Original Article

Molecular Imaging for Cancer Diagnosis and Surveillance

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Abstract

Nowadays, molecular imaging technologies have a pivotal role in the field of clinical oncology. The utilization of imaging methods in the early detection of cancer, assessment of treatment response, and development of new therapies is steadily increasing and has already had a significant impact on the clinical management of cancer. Molecular imaging is indispensable for both the detection and treatment of cancer. It focuses on various biomarkers used in targeted therapy, and nuclear medicine-based molecular imaging is a real-time and non-invasive technique that has the potential to identify tumors at an earlier and more manageable stage, before anatomical imaging methods reveal the presence of the disease. Molecular imaging offers extensive possibilities for visualizing cellular and molecular activities throughout tumor growth, serving as a biomedical imaging technology with remarkable sensitivity in detecting and resolving images. It provides non-invasive methods for observing, characterizing, and quantifying biological processes at the cellular and subcellular levels. The development of molecular imaging biomarkers is aimed at improving the evaluation of the effects of targeted therapy. Examples of molecular imaging techniques include positron emission tomography (PET), single-photon emission computed tomography (SPECT), magnetic resonance imaging (mMRI), magnetic resonance spectroscopy (MRS), optical imaging, photoacoustic imaging, and multimodal imaging. Some modalities require the administration of molecular probes, while mMRI and photoacoustic imaging can track the effectiveness of drugs using either endogenous molecules or exogenous molecular probes.

Keywords: *Imaging, Molecular imaging, MRI, Photoacoustic imaging, PET, SPECT*

Introduction

Several distinct imaging techniques are utilized in medical contexts as imaging plays a vital role in both the detection and treatment of cancer. The objective of molecular imaging is to detect and evaluate the key biomolecules and molecular mechanisms that contribute to cancer in vivo. This offers a non-invasive method for detecting cancer metastases in preclinical and clinical models by examining, characterizing, and measuring biological processes at the microscopic scale.[1] Molecular imaging is a medical imaging technique that merges molecular biology and biomedical imaging to track and evaluate the complete spread of biological activities in living organisms without invasive procedures. It has diverse applications in biochemical, biological, diagnostic, and therapeutic domains.[2, 3] A few illustrative examples of molecular imaging techniques are radionuclide imaging (PET), single-photon emission computed tomography (SPECT), molecular magnetic resonance imaging (mMRI), magnetic resonance spectroscopy (MRS), optical imaging (optical bioluminescence, optical fluorescence), photoacoustic imaging PAI, and multimodal imaging.

To achieve optimal in vivo cancer imaging, the use of chemosensitive or genetic sensors is essential. The main problem for molecular imaging is to create unique reporter probes, which exist in a variety of forms and sizes, but their main components are a targeting molecule and a specific ligand. The probe should target and visualise the biological process of interest in vivo. Although endogenous molecules or exogenous probes can evaluate drug efficacy, molecular probes must be administered through injection to obtain imaging signals for both radionuclide and optical imaging.[4, 5] Metabolic probes or their analogues are substances used in metabolic reactions that can be designed to attach to or function as substrates for specific enzymes, receptors, antigens, or transporters. A sensor or scanner is required

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to locate them and convert their discovery into spatial data. When evaluating the physiological effects of immunosurveillance imaging probes, it is important to consider how antibodies can reduce the number of target cells, activate or inhibit receptor signaling, or interfere with the normal functions of soluble proteins.[6-8]

Methods of molecular imaging

The anatomical imaging modalities of ultrasound, computed tomography, and magnetic resonance imaging (MRI) can be utilized in comparison to enhance contamination detection. Techniques for molecular imaging in 2 and 3 dimensions provide valuable information. Unlike hybrid imaging techniques like SPECT/CT, PET/CT, and PET/MRI, which combine anatomical specificity, spatial resolution, and molecular sensitivity, scintigraphy uses flat scanning to provide a two-dimensional image.[8, 9]

The expansion of cancerous cells can serve as a dependable indicator to evaluate the effectiveness of modern anti-tumor medications. The significance of 18F-FDG-PET scanning in cancer therapy is growing as it can detect, classify, and monitor tumor reactions to chemotherapy and chemoradiotherapy. The application of radioligands with targeted molecular validation will have a notable favorable influence on the creation of therapeutic drugs as it will simplify the process of matching the right treatment with the suitable patient.[7]

Optical imaging

A safe technique called optical visualization that uses light and the optical properties of protons to see the tissues, cells, and molecules that make up an organism. It is more secure than ionizing radiation, making it acceptable for routine use to monitor gene expression, the development of a disease, or the effectiveness of therapy. Even though it has a shallow infiltration depth and insufficient spatial resolution, it contains a variety of subtypes.[2, 10, 11] For biomedical imaging, optical imaging has been used because of its non-invasiveness and high-resolution capabilities.[4, 12, 13]

Non-ionizing radiation is used in optical imaging to evaluate gene expression, disease progression, and therapy effectiveness. The cell membrane, organelles, and chemical components that control cancer metabolism may be identified thanks to genetically encoded optical markers like fluorescent protein and luciferase. However, due to their limited tissue penetration and the necessity of transfecting the luciferase gene into BLI, the practical use of BLI and FLI is challenging.[2]

Bioluminescence imaging (BLI) Through the interaction of luciferases and their substrates, the technique known as Bioluminescence Imaging (BLI) [2, 4, 14, 15] produces light. This technique is used to detect cancer, monitor the course of the disease, and assess how well cancer therapies work in real-world situations. Using the photoacoustic effect to generate an ultrasonic signal, PAI is another non-invasive molecular imaging technique. An ultrasonic signal is produced when a substance is exposed to laser pulses, which caused part of the energy to be absorbed and converted into heat. Monitoring the development of tumor-specific biomarkers, detecting tumor cells, and assessing endogenous contrast agents are all possible using PAI. By evaluating vascular regression, normalisation, and tumor hypoxia in preclinical models, it was possible to gauge the effectiveness of antiangiogenic treatment.[16-18]

Fluorescence imaging[19-22] (FLI) Optical imaging, sometimes referred to as FLI, uses fluorescent proteins or dyes that have undergone genetic modification to generate pictures of tumors by detecting light that is released. This method is used in preclinical research for therapeutic response monitoring, fluorescence imaging-guided surgery, and cancer diagnosis. However, autofluorescence noise, which is brought on by endogenous fluorophores in the tissue, lowers the signal-to-noise ratio. Although NIR FLI has been investigated in preliminary clinical research to direct cancer surgery, there have been no reports of FLI deployment in clinical settings to assess the efficacy of targeted therapies. Jermyn *et al*. investigated the use of SERS for intraoperative brain tumor identification, a technique with great sensitivity and specificity for evaluating surgical margins. SERS is an optical imaging technique with great sensitivity and specificity for evaluating surgical margins.[6, 23]

Chemiluminescence

Bioluminescence may be utilized to study a variety of key mechanistic elements of cancer biology and is frequently used to track the outcomes of cancer therapy thanks to clever uses of chemical methods.[24, 25]

Ultrasonic imaging (US): High-frequency sound waves are used in the ultrasonography procedure to create anatomical images. Its high spatial and temporal resolution makes it possible to observe deep tissues up to a centimetre in depth. It has been proven that contrast media, such as gas microbubbles encased in lipid or protein shells, make tumor angiography easier. However, because of its poor resolution and operator-dependent findings, its usefulness is constrained.[26, 27] Fluorescent imaging in the near-infrared (NIR) range offers significant advantages for capturing surgical targets in real time. The depth of light penetration is sufficient, and NIR imaging is characterized by low absorption in blood and other tissues, minimal scattering, and invisibility to the human eye, making it ideal for intraoperative imaging.[28, 29]

Magnetic resonance imaging (MRI): A high-resolution imaging technique that gives excellent tissue contrast regardless of depth is magnetic resonance imaging (MRI). Contrast agents are typically comprised of superparamagnetic substances like ultrasmall superparamagnetic iron oxide (USPIO) and nanoparticle iron oxide (SPION), or paramagnetic metal complexes like gadolinium (III), dysprosium (III), or manganese (II).[30, 31] Excellent anatomical resolution is provided by magnetic resonance imaging (MRI), which is distinguished by its capacity to provide stunning pictures of soft tissues. This non-invasive imaging method is frequently referred to as an anatomical imaging modality.[8]

Using specialized magnetic nanoparticles, targeted MRI can find molecular markers that are particular to tumors. This makes it possible to categorize patients, administer individualized therapy specifically to the area that is harmed, and evaluate the success of treatment for tumors that express certain biomarkers using MRI. The main goal of using MRI in cancer-targeted therapy is to anticipate the response to targeted therapy by examining data collected by MRI before treatment and evaluating changes in MRI during treatment to evaluate the response.[2, 8, 30]

Radionuclide imaging refers to the utilization of radioisotopes in single photon emission computed tomography (SPECT) and positron emission tomography (PET). Due to the availability of numerous radiopharmaceuticals for clinical purposes, SPECT imaging is frequently employed in clinical settings over PET imaging. PET images possess remarkable sensitivity and exhibit quantifiable imaging traits, including the standardized uptake value (SUV).[2] PET-MRI allows for precise correction of anatomical structures and thorough examination of the molecular characteristics of tumors, broadening the scope of multimodal imaging and decreasing patients' radiation exposure. Tumor imaging employs nuclear medicine tomography and molecular imaging tracers with genetic coding.[2, 4, 32]

A therapeutic context can benefit ”rom 'adionuclide imaging because of its great sensitivity and tissue penetration. Using several X-ray transmissions, CT imaging reconstructs high-resolution images. In intravascular CT, contrast agents, such as B. iodinated compounds, are employed to enhance image contrast. CT scans are frequently used in conjunction with PET and SPECT images to enable accurate probe anatomical localization.

Images are taken using Molecular Imaging Probes. Biological changes related to sickness can be monitored using MRI and other imaging methods like photoacoustic imaging. In medical practice, imaging agents such as 18F-FDG and 99mTc-sulfur colloid, which are not specific to tumors, are commonly employed to locate lesions or lymph nodes in patients with cancer and to evaluate the efficacy of cancer treatment.[2, 33, 34]

Radiation exposure risks and inadequate spatial resolution are problems with multimodal PET/SPECT imaging. While optical imaging offers a greater depth of penetration and higher spatial resolution than MRI, the latter has a lower specificity. Low resolution and variable subjective results characterize US images. To circumvent these restrictions, researchers have attempted to merge two or more imaging techniques to produce multimodal molecular images. Multimodality molecular imaging has been utilized in preclinical and clinical investigations for timely identification, disease staging, evaluation of therapeutic responses, surgical guidance, and prognostic evaluation.[2, 6, 35]

A cheap and easily accessible radiotracer with several therapeutic applications is 18F-FDG. Although it performs clinically very well, it cannot be used to evaluate therapeutic response. Additionally, individuals who receive targeted therapy can have their prognosis predicted using radionuclide imaging. It will be challenging to replace 18F-FDG as a general cancer imaging agent because of its vast application and well-established clinical procedures. 18F-FDG is a cheap and easily accessible radiotracer. It is expected that molecular imaging in oncology will continue to be dominated by the uniform use of 18F-FDG, which follows a standard approach of patient preparation, dosage, uptake time, and scanner procedure for all types of tumors.[2, 6, 36]

The integration of multiple imaging modalities for integrated image processing and information retrieval is known as multimodal imaging. There are techniques to increase in vivo safety using non-viral vectors including liposomes, cationic polymers, nanocarriers, and others. The development of multimodal imaging for robotic surgery also included the creation of a unique laparoscopic drop-in-G detector that improved the sensitivity of SLN detection in patients with prostate cancer. Researchers are developing multimodal imaging systems that combine the capabilities of two or more MI modalities to solve the limitations of individual modalities. A modern medical invention, medical imaging enables the viewing of the whole human body.[2, 37]

Applications of molecular imaging

Tracking therapy response for drug development, finding positive surgical margins after tumor resections, optimizing dosing schedule, determining therapeutic regimes, and monitoring therapeutic response. Preclinical research study of the tumor microenvironment, hypoxia in relation to flash radiotherapy, hypoxia in relation to cancer progression, and therapy response to radiotherapy. The acidic environment of the tumor detects metastatic lesions, genetic and epigenetic abnormalities.

Advanced anatomical imaging and molecular imaging (MI) enable accurate identification and thorough examination of biomarker status, disclosing valuable biochemical insights at microscopic levels in vivo and promoting the progress of drug development.

Personalized medicine seeks to increase diagnosis accuracy and minimize treatment failure, and Molecular Imaging is essential for this. Prognostic AI techniques have the potential for automated molecular imaging approaches to optimize dosing schedules, determine therapy regimens, and monitor therapeutic response. FDG-PET imaging is becoming increasingly relevant in cancer treatment due to its capacity to diagnose, grade, and measure tumor response to chemotherapy and chemoradiotherapy.

Conclusion

Molecular imaging (MI) is used to study biological activity at the cellular and subcellular levels in live animals, including patients. MI pictures shed light on illness-related processes and mechanisms, facilitating early disease identification, medication optimization, treatment response prediction and

tracking, and disease recurrence monitoring. MI is also used by biotechnology companies to enhance the processes for medication discovery and validation. MI can detect tumors at an earlier, more curable stage and is a non-invasive and real-time method. Genetically encoded molecular imaging probes have been produced extensively to mark certain cells or proteins of interest in tumor tissues. With the use of technology and MI agents, it is now possible to do image-guided biopsies for cancer imaging, investigate tumor heterogeneity, evaluate therapy response, and diagnose tumors with greater precision.

MRI offers high spatial resolution and is ideal for morphological and functional imaging. Targeted contrast agents with high specificity and relaxivity are needed for molecular imaging of disease biomarkers, often connected to high payload or relaxivities. The most beneficial aspect of optical imaging is that, unlike other medical imaging modalities, it and ultrasound do not raise significant safety issues. The disadvantage of optical imaging is the limitation of penetration depth, particularly at visible wavelengths. SPECT is a molecular imaging technique with long half lives, making it easy to produce and cheap. However, it lacks spatial and temporal resolution, and due to radioactivity, there are safety concerns regarding the administration of radioisotopes to subjects, especially for serial studies. PET is a nuclear medicine imaging technique that produces three-dimensional images of body functions. However, its disadvantages include requiring cyclotron probes and a high half-life, making it prohibitively expensive. However, PET has advantages, including high sensitivity.

For PET, SPECT, scintigraphy, and optical imaging, cytokines, receptor ligands, and antibodies are frequently utilized as molecular imaging agents. Non-invasive physiological and metabolic processes may be seen with PET and SPECT imaging, which can be important for medication development. The development of affordable, transportable, and user-friendly imaging systems supports the acceptance of these technologies as the gold standard in surgical treatment around the globe. AI techniques can automate image interpretation, and predict treatment efficacy and patient survival.

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None.

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None.

References

1. Saadatpour Z, Rezaei A, Ebrahimnejad H, Baghaei B, Bjorklund G, Chartrand M, et al. Imaging techniques: new avenues in cancer gene and cell therapy. Cancer Gene Ther. 2017;24(1):1-5. doi:10.1038/cgt.2016.61
2. Bai JW, Qiu SQ, Zhang GJ. Molecular and functional imaging in cancer-targeted therapy: Current applications and future directions. Signal Transduct Target Ther. 2023;8(1):89. doi:10.1038/s41392-023-01366-y
3. Nguyen KN, Do TD. Factors influencing knowledge sharing in higher education: An empirical study of students in Vietnam. J Organ Behav Res. 2021;6(2):134-51. doi:10.51847/LJZB9XoP0F
4. Du M, Wang T, Yang Y, Zeng F, Li Y, Chen Z. Application of genetically encoded molecular imaging probes in tumor imaging. Contrast Media Mol Imaging. 2022;2022:5473244. doi:10.1155/2022/5473244
5. Aloufi BH. Structure-based multi-targeted molecular docking and molecular dynamic simulation analysis to identify potential inhibitors against ovarian cancer. J Biochem Technol. 2022;13(2):29-39. doi:10.51847/b1KFmETha6
6. Rowe SP, Pomper MG. Molecular imaging in oncology: Current impact and future directions. CA Cancer J Clin. 2022;72(4):333-52. doi:10.3322/caac.21713
7. Berz AM, Dromain C, Vietti-Violi N, Boughdad S, Duran R. Tumor response assessment on imaging following immunotherapy. Front Oncol. 2022;12:982983. doi:10.3389/fonc.2022.982983. Erratum in: Front Oncol. 2023 Mar 07;13:1175321. PMID: 36387133; PMCID: PMC9641095.
8. McCarthy CE, White JM, Viola NT, Gibson HM. In vivo imaging technologies to monitor the immune system. Front Immunol. 2020;11:1067. doi:10.3389/fimmu.2020.01067
9. Das N, Kalita PP, Sarma MP, Bhattacharjee M. Molecular modeling of HEV core protein and active compounds from northeast folk medicine. J Biochem Technol. 2021;12(2):12-8. doi:10.51847/j3XkpgE1XE
10. Müller J, Wunder A, Licha K. Optical imaging. Recent Results Cancer Res. 2013;187:221-46. doi:10.1007/978-3-642-10853-2_7
11. Serkova NJ, Glunde K, Haney CR, Farhoud M, De Lille A, Redente EF, et al. Preclinical applications of multi-platform imaging in animal models of cancer. Cancer Res. 2021;81(5):1189-200. doi:10.1158/0008-5472.CAN-20-0373
12. Alshammari AM. Screening of phytochemicals against snake venom metalloproteinase: Molecular docking and simulation-based computational approaches. Arch Pharm Pract. 2022;13(3):76-84. doi:10.51847/HIrDcdPCGL
13. Mekeres GM, Buhaș CL, Csep AN, Beiușanu C, Andreescu G, Marian P, et al. The importance of psychometric and physical scales for the evaluation of the consequences of scars—A literature review. Clin Pract. 2023;13(2):372-83. doi:10.3390/clinpract13020034
14. Dumitru M, Berghi ON, Taciuc IA, Vrinceanu D, Manole F, Costache A. Could artificial intelligence prevent intraoperative anaphylaxis? Reference review and proof of concept. Medicina. 2022;58(11):1530. doi:10.3390/medicina58111530
15. Sandu N, Rosemann T, Schaller B. Molecular imaging and tracking stem cells in neurosciences. Methods Mol Biol. 2020;2150:1-9. doi:10.1007/7651_2019_218
16. Attia ABE, Balasundaram G, Moothanchery M, Dinish US, Bi R, Ntziachristos V, et al. A review of clinical photoacoustic imaging: Current and future trends. Photoacoustics. 2019;16:100144. doi:10.1016/j.pacs.2019.100144
17. Steinberg I, Huland DM, Vermesh O, Frostig HE, Tummers WS, Gambhir SS. Photoacoustic clinical imaging. Photoacoustics. 2019;14:77-98. doi:10.1016/j.pacs.2019.05.001
18. Zhang J, Duan F, Liu Y, Nie L. High-resolution photoacoustic tomography for early-stage cancer detection and its clinical translation. Radiol Imaging Cancer. 2020;2(3):e190030. doi:10.1148/rycan.2020190030
19. Voskuil FJ, Steinkamp PJ, Zhao T, van der Vegt B, Koller M, Doff JJ, et al. Exploiting metabolic acidosis in solid cancers using a tumor-agnostic pH-activatable nanoprobe for fluorescence-guided surgery. Nat Commun. 2020;11(1):3257. doi:10.1038/s41467-020-16814-4
20. Koller M, Qiu SQ, Linssen MD, Jansen L, Kelder W, de Vries J, et al. Implementation and benchmarking of a novel analytical framework to clinically evaluate tumor-specific fluorescent tracers. Nat Commun. 2018;9(1):3739. doi:10.1038/s41467-018-05727-y
21. Suurs FV, Qiu SQ, Yim JJ, Schröder CP, Timmer-Bosscha H, Bensen ES, et al. Fluorescent image-guided surgery in breast cancer by intravenous application of a quenched fluorescence activity-based

probe for cysteine cathepsins in a syngeneic mouse model. EJNMMI Res. 2020;10(1):111. doi:10.1186/s13550-020-00688-0
22. Zhao T, Huang G, Li Y, Yang S, Ramezani S, Lin Z, et al. A Transistor-like pH nanoprobe for tumor detection and image-guided surgery. Nat Biomed Eng. 2016;1:0006. doi:10.1038/s41551-016-0006
23. Jermyn M, Mok K, Mercier J, Desroches J, Pichette J, Saint-Arnaud K, et al. Intraoperative brain cancer detection with Raman spectroscopy in humans. Sci Transl Med. 2015;7(274):274ra19. doi:10.1126/scitranslmed.aaa2384
24. Godinat A, Bazhin AA, Goun EA. Bioorthogonal chemistry in bioluminescence imaging. Drug Discov Today. 2018;23(9):1584-90. doi:10.1016/j.drudis.2018.05.022
25. Koessinger AL, Koessinger D, Stevenson K, Cloix C, Mitchell L, Nixon C, et al. Quantitative in vivo bioluminescence imaging of orthotopic patient-derived glioblastoma xenografts. Sci Rep. 2020;10(1):15361. doi:10.1038/s41598-020-72322-x
26. Maresca D, Lakshmanan A, Lee-Gosselin A, Melis JM, Ni YL, Bourdeau RW, et al. Nonlinear ultrasound imaging of nanoscale acoustic biomolecules. Appl Phys Lett. 2017;110(7):073704. doi:10.1063/1.4976105
27. Fernandes DA, Kolios MC. Intrinsically absorbing photoacoustic and ultrasound contrast agents for cancer therapy and imaging. Nanotechnology. 2018;29(50):505103. doi:10.1088/1361-6528/aadfbc
28. Hyun H, Henary M, Gao T, Narayana L, Owens EA, Lee JH, et al. 700-nm zwitterionic near-infrared fluorophores for dual-channel image-guided surgery. Mol Imaging Biol. 2016;18(1):52-61. doi:10.1007/s11307-015-0870-4
29. Liu Z, Yang R, Cao H. Near-infrared intraoperative imaging with indocyanine green is beneficial in video-assisted thoracoscopic segmentectomy for patients with chronic lung diseases: A retrospective single-center propensity-score matched analysis. J Cardiothorac Surg. 2020;15(1):303. doi:10.1186/s13019-020-01310-z
30. Jeong Y, Hwang HS, Na K. Theranostics and contrast agents for magnetic resonance imaging. Biomater Res. 2018;22:20. doi:10.1186/s40824-018-0130-1
31. Alsubeie MS. Morphology and molecular study of cassia angustifolia vahl. in Saudi Arabia using RAPD technique. Entomol Appl Sci Lett. 2022;9(2):11-6. doi:10.51847/434ps9amNE
32. Wu B, Warnock G, Zaiss M, Lin C, Chen M, Zhou Z, et al. An overview of CEST MRI for non-MR physicists. EJNMMI Phys. 2016;3(1):19. doi:10.1186/s40658-016-0155-2
33. Hentzen JEKR, de Jongh SJ, Hemmer PHJ, van der Plas WY, van Dam GM, Kruijff S. Molecular fluorescence-guided surgery of peritoneal carcinomatosis of colorectal origin: A narrative review. J Surg Oncol. 2018;118(2):332-43. doi:10.1002/jso.25106
34. Dumitru M, Vrinceanu D, Banica B, Cergan R, Taciuc IA, Manole F, et al. Management of aesthetic and functional deficits in frontal bone trauma. Medicina. 2022;58(12):1756. doi:10.3390/medicina58121756
35. Nguyen PDT, Pham NH, Truong PK. Molecular characterization of proprotein convertase subtilisin/kexin type 9 gene mutations in Vietnamese patients with hypercholesterolemia. Pharmacophore. 2021;12(3):23-8. doi:10.51847/W5tOunb2Bw
36. Billones LT, Gonzaga AC. Random forest modeling of molecular descriptors of COX-2-targeted non-steroidal anti-inflammatory drugs (NSAIDs). Pharmacophore. 2022;13(6):106-14. doi:10.51847/OkYCPAEXPR
37. Mondal SB, O'Brien CM, Bishop K, Fields RC, Margenthaler JA, Achilefu S. Repurposing molecular imaging and sensing for cancer image-guided surgery. J Nucl Med. 2020;61(8):1113-22. doi:10.2967/jnumed.118.220426