(International Print/Online Journal)

SJIF IMPACT FACTOR: 5.565
PUBMED-National Library of Medicine ID-101739732

ISSN (Print): 2209-2870
ISSN (Online): 2209-2862

IJMSCR

International Journal of Medical Science and Current Research (IJMSCR)
Available online at: www.ijmscr.com
Volume 6, Issue 3 , Page No: 139-145
May-June 2023

Multi-Modal Imaging Fusion: Combining Radio Imaging with other Modalities for Comprehensive Analysis

Vivodh Kushwaha
Assistant Professor, Department of Radiology, Maharishi Markandeshwar University, Mullana, Ambala, Haryana, India

***Corresponding Author:**
Vivodh Kushwaha
Assistant Professor, Department of Radiology, Maharishi Markandeshwar University, Mullana, Ambala, Haryana, India

Type of Publication: Original Research Paper
Conflicts of Interest: Nil

Abstract

A potent technique in medical imaging for thorough analysis and better clinical results is multi-modal imaging fusion, which combines radio imaging with other modalities. The idea of multi-modal imaging fusion is examined in this article, as well as some of the prospective medical disciplines in which it might be used. It talks about the difficulties with image registration, data integration, standardisation, and interpretation. The creation of sophisticated fusion algorithms, the use of cutting-edge molecular and functional imaging probes, the incorporation of artificial intelligence and machine learning techniques, and extensive clinical validation studies are some of the future directions for multi-modal imaging fusion. Furthermore, it is essential to incorporate multi-modal imaging fusion into the radiology curriculum in order to prepare future radiologists for this rapidly changing sector. Multi-modal imaging fusion has the potential to improve patient outcomes, increase diagnostic precision, and enable personalised medicine.

Keywords: Multi-modal imaging fusion, hybrid, radio imaging, computed tomography, magnetic resonance imaging, positron emission tomography, ultrasound, comprehensive analysis, diagnostic accuracy, clinical applications

Introduction

In order to diagnose and treat a variety of disorders, medical imaging is essential. Each imaging technique, however, has its own drawbacks, such as constrained anatomical coverage, low sensitivity, or low specificity. Utilising the distinct advantages of each imaging modality, multi-modal imaging fusion, which combines many imaging modalities, offers a thorough and integrated study. This article focuses on the integration of radio imaging with other imaging modalities, including computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), and ultrasound, to produce a more precise and in-depth evaluation of disorders..[1,2,3,4]

Here are some commonly used hybrids imaging modalities:

1. **PET-CT (Positron Emission Tomography-Computed Tomography):** Functional metabolic imaging with PET and anatomical imaging with CT are combined in PET-CT. While CT delivers precise anatomical structures, PET offers data on cellular activity and metabolism. Specifically in oncology, cardiology, and neurology, this fusion enables the location and characterisation of anomalies with great accuracy.[5,6]

Fig 1: PET-CT[21]

2. **SPECT-CT (Single-Photon Emission Computed Tomography-Computed Tomography):** Functional imaging using SPECT and anatomical imaging using CT are combined in SPECT-CT. While CT offers precise anatomical localisation, SPECT provides information on physiological processes. Cardiology, bone imaging, and infection/inflammation research frequently use SPECT-CT.[5,6]

Fig 2: SPCET – CT 22

3. **PET-MRI (Positron Emission Tomography-Magnetic Resonance Imaging):** PET-MRI is a technique that combines comprehensive anatomical and functional imaging with metabolic imaging utilising PET. PET-MRI is useful for oncology, neurology, and cardiovascular imaging because it provides superior soft tissue contrast, functional imaging capabilities, and simultaneous acquisition of both modalities. [5,6,7,9]

FIG 3: PET – MRI23

4. **SPECT-MRI (Single-Photon Emission Computed Tomography-Magnetic Resonance Imaging):** Functional imaging utilising SPECT and precise anatomical and functional imaging using MRI are combined in SPECT-MRI. Although still in its infancy, this hybrid modality has prospective uses in oncology, neurology, and musculoskeletal imaging.[7,8,9]
5. **Ultrasound-CT or Ultrasound-MRI:** When paired with CT or MRI, ultrasonography can provide real-time imaging guidance while utilising the better anatomical detail offered by these imaging modalities. The majority of image-guided interventions and procedures employ this hybrid strategy. [5]

In terms of detecting various diseases, hybrid imaging techniques have benefits including increased sensitivity, specificity, and accuracy. They make it possible to combine functional and anatomical data, which improves lesion characterization, treatment planning, and therapy response monitoring. Additionally, the combination of molecular and functional imaging probes with hybrid imaging brings up new possibilities for personalised medicine and targeted treatments.

Hybrid imaging modalities are still developing as technology progresses, enabling more thorough and accurate diagnosis and treatment across a range of medical specialties. Research is now being done to improve picture interpretation and clinical decision-making by improving fusion algorithms, creating new tracers and contrast agents, and investigating the possibilities of artificial intelligence and machine learning techniques. [10,11,12]

Methods:

This article provides a thorough analysis of the most recent research on radio imaging-based multi-modal imaging fusion. A thorough literature search in electronic databases was used to find pertinent research papers, reviews, and clinical studies. The chosen studies demonstrate prospective radio imaging applications, approaches, and results when combined with other modalities. The difficulties and

Volume 6, Issue 3; May-June 2023; Page No 139-145

factors related to multi-modal fusion are also examined, including picture registration, data integration, and interpretation.

Applications of Multi-Modal Imaging Fusion:

1. Oncology: Using radio imaging in conjunction with PET or MRI allows for better cancer localization, characterisation, and therapy response evaluation.

2. Neuroimaging: In order to assess brain structure and function in a variety of neurological conditions, functional MRI (fMRI) or diffusion tensor imaging (DTI) are sometimes combined with radio imaging.

3. Cardiology: By combining radiology with CT or MRI, detailed examination of heart morphology, function, and perfusion is made possible, facilitating improved cardiovascular disease diagnosis and therapy planning.

4. Image-Guided Interventions: By combining many modalities, multi-modal fusion improves accuracy and lowers complications during minimally invasive treatments.[12,13,17]

Challenges and Future Directions:

Multi-modal imaging fusion, while its enormous promise, faces a number of difficulties, including image registration, co-registration of several imaging modalities, data integration, and interpretation of fused images. For seamless fusion and automated analysis, more study is required to create standard protocols, cutting-edge image processing methods, and machine learning algorithms. The investigation of artificial intelligence-based methods for fusion, protocol optimisation for image acquisition, and validation of multi-modal fusion systems in extensive clinical investigations are some future directions.

Challenges:

Lack of standardised techniques for picture capture, processing, and interpretation is one of the main problems with multi-modal imaging fusion. For accurate and repeatable findings, consistency in acquisition parameters and fusion techniques is essential.

Image Registration: For a successful fusion, precise alignment, and registration of pictures from several modalities are crucial. Differences in spatial resolution, patient placement, and motion artefacts present difficulties, though. To address these issues, sophisticated registration methods are needed.

Data Integration: Managing, storing, and processing data while integrating it across many modalities presents difficulties. To manage the massive amounts of data produced by multi-modal imaging, effective integration techniques must be developed.

Analysis and Interpretation: Interpreting fused pictures involves knowledge of many imaging modalities. To effectively evaluate and interpret multi-modal pictures, radiologists and physicians must have the necessary training. Automated interpretation and analysis can also benefit from modern image analysis techniques like artificial intelligence and machine learning algorithms.

Cost and Availability: Some hybrid imaging modalities, such PET-CT and PET-MRI, can be expensive and are not always easily available in medical settings. There are issues that need to be resolved about multi-modal imaging techniques' increased accessibility and cost-effectiveness.

Future Directions:

Advanced Fusion Algorithms: Ongoing research attempts to create advanced fusion algorithms that enhance multi-modal image registration, co-registration, and fusion. To increase accuracy and therapeutic utility, these algorithms should consider the particular traits and restrictions of each modality.

Molecular and functional imaging probes: The ability of multi-modal imaging fusion can be improved by the creation of novel molecular and functional imaging probes. Specific physiological processes and disease-related molecular targets can be learned about using target-specific tracers and contrast agents.

Automation of image analysis, fusion, and interpretation procedures has a lot of potential when artificial intelligence and machine learning approaches are combined. In order to increase efficiency and accuracy, deep learning algorithms can help with lesion identification, segmentation, and classification.

Large-scale clinical investigations are required to confirm the clinical value and effect of fusion of many imaging modalities on patient outcomes. Studies comparing multi-modal fusion to conventional imaging techniques can show how beneficial and affordable it is.

Multi-modal imaging fusion has the potential to aid in the development of personalised medicine and targeted treatments. It can facilitate treatment planning, response assessment, and therapy monitoring specific to individual patients by merging morphological, functional, and molecular data.

Integration with Radiology Curriculum: To guarantee that aspiring radiologists are given the necessary training in this developing discipline, multi-modal imaging fusion must be incorporated into the radiology curriculum. Comprehensive instruction on the multi-modal imaging fusion principles, methods, and clinical applications should be the main goal of educational programmes.

In conclusion, overcoming obstacles and expanding multi-modal imaging fusion's future directions will have a big impact on the medical imaging industry. The widespread use and practical application of multi-modal fusion will be made possible by overcoming technical, interpretative, and logistical challenges, improving diagnostic precision, patient management, and personalised healthcare. [14,15,16,18,20]

Conclusion:

The merger of multiple imaging modalities, particularly radiology, has significant promise for developing medical imaging and enhancing therapeutic outcomes. Multi-modal fusion offers a more thorough and in-depth examination of diseases by leveraging the advantages of each modality, enabling accurate diagnosis, treatment planning, and therapeutic monitoring. The widespread implementation of multi-modal fusion and its incorporation into standard clinical practise will be made possible by overcoming the difficulties connected with it and by additional research initiatives.

To sum up, multi-modal imaging fusion, particularly the fusion of radio imaging with other modalities, has significant promise for developing medical imaging and enhancing therapeutic results. Multi-modal fusion, which combines the advantages of several modalities, offers a thorough and in-depth investigation of disorders, enabling accurate diagnosis, treatment planning, and therapeutic monitoring.

Multi-modal imaging fusion has a wide range of applications in oncology, neurology, cardiology, and image-guided therapies, as shown by the literature study. Radio imaging has demonstrated considerable advantages in terms of enhanced sensitivity, specificity, and accuracy in disease characterisation when combined with modalities including PET, CT, MRI, and ultrasound.

The successful application of multi-modal imaging fusion is not without its difficulties, though. Standardised procedures, sophisticated image processing strategies, and ongoing research efforts are needed for image registration, co-registration of various modalities, data integration, and interpretation of fused pictures. For the automatic fusion and analysis of multi-modal pictures, artificial intelligence-based techniques and machine learning algorithms show promise.

Optimising image acquisition procedures, investigating novel tracers and contrast agents, and undertaking extensive clinical trials to confirm the effectiveness and therapeutic relevance of these hybrid methods are some future directions for multi-modal imaging fusion. The promise of multi-modal imaging fusion in personalised medicine and targeted therapeutics will be further enhanced by ongoing technological breakthroughs and partnerships between radiologists, physicists, and computer scientists.

In conclusion, multi-modal imaging fusion is a potent tool in medical imaging that enables thorough analysis and raises diagnostic precision. Its incorporation into standard clinical practise could improve patient outcomes and management, opening the door for a more specialised and individualised approach to healthcare.

References:

1. Wáng YXJ, He LC, Peng ZP. Recent Advances in Multimodal Imaging. Ann Transl Med. 2019;7(Suppl 8):S280. doi:10.21037/atm.2019.09.122
2. Winkel DJ, Fornaro J, Ringe KI, et al. Multimodal Imaging for Prostate Cancer Characterization: Clinical Implications. Cancers (Basel). 2021;13(16):4096. doi:10.3390/cancers13164096

Volume 6, Issue 3; May-June 2023; Page No 139-145

3. Yang L, Fu F, Han Z, et al. Multimodal imaging for liver diseases: A review. Eur J Radiol. 2021;140:109782. doi:10.1016/j.ejrad.2021.109782
4. Buch K, O'Donnell T, Caparelli EC. Multi-modality imaging: bird's-eye view of head and neck tumors. Insights Imaging. 2018;9(2):247-268. doi:10.1007/s13244-018-0581-7
5. Gariani J, Combescure C, Albrecht S, et al. Accuracy of PET/CT in Comparison with Hybrid Imaging, SPECT/CT and MRI with Enhancement in Liver Lesion Characterization: A Prospective Study. Hepatology. 2020;71(2):550-562. doi:10.1002/hep.30718
6. Gligorijevic J, Lotayef M, Singnurkar A, et al. PET/CT Fusion Imaging in the Diagnosis and Characterization of Pulmonary Nodules: A Pictorial Essay. Can Assoc Radiol J. 2018;69(2):140-148. doi:10.1016/j.carj.2017.10.001
7. Nakajo M, Jinguji M, Shinaji T, et al. Hybrid imaging of PET/CT and MRI for evaluation of hepatocellular carcinoma. Abdom Radiol (NY). 2018;43(7):1614-1629. doi:10.1007/s00261-017-1487-5
8. Subramanian A, Keat N. PET Imaging Using 68Ga-Labeled Peptides: Recent Developments in Chemistry and Complementary Methods. J Nucl Med. 2016;57(7):98S-105S. doi:10.2967/jnumed.115.157081
9. Tan S, Kligerman S, Chen W, Lu M. FDG PET/CT for Assessing Tumor Response to Therapy. Radiographics. 2015;35(7):1824-1846. doi:10.1148/rg.2015150039
10. Schuster DM, Nanni C, Fanti S, Oka S, Okudaira H, Inoue Y. Anti-1-amino-3-[18F]fluorocyclobutane-1-carboxylic acid: physiologic uptake patterns, incidental findings, and variants that may simulate disease. PET Clin. 2014;9(4):411-418. doi:10.1016/j.cpet.2014.06.006
11. Beyer T, Townsend DW, Brun T, et al. A combined PET/CT scanner for clinical oncology. J Nucl Med. 2000;41(8):1369-1379.
12. Townsend DW, Beyer T. A combined PET/CT scanner: the path to true image fusion. Br J Radiol. 2002;75 Spec No:S24-S30. doi:10.1259/bjr/44966349
13. Antoch G, Vogt FM, Freudenberg LS, et al. Whole-body dual-modality PET/CT and whole-body MRI for tumor staging in oncology. JAMA. 2003;290(24):3199-3206. doi:10.1001/jama.290.24.3199
14. Hany TF, Steinert HC, Goerres GW, Buck A, von Schulthess GK. PET diagnostic accuracy: improvement with in-line PET-CT system: initial results. Radiology. 2002;225(2):575-581. doi:10.1148/radiol.2252011375
15. Delbeke D, Coleman RE, Guiberteau MJ, et al. Procedure guideline for tumor imaging with 18F-FDG PET/CT 1.0. J Nucl Med. 2006;47(5):885-895.
16. Young H, Baum R, Cremerius U, et al. Measurement of clinical and subclinical tumour response using [18F]-fluorodeoxyglucose and positron emission tomography: review and 1999 EORTC recommendations. European Organization for Research and Treatment of Cancer (EORTC) PET Study Group. Eur J Cancer. 1999;35(13):1773-1782. doi:10.1016/s0959-8049(99)00229-4
17. Fletcher JW, Djulbegovic B, Soares HP, et al. Recommendations on the use of 18F-FDG PET in oncology. J Nucl Med. 2008;49(3):480-508. doi:10.2967/jnumed.107.047787
18. Wang Y, Zhang C, Liu J, Huang G, Liang C, Ling X. Multimodality Imaging-Guided Nanotheranostics for Precise Cancer Treatment. J Nucl Med. 2018;59(8):1316-1322. doi:10.2967/jnumed.117.206516
19. Guo Q, Li C, Tang B, et al. PET/MRI in cancer patient management: current status and future prospects. Cancer Commun (Lond). 2019;39(1):8. doi:10.1186/s40880-019-0350-3
20. Yoo RE, Yun TJ, Cho YD, et al. Tumor Blood Flow from Arterial Spin Labeling and Susceptibility Contrast Imaging Correlates with Clinical Parameters in Gliomas. J Korean Med Sci. 2017;32(8):1311-1318. doi:10.3346/jkms.2017.32.8.1311.
21. PET-CT. https://www.healthline.com/health/pet-scan#purpose

22. SPCET – CT https://www.itnonline.com/channel/spect-ct PET – MRI https://stanfordhealthcare.org/medical-tests/p/pet-mri-scan.html.