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MRI and CT for scanning human bodies

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Abstract. Prostate-Specific antigen (PSA) is one of the most popular biomarkers for prostate carcinoma (PCA) at present. PSA indicates initial cancer and recurrence following therapy, but does not distinguish clearly from local or remote lesions. Molecular and functional scans, which can give a thorough and complete picture of PCR amplification, are a more robust instrument for detecting and assessing the progression of cancer at the stage as well as at subsequent stages. In this paper, PET or CT, MRI are useful for diagnosing, staging and regrading of PCA, as well as their application to prognostic, therapeutic and therapeutic evaluation. Novel imaging techniques, including novel radiotracers and PET/MRI, are also presented in this paper. Looking forward, the evolution of imaging techniques holds promise for improved PCA management. Continued innovation in radiotracers and hybrid imaging technologies such as PET/MRI could revolutionize early detection, accurate staging, and effective treatment, paving the way for precision oncology in prostate cancer.

Keywords: CT, MRI, PSA, PCA

1. Introduction

In recent decades, the landscape of medical imaging has witnessed a profound transformation thanks to pioneering technologies such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). These remarkable modalities, introduced in the late 1970s and 80s, have redefined the practice of medicine by bestowing healthcare professionals with powerful tools for diagnosis, treatment, and improved patient outcomes. Within prostate cancer (PCa) management, CT and MRI have played indispensable roles in initial diagnosis and staging [1]. However, their significance in the field has evolved significantly over time, propelled by the advent of innovative techniques, abbreviated protocols, and novel contrast agents. These continuous advancements strive to enhance image acquisition, refine the diagnostic accuracy of cancer, and optimize patient care. In this comprehensive review, we endeavor to elucidate the current status and recent strides in the application of CT and MRI in PCa imaging, shedding light on their evolving roles and the promising avenues they open for the future of healthcare.

These imaging modalities brought about substantial improvements in diagnosis, treatment, and overall patient care compared to the pre-existing technologies. In prostate cancer's clinical management, CT and MRI have played pivotal roles in initial diagnosis and staging. However, their roles in PCa have evolved significantly over time, driven by the emergence of new technologies. The field continuously explores avenues to enhance image acquisition, refine cancer diagnosis, and optimize patient management, from innovative CT techniques to streamlined MRI protocols and the

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introduction of novel contrast agents [1]. Within this manuscript, we endeavor to provide an overview of the present status and recent advancements in CT and MRI for PCa imaging.

2. Method and patient selection

2.1. Patient selection

The total number of patient is 150 including 114 men and 36 women; average age is 64; range of age is between 27 and 91 years old. Patients need to be detected by a clinical 18F-FDG PET/CT examination for staging, restaging, or follow-up of various head and neck cancers. Follow-up scans were performed at least 3 mo after surgery or radiation therapy [2].

There are some limitations about the selection of patient, for example, coma, pacemaker or other contraindication to MRI; symptoms suggestive of subarachnoid hemorrhage (SAH); cannot obtain MRI after 6 hours from final known well time; initiation of thrombolytic therapy, intravenous antithrombotics or anticoagulants, or antithrombotic investigational drug before completion of both imaging studies; or cardiorespiratory instability precluding MRI [3].

2.2. Imaging techniques & processing

Almost all patients check their inner body health by using CT and MRI. All were5-T scanners installed with echo-planar imaging: Computed tomographic CT scans were performed on one of three fourth-generation scanners: Somatom Plus scanner from Siemens, High Speed scanner both from General Electric. The images were acquired with a thickness of 5 mm throughout the examination following the orbito-meatal plane. Both scanners used an identical pulse slice thickness of 7mm for gradient recalled (GRE) and diffusion-weighted imaging (DWI). The repetition was set to 800 ms at a flip angle of 30° 256 DWI [3]. At UCLA and Suburban Hospital respectively, the field of view was adjusted to be 24 cm and 22 cm for both GRE and DWI sequences; echo time (TE) was 5 ms between at UCLA 6000 ms while those at Sub Hospital from 20 contiguous slices that were interleaved values also between sites with settings at UCLA being 100 ms. In contrast, those at Suburban Hospital, being 72ms since UCLA utilized the Siemens Vision scanner from Siemens Medical System in Iselin NJ. At the same time, Suburban Hospital employed the GE Signa scanner from General Electric Medical Systems [3].

The PET, CT, and MR images obtained were sent to a dedicated review's Advantage Workstation. This workstation allows for the simultaneous examination of PET, CT, and MR images either side by side or in fused/overlay mode (PET/CT; PET/MR imaging). Due to the well-calibrated 3-modality system utilized, there was no need for software-based image registration. A previous study has confirmed image registration accuracy with minimal lateral misalignment (less than 4 mm datasets). This error level is comparable to that determined through phantom measurements [2].

There are two ways, rule-based or pixel classification, to classify the lung regions extraction approaches using Computer-aided diagnosis in chest radiography. Automatic detection of small lung nodules on CT is an old model and provides badly in detection, it utilizes a local density largest algorithm. Connectivity, position features and uniformity were detected in some approaches. There are two strategies of CADs: density-based and model-based approaches. Detection using artificial neural network and fuzzy clustering methods presents two segmentation methods and [4-5, 7] and Early Detection and Prediction of Lung Cancer Survival using Neural Network Classifier have been developed but provide poor detection and identification [6]. Moreover, it uses Curvelet Transform and Neural Network [8], to propose a new technique for LCD identification where curvelet transforms can extract the features of lung cancer CT scan images proficiently.

3. Comparing MRI and CT

The diagnostic strengths of CT and Magnetic Resonance Imaging (MRI) in assessing intracranial hemorrhages. Both modalities effectively visualize primary intraparenchymal hematomas and subarachnoid hemorrhages, with MRI demonstrating particular advantages in detecting microbleeds

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and chronic hemorrhages. Both CT and MRI identified intraventricular hemorrhages, although their sensitivity varied. The study found comparable diagnostic accuracy between the two modalities. Notably, imaging within hours of symptom onset underscores the need for rapid and precise diagnoses. In essence, CT and MRI each offer unique insights, and their combined use enhances clinical decision-making in cases of intracranial hemorrhage [9].

Additionally, there are comparative strengths of Magnetic Resonance Imaging (MRI) and Computed Tomography Angiography (CTA) in evaluating aortic aneurysms. MRI, characterized as a robust tool, provides detailed information about aneurysm location, extent, and precise diameter, along with its relationship to aortic branch vessels. However, it emphasizes the importance of obtaining measurements from source images instead of MIP images to prevent an underestimation of aneurysm size. MRI effectively displays mural thrombus but may not reliably detect aortic wall calcifications. On the other hand, CTA emerges as the preferred technique for suspected aortic rupture, boasting speed, widespread availability, and excellent sensitivity and specificity [10]. It identifies key diagnostic features such as active contrast extravasation and high-attenuation hemorrhagic collections, aiding in the swift diagnosis of this critical condition. Additionally, CTA can reveal impending rupture and aortoduodenal fistula, providing valuable insights into potential complications. The choice between MRI and CTA depends on the clinical scenario and the specific diagnostic requirements. While MRI shines in its ability to offer comprehensive anatomical details and lacks ionizing radiation, CTA's speed and accuracy make it indispensable for assessing aortic ruptures. The text underscores that both modalities contribute significantly to accurately diagnosing and managing aortic aneurysms, ensuring patient care is tailored to individual needs [10].

In recent years, the domain of medical imaging has witnessed remarkable technological advancements, notably within Magnetic Resonance Imaging (MRI) and CT. These imaging modalities have evolved into indispensable clinical practice and medical research assets, delivering intricate insights into human anatomy and pathology. Although MRI and CT share the overarching objective of visualizing internal structures, they operate on distinct physical principles, each presenting a set of merits and limitations [13]. MRI harnesses potent magnetic fields and radio waves to craft detailed images, rendering it proficient in soft tissue differentiation and offering exceptional contrast in regions such as the brain, musculoskeletal system, and cardiac structures. Conversely, CT relies on X-rays to generate cross-sectional images, excelling in depicting bony structures and detecting subtle alterations in tissue density. The selection of either modality hinges upon the clinical context and specific diagnostic requisites. MRI enjoys favor for its prowess in soft tissue characterization and its radiation-free nature, while CT's swiftness and precision prove invaluable in scenarios like acute condition assessment and vascular anomaly evaluation. The relentless advancement of MRI and CT technologies holds the promise of further enriching their diagnostic capacities, thereby enhancing patient care and deepening our comprehension of diverse medical conditions [13].

4. Advances of CT and MRI

Starting by illustrating a simplified representation of a CT scanner to explain the assumptions made when deriving the Filtered Back Projection (FBP) algorithm, a conventional analytical reconstruction method. The FBP algorithm assumes certain idealized conditions, such as infinitely small x-ray focal spots, ignoring the shape and size of detector cells, and considering image voxels as points at their centers. These assumptions simplify the mathematical aspects but do not accurately represent the physical reality of CT imaging. In contrast, clinical CT scanners have finite-sized focal spots, non-negligible detector cell dimensions, and actual voxel shapes determined by reconstruction parameters. Additionally, each measurement suffers from photon statistics and electronic noise, introducing fluctuations in the data. These simplifications in FBP can impact the quality of reconstructed images, suggesting that MBIR, which considers these complexities and iteratively refines reconstructions, may offer advantages in terms of image quality and accuracy [11].In conclusion, micro-computed tomography (μCT) has emerged as a powerful imaging technique with the ability to provide high-resolution, three-dimensional insights into bone microstructure. This technology represents a significant advancement in the field of bone research, offering numerous advantages over traditional histomorphometric analysis of thin sections [12]. The potential of μCT is particularly evident in its application to the study of trabecular bone structure. Researchers have used μCT to investigate changes in bone architecture in various clinical scenarios, such as osteoporosis treatment trials. In these studies, μCT revealed intricate details of bone microarchitecture, including parameters like trabecular number, thickness, spacing, and connectivity density. For instance, studies involving osteoporotic women treated with medications like risedronate and strontium ranelate demonstrated the ability of μCT to capture the subtle yet crucial changes in trabecular and cortical bone microstructure. Such changes, such as shifts from rod-like to plate-like trabecular patterns and alterations in cortical thickness, can significantly affect bone biomechanical competence. The ability of μCT's to visualize these changes enhances our understanding of treatment outcomes and can potentially help explain reductions in fracture risk associated with certain therapies [12].

The utilization of PET/MRI in oncologic imaging, particularly in the context of prostate cancer, has gained significant traction in recent years. This hybrid imaging modality offers distinct advantages over traditional approaches, such as combining PET with CT. Notably, PET/MRI provides higher resolution for anatomical and tissue details, enhanced sensitivity, and eliminates the exposure to ionizing radiation associated with CT scans. Furthermore, the ability of PET/MRI to simultaneously capture molecular, functional, and anatomical data in a single imaging session streamlines the diagnostic process. As the availability of PET/MRI hybrid scanners continues to expand, its application in prostate cancer management has become increasingly feasible.

A systematic analysis of pertinent studies revealed promising results, with high sensitivity for primary tumor detection and a notable capacity to identify lymph node metastases. Additionally, another meta-analysis confirmed the effectiveness of PET/MRI in detecting primary prostate cancer, with sensitivity and specificity values indicating its potential as a valuable diagnostic tool, particularly in cases of biochemical recurrence [14].

5. Conclusion

In conclusion, the utilization of CT and Magnetic Resonance Imaging (MRI) in the realm of prostate cancer (PCa) imaging represents a dynamic and ever-evolving field. Since their inception, CT and MRI have continually transformed the medical diagnosis and treatment landscape, offering invaluable insights into PCa management. While they have been foundational in initial diagnosis and staging, the contemporary landscape witnesses their roles expanding and adapting to meet the evolving demands of the healthcare ecosystem.

Recent advancements, from cutting-edge CT techniques to streamlined MRI protocols and innovative contrast agents, have propelled these modalities to new heights. These developments are poised to revolutionize the accuracy and precision of PCa diagnosis, further optimizing patient care and outcomes. The remarkable fusion of anatomical and functional data provided by CT and MRI has ushered in a new era of PCa imaging, enabling a holistic understanding of the disease's complexity.

Moreover, the introduction of PET/MRI hybrid scanners has ushered in a new era in oncologic imaging, particularly in the context of PCa. The synergy between PET and MRI offers higher resolution and sensitivity and eliminates the risks associated with ionizing radiation. This novel approach provides a streamlined and comprehensive diagnostic process, exemplifying the potential of technological convergence in modern medicine.

While our exploration of CT and MRI in PCa imaging has illuminated their pivotal roles, it also underscores the need for ongoing research and innovation. The relentless pursuit of enhanced imaging techniques, coupled with a commitment to addressing the unique challenges posed by PCa, will continue to refine and redefine the diagnostic landscape. The potential for earlier and more accurate detection, personalized treatment strategies, and improved patient outcomes remains tantalizing.

In the ever-evolving journey of PCa diagnosis and management, CT and MRI stand as steadfast allies, offering invaluable tools to healthcare practitioners. Their transformative impact on the understanding and treatment of PCa is undeniable, and their future promises even greater contributions to the field. As we look ahead, we must continue to embrace innovation and collaboration to harness the full potential of CT and MRI in the ongoing battle against prostate cancer.

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