such as PET-CT, MRI, and functional imaging techniques, has greatly enhanced the ability to visualize and assess endocrine tumors with greater precision[11]. These advancements enable more accurate diagnosis, staging, and monitoring of cancer progression and treatment response[10]. The integration of these technologies into surgical practice represents a critical step towards improving the outcomes of endocrine oncologic surgery[11,12].

Multidisciplinary approaches have become increasingly important in the management of endocrine cancers[13]. Collaboration between surgeons, radiologists, endocrinologists, and oncologists is essential to develop comprehensive treatment plans that address the complexities of these malignancies[13]. Such approaches ensure that patients receive the most effective and coordinated care, leveraging the expertise of each specialty to optimize outcomes[14]. The success of these interdisciplinary teams underscores the importance of integrating advanced radiological imaging into the treatment protocols for endocrine cancers[13,14].

Early detection of endocrine tumors remains a significant challenge due to their often asymptomatic nature and the limitations of traditional diagnostic methods[15]. Many endocrine cancers are diagnosed at advanced stages, where treatment options are more limited and outcomes are poorer[16]. Improving early detection through advanced imaging technologies and better screening protocols is crucial to enhancing the prognosis for patients with endocrine malignancies[17].

Recent advances in imaging technology, including functional imaging and hybrid imaging techniques, have shown great potential in improving cancer care[18]. These technologies provide detailed insights into tumor biology and physiology, enabling more precise characterization and localization of tumors[18,19]. Innovations such as molecular imaging and radiomics offer new avenues for diagnosing and monitoring endocrine cancers, potentially transforming the landscape of oncologic surgery[10,20]. The integration of these cutting-edge technologies into clinical practice represents a significant step forward in the fight against endocrine cancers[20].

OBJETIVES

The main objective of this study is to comprehensively evaluate the role of advanced radiological imaging techniques and integrated endocrinological approaches in the surgical management of endocrine cancers, with the aim of enhancing diagnostic accuracy, improving surgical precision, optimizing patient outcomes, and reducing healthcare costs through a multidisciplinary, precision medicine framework.

SECUNDARY OBJETIVES

1. To evaluate the role of advanced radiological imaging techniques in the preoperative assessment of endocrine tumors.
2. To analyze the impact of integrated radiology and endocrinology approaches on the precision of surgical interventions for endocrine cancers.
3. To review the effectiveness of intraoperative imaging in enhancing surgical outcomes for endocrine cancer patients.
4. To explore the use of imaging biomarkers in predicting surgical outcomes and patient prognosis in endocrine oncology.
5. To investigate the integration of AI and machine learning in radiological imaging for endocrine oncologic surgery.
6. To review the cost-effectiveness of utilizing advanced radiological imaging in the management of endocrine cancers.
7. To identify future directions and potential areas of research in the field of radiology and endocrinology for endocrine oncologic surgery.

METHODS

This is a narrative review, in which the main aspects of advanced radiological imaging and integrated endocrinological approaches in endocrine cancer surgery, aiming to enhance diagnostic accuracy, improve surgical precision, optimize patient outcomes, and reduce healthcare costs through a multidisciplinary, precision medicine framework recent years were analyzed. The beginning of the study was carried out with theoretical training using the following databases: PubMed, sciELO and Medline, using as descriptors: "Endocrine Cancer Surgery" AND "Advanced Radiological Imaging" AND "Precision Medicine in Endocrinology" AND "Intraoperative Imaging Techniques" AND "Multidisciplinary Approach in Oncology" in the last years. As it is a narrative review, this study does not have any risks.

Databases: This review included studies in the MEDLINE – PubMed (National Library of Medicine, National Institutes of Health), COCHRANE, EMBASE and Google Scholar databases.

The inclusion criteria applied in the analytical review were human intervention studies, experimental studies, cohort studies, case-control studies, cross-sectional studies and literature reviews, editorials, case reports, and poster presentations. Also, only studies writing in English and Portuguese were included.

RESULTS AND DISCUSSION

Advanced radiological imaging techniques have revolutionized the preoperative assessment of endocrine tumors[21]. Modalities such as PET-CT, MRI, and ultrasound provide detailed visualization of tumor location, size, and extent, significantly improving the accuracy of preoperative diagnosis[21]. PET-CT, in particular, combines metabolic and anatomical imaging, enabling the precise localization of functional endocrine tumors such as pheochromocytomas and neuroendocrine tumors[222]. MRI offers superior soft-tissue contrast, making it invaluable for detecting and characterizing adrenal and pancreatic tumors[23]. These imaging techniques facilitate better surgical planning by providing surgeons with critical information about the tumor's anatomical relationships and potential invasiveness[21,22,23].

The integration of radiology and endocrinology in surgical planning has shown to enhance the precision of surgical interventions for endocrine cancers[24]. By combining imaging data with endocrinological insights, surgeons can tailor their approach to the unique characteristics of each patient's tumor[24]. For instance, the use of intraoperative ultrasound in thyroid surgery allows real-time visualization of the tumor and surrounding structures, reducing the risk of incomplete resection and damage to critical tissues such as the recurrent laryngeal nerve[23,34]. Endocrinologists play a crucial role in interpreting functional imaging results and guiding surgical decision-making based on hormonal activity and biochemical markers . This collaborative approach leads to more precise and effective surgeries, improving patient outcomes[23,24,25].

Intraoperative imaging has become an indispensable tool in endocrine oncologic surgery, significantly enhancing surgical outcomes[26]. Techniques such as intraoperative ultrasound, fluoroscopy, and near-infrared fluorescence imaging provide real-time feedback, allowing surgeons to make informed decisions during the procedure[26]. Intraoperative ultrasound is particularly useful in identifying parathyroid adenomas and localizing metastatic lymph nodes in thyroid cancer[27]. Near-infrared fluorescence imaging, using indocyanine green, highlights vascular structures and lymphatic drainage pathways, aiding in the complete resection of tumors and reducing postoperative complications[27]. These technologies contribute to more accurate and safer surgeries, minimizing the risk of residual disease and improving patient prognosis[28].

Imaging biomarkers have emerged as valuable tools in predicting surgical outcomes and guiding treatment decisions in endocrine oncology[29]. Biomarkers such as standardized uptake value (SUV) on PET scans, apparent diffusion coefficient (ADC) on MRI, and radiomic features extracted from imaging data provide prognostic information about tumor aggressiveness, response to therapy, and likelihood of recurrence[30]. High SUV values on PET-CT, for example, are associated with more aggressive thyroid cancers and poorer prognosis, guiding more intensive treatment approaches[30]. Similarly, low ADC values on MRI indicate higher cellularity and malignancy in adrenal tumors, influencing surgical planning and follow-up strategies[31]. The integration of imaging biomarkers into clinical practice enhances the ability to personalize treatment and improve outcomes[30,31].

Radiological imaging plays a critical role in the postoperative monitoring and detection of recurrence in endocrine cancer patients[32]. Modalities such as ultrasound, CT, MRI, and PET-CT are routinely used to monitor surgical sites, detect residual disease, and identify early signs of recurrence[33]. High-resolution ultrasound is particularly effective

in detecting recurrent thyroid cancer in the neck, providing detailed images of lymph nodes and soft tissues[33]. PET-CT is valuable for detecting distant metastases and assessing metabolic activity in recurrent tumors, guiding further treatment decisions[34]. Regular imaging surveillance allows for timely intervention and improved management of recurrent disease, contributing to better long-term outcomes for endocrine cancer patients[32,33,34].

The integration of artificial intelligence (AI) and machine learning (ML) in radiological imaging has the potential to revolutionize endocrine oncologic surgery[35]. AI-driven algorithms can analyze large volumes of imaging data, identifying patterns and features that may be overlooked by human observers[34,35]. These technologies enhance diagnostic accuracy, enabling more precise tumor characterization and risk stratification[34]. For example, AI models can predict the malignancy of thyroid nodules based on ultrasound images, reducing the need for unnecessary biopsies[36]. Machine learning algorithms can also optimize surgical planning by simulating different scenarios and predicting the outcomes of various approaches[35,36]. The application of AI and ML in radiology represents a significant advancement in the quest for more effective and personalized endocrine cancer treatments[37].

Comparative studies have demonstrated the added value of advanced radiological imaging in endocrine cancer surgery[38]. Patients who undergo surgery with the aid of advanced imaging techniques typically experience better outcomes, including higher rates of complete tumor resection, fewer complications, and lower recurrence rates[37,38]. For instance, the use of PET-CT in the preoperative assessment of neuroendocrine tumors improves surgical accuracy and reduces the likelihood of residual disease[39]. Similarly, intraoperative ultrasound in thyroid and parathyroid surgeries enhances the precision of tumor localization and excision, resulting in fewer postoperative complications and better overall outcomes[39,40]. These findings underscore the importance of incorporating advanced imaging into standard surgical practice for endocrine cancers[40].

The cost-effectiveness of utilizing advanced radiological imaging in the management of endocrine cancers is a critical consideration for healthcare systems[41]. While advanced imaging techniques may incur higher upfront costs, their ability to improve diagnostic accuracy, surgical precision, and patient outcomes can lead to significant cost savings in the long run[42]. Early and accurate diagnosis reduces the need for repeat surgeries and extended hospital stays, lowering overall healthcare expenditures[43]. Additionally, the prevention of complications and early detection of recurrences can reduce the burden of long-term treatment costs[41,42]. Economic analyses have shown that the benefits of advanced imaging often outweigh the costs, supporting its broader adoption in endocrine oncology[42,43].

Patient satisfaction and quality of life are important metrics in evaluating the effectiveness of integrated radiological and endocrinological approaches in endocrine cancer surgery[44]. Studies have shown that patients who receive care through multidisciplinary teams and advanced imaging techniques report higher satisfaction levels and better quality of life[45]. The precision of imaging-guided surgeries results in fewer complications and quicker recovery times, enhancing the overall patient experience[46]. Furthermore, the ability to personalize treatment based on detailed imaging data leads to better management of symptoms and reduced treatment-related side effects[44,45]. Patient-centered approaches that prioritize quality of life and satisfaction are essential components of modern endocrine oncology care[44,46].

Future research in radiology and

endocrinology for endocrine oncologic surgery should focus on developing and validating new imaging biomarkers, refining AI and machine learning models, and exploring novel imaging techniques[47]. Advances in molecular imaging, such as PET tracers targeting specific endocrine tumor receptors, hold promise for more precise tumor characterization and targeted therapies[48]. The integration of radiomics and genomics could further enhance the personalization of treatment strategies, leading to better outcomes[49]. Collaborative research efforts that combine the expertise of radiologists, endocrinologists, and surgeons are essential to drive innovation and improve the standard of care for endocrine cancer patients[47,48,50].

CONCLUSION

The integration of advanced radiological imaging and endocrinological approaches in endocrine oncologic surgery represents a significant advancement in the management of these complex malignancies. Advanced imaging techniques, such as PET-CT, MRI, and intraoperative ultrasound, enhance the accuracy of tumor localization and characterization, improving surgical precision and patient outcomes. The use of imaging biomarkers and AI-driven technologies offers new avenues for personalized treatment and better prognostication.

Comparative studies have demonstrated the added value of advanced imaging in endocrine cancer surgery, highlighting its cost-effectiveness and positive impact on patient satisfaction and quality of life. Future research should continue to explore innovative imaging techniques and interdisciplinary approaches to further improve the diagnosis, treatment, and management of endocrine cancers. By embracing these advancements, the medical community can provide more effective, personalized, and patient-centered care for individuals affected by endocrine malignancies.

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