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The Future of Radiology: Exploring Emerging Technologies and Their Clinical Applications

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ABSTRACT
Introduction: Radiology has always been one of the pillars of the medical field alongside being one of the first specialties in use in the diagnosis and management of diseases. Technological developments have moved radiology from simple and basic procedure such as x-ray to the use of modern devices such as the computed tomography (ICT), magnetic resonance imaging (MRI) and positron emission tomography (PET). Radiology has prepared to take steps forward and enter the age of rapid technological advancement in healthcare delivery. Advanced imaging systems such as ;artificial intelligence (AI), molecular imaging and hybrid imaging systems, 3D printing, and advanced interventional radiology techniques etc. are changing the dynamic of medical imaging.
Aim of work: To explore the transformative impact of emerging technologies on the field of radiology, focusing on their current advancements, clinical applications, and potential future developments.
Methods: We conducted a comprehensive search in the MEDLINE database's electronic literature using the following search terms: Future, Radiology, Emerging, Technologies, Clinical, and Applications. The search was restricted to publications from 2016to 2024 in order to locate relevant content. We performed a search on Google Scholar to locate and examine academic papers that pertain to my subject matter. The selection of articles was impacted by certain criteria for inclusion.
Results: The publications analyzed in this study encompassed from 2016 to 2024. The study was structured into various sections with specific headings in the discussion section.
Conclusion: It is a well-established fact that the radiology prospective is blest with unprecedented opportunities for innovation and change. Technologies like artificial intelligence, molecular and hybrid imaging systems, interventional radiology, and 3D printing are the innovative horizons that are defining the future of radiology, increasing its scope and importance in making radiology a personalized and predictive medicine. Thus, radiology will remain firmly planted on the trajectory of future development of health care, enhancing the diagnosis's accuracy as well as the efficacy of treatment interventions and general hospital care. By overcoming the challenges that their implementation poses to the radiology community, the potential of these technologies will be realized, and a new generation of medical advancements opened up.
Keywords: Future, Radiology, Emerging, Technologies, Clinical, and Applications

INTRODUCTION

Diagnostic imaging in radiology has been in the forefront of the medical arena, offering a critical support if not a fundamental tool, for diagnosis and treatment of diseases. Technological improvement in this practice has seen radiology develop from simple X-ray imaging to the modern day complex machines like computed tomography (CT), magnetic resonance imaging machines (MRI), and positron emission tomography (PET) (Alsubaiei et al., 2023). With the advancement of technology more drastic changes have been observed and the new age ahead also promises to bring in more radical changes in radiology. Some of the advanced technologies that are today changing the face of medical imaging are artificial intelligence, molecular imaging, hybrid imaging systems, 3D printing, and advanced interventional radiology techniques. These innovations not only increase the accuracy of diagnostics, but also expand the therapeutic functions of radiology, making it one of the key applications of personalized and prognosis medicine (Kitson, 2024).

Another significant renewal that is currently rapidly developing in radiology is AI, especially in the areas of image analysis and interpretation (Pinto-Coelho, 2023). Big data can be analyzed much faster and with a higher accuracy with help of the machine learning algorithms which can support the radiologists in analysis of the suspicious patterns which can be unnoticed by even experienced traders. For example, AI-enabled technologies are used for an early-stage cancer diagnosis, the interpretation of cardiovascular images or neurological disorders like Alzheimer's disease. Furthermore, AI can be used to ease the growing burden of work that radiologists are experiencing through functions like image segmentation and report drafting, so that the radiologists can also concentrate on more intricate decision-making and patients (Madal et al., 2018).

Similar to AI, molecular imaging is gradually evolving into a strong means of studying disease at a cellular and molecular level. Unlike conventional imaging methods in which information is chiefly based on anatomical changes, molecular imaging captures functional and biochemical changes within the body. This capability is vital in a process of screening the early signs of diseases, assessing the effectiveness of the administered treatments, and choosing corresponding therapies ad treatments. For instance, radiotracers used in the PET scans are now optimized for a particular molecular receptor, which allows oncologists to map tumour metabolism and therapeutic outcomes from immunotherapy more accurately (MacRitchie et al., 2024).

The use of hybrid imaging systems where two or more systems like PET/CT or MRI/PET are used in imaging are other advancements in the radiological technology. These systems contain both structural and functional imaging and thus provide valuable information regarding disease processes. These techniques are extremely valuable in oncology, cardiology, and neurology as accurate determination of the location of the changes is crucial for further management. Consequently, the utilization of hybrid systems not only enhances the diagnostic accuracy but also shrinks the number of scans required, consequently decreasing patient exposure to radiation and optimizing the clinical processes (Kastelik-Hryniewiecka et al., 2022).

Secondly, there are improvements in the field of interventional radiology that is leading to the changing therapeutic frontier of the discipline. Many conventional surgeries are now being replaced by image-guided minimally invasive surgeries providing the patient with less hospitalization time, less postoperative complications and quicker rehabilitation time. Interventional activities such as radiofrequency ablation, transcatheter embolization, and image-guided biopsies are some of the ways that radiology is moving beyond merely diagnosing diseases to actually managing them (Ahmad, 2024).

Finally, 3D and virtual reality technologies bring their ways into radiology, more specifically in surgical planning and patients' information. Self-training: Radiologists can construct a congruent anatomical model on the basis of imaging data; the surgeons can rehearse complicated operations and explain to the patients what they are going to do. They also have implications for medical education and the training of health care professionals (Lastrucci&Giansanti, 2024).

While including these innovative technologies into its practice, radiology will continue to progress and contribute to the creation of a healthcare model in which diagnostics and treatment are inextricably connected. However, this evolution is not devoid of its problems among which are the need for multispecialty cooperation and integration, ethical issues on AI and inequality in the availability of enhanced imaging techniques. It will be critical to tackle these factors in order to unleash the full potential of these innovations, ensuring better treatment of patients while setting the course for the development of medicine in the future.

AIM OF WORK

The purpose of this review is to discuss the transformatory effect of current and potential new technologies and advanced applications in radiology. In this essay, the author intends to shed light to how specific innovations including the above mentioned like artificial intelligence, molecular imaging, hybrid imaging systems, interventional radiological techniques and 3D printing are changing diagnostics and treatments. Further, it seeks to discuss the issues and ethical concerns associated with their implementation into routine practice, provide an understanding of how radiology can adapt to the needs of precision and preventive medicine for equal and superior patient care.

METHODS

A thorough search was carried out on well-known scientific platforms like Google Scholar and Pubmed, utilizing targeted keywords such as Future, Radiology, Emerging, Technologies, Clinical, and Applications. The goal was to collect all pertinent research papers. Articles were chosen according to certain criteria. Upon conducting a comprehensive analysis of the abstracts and notable titles of each publication, we eliminated case reports, duplicate articles, and publications without full information. The reviews included in this research were published from 2016 to 2024.

RESULTS

The current investigation concentrated on the transformative impact of emerging technologies on the field of radiology, focusing on their current advancements, clinical applications, and potential future developments between 2016 and 2024. As a result, the review was published under many headlines in the discussion area, including:Artificial Intelligence in Radiology, Molecular Imaging and Precision Medicine, Hybrid Imaging Systems, Advances in Interventional Radiology, 3D Printing and Virtual Reality in Radiology and Challenges and the Road Ahead

DISCUSSION

Radiology, as a fundamental specialty of the contemporary medical practice, has imposed itself in the continuous process of development in parallel with the progression of technology in relation to diseases' detection, diagnostics, and treatment. From the time when X rays were discovered, to the modern imaging techniques like CT scan, MRI, and PET scan, radiology has emerged and continue as an active and important branch of medicine. Today, radiology is ready to change its perspectives with such trends as AI, molecular and hybrid imaging systems, interventional radiology, 3D printing. These improvements are revolutionizing radiology by changing how it is practiced, its clinical uses, and its potential for individualized and prognostic medicine (Najjar, 2023). This review sought to establish the dynamics, current and future uses of these technologies, and the limitations that need be surmounted to fully unlock their power.

Artificial Intelligence in Radiology

Currently AI is established as a powerful tool in radiology that can transform image analysis, diagnostics and work output. Machine learning and deep learning are two categories of AI algorithms that can perform gigantic data analysis at comparatively high speed and accuracy (Hosny et al., 2018). Such capabilities are very advantageous for instance in medical imaging where an AI system can support the radiologist in detecting minor anomalies that might not be recognized in the course of a review. For example, when it comes to identifying preclinical cancers, including breast cancer in mammography, or lung nodules in computed tomography scans, AI has shown superior sensitivity and specificity compared to human practitioners (Saleh et al., 2023).

Aside from use in anomaly detection, AI is also finding utility in other areas of radiology by performing tasks that are otherwise repetitive. Certain tasks such as image segmentation, lesion quantification, and report preparation are some of the tasks that can be automated and this relieves the radiologists to deal with and make complex decisions on more difficult cases (Bhandari, 2024). Also, artificial intelligence is being incorporated into imaging devices so that diagnostic support can be provided during the image capture process. For instance, today's advanced AI can help to determine optimal scan-settings, minimize image artifacts and to acquire better image quality, which helps to enhance diagnostic certainty and thus, patient outcomes (Oladele, 2024).

However, using AI in radiology is not without its problems. AI algorithms' explainability, data privacy and ethics issues, and data bias are required issues to mitigate for equitable and accurate applicability. Furthermore, it is crucial to bear in mind that AI is merely an assistant to radiologists rather than a subsitute for them. The chances for continued application of AI in radiology rely on the integration of both human and artificial intelligence systems to create the best approach to patient treatment (Recht et al., 2020).

Molecular Imaging and Precision Medicine

Molecular imaging is an enhancement of traditional radiology that addresses the molecular and cellular level imaging of the body in the correspondent processes. While the traditional imaging techniques are associated with morphological imaging, molecular imaging offers functional information that is important in the early stages and monitoring of the disease, and therapy (Gupte, & Hamilton, 2016). It is especially useful in oncology because, besides revealing the current status of the disease, molecular imaging pinpoints tumor metabolism, response to therapies and the presence of metastases.

However, probably the most attractive area for the execution of molecular imaging is by using targeted radiotracers in the PET imaging (Vāvere& Scott, 2017). These radiotracers attach to certain molecules, particular proteins or receptors related to affliction, so that practitioners can observe the cause of the disease. For instance, Fluorodeoxyglucose positron emission tomography (FDG PET) is often used to assess the consumption rate of glucose in cancer cells; and new tracers are being generated for disease biomarkers related to neurological disorders, cardiac diseases, and infections (Sarikaya et al. 2021). In the further development of molecular imaging as a discipline, there is great hope for it to serve as one of the important diagnostic tools in precision medicine, in which individual patients would receive molecular-guided, distinct treatment.

Logically, the combination of molecular imaging with other technologies including AI and hybrid imaging systems makes it even more useful in clinical medicine. Machine learning creates signal patterns and evaluates molecular imaging data, while hybrid architectures offer structural and functional images as in PET/CT as well as PET/MRI. The existing and emerging imaging techniques are not only enhancing the diagnostic capabilities, but also creating new horizons in treatments, like radiotheranostics where molecular imaging is employed to direct the overall local irradiation treatment (Ming et al., 2020).

Hybrid Imaging Systems

Other important innovation in radiology is the use of hybrid imaging analysers that uses numerous images to give a broader perspective of diseases. Among all the hybrid systems, PET/CT and PET/MRI have functional imaging along with anatomic details; they are extremely beneficial compared to conventional imaging techniques at detection rates and treatment decisions. Such systems are especially useful in cases of carcinomas, myocardial diseases, and cerebral disorders at which accurate identification of foci of changes is of great potential for making a differential diagnosis and prognosis of the further evolution and therapeutic management of the process (Padmanabhan et al., 2017).

In oncology, PET/CT is used for staging and monitoring disease since it provides metabolic and anatomic information of the disease (Mahajan& Cook, 2017). Similarly, when there is improved soft tissue contrast, PET/MRI is favorable for detecting brain malignancy, prostate carcinoma, and other diseases in which MRI has a beneficial diagnostic role (Becker &Garibotto, 2023). Apart from oncologic cases, hybrid imaging systems have applications in cardiological, myocardial viability and perfusion, inflammation and neurodegenerative disorder, diagnosis of epilepsy cases (Giovannini et al., 2016).

Nonetheless, the application of hybrid imaging systems comes with certain issues that are associated with its cost, availability and When it comes to the limitation, then it is very complex . These systems are capital intensive bearing the cost of infrastructure and training implying that they may not be widely available where resources are scarce. Furthermore, the combination of a variety of imaging techniques requires high levels of understanding for correct implementation and interpretation. To overcome these factors, new strategies will be needed for the best use of hybrid imaging with an aim of increasing its use and ensuring its positive impact on patient's management (Sundaram et al., 2023 Tarighatnia et al., 2023).

Advances in Interventional Radiology

Interventional radiology specialties are a are growing and its minimally invasive methods are replacing traditional surgical approaches. IR techniques that are supported by real-time imaging allow better diagnosis and targeted treatment with relatively low risk for patients and subsequent reduced time required to recover. In the years that followed, IR has been adopted in essentially all fields of medicine, including oncology, cardiology, gastroenterology and neurology (Brock et al (2023).

Some of the current major steps in the progress of IR are the innovations in IMS techniques including RFA, Microwave ablation, and cryoablation (Cazzato et al., 2016). These procedures are standard for managing Carcinoma, especially liver, kidney, and lung cancer are considered. In killing cancerous cells while leaving the healthy ones to function as they normally would, the ablation methods give a patient an effective and less invasive treatment method than surgery. Another major development in the field of IR includes embolization in which the blood flow to tumour or some abnormal blood vessel is occluded to resulted in ischaemia to aid healing. Embolization is widely employed in management of fibroid, AVM and GI bleed (Varghese &Adhyapak, 2017).

Besides these therapeutic uses, IR is also improving diagnoses through methods such as guided biopsies and catheter angiography . These procedures make it possible to obtain good sample of the tissue and vascular so that any delays in the diagnosis can be well addressed. The addition of cone-beam CT and MRI to the IR continues to enhance the accuracy and safety of these interventions (Mashoufi&Mashoufi, 2023).

3D Printing and Virtual Reality in Radiology

Recently, 3D printing and virtual reality (VR) are revolutionizing radiology by providing radical approaches to patients' treatment, surgical planning, and training. The major benefit of 3D printing, which is based on issuing physical objects starting from visual data, is its applicability to preoperative preparation and specific surgical interventions. For example, the medical professionals can apply the models in the surgery, envision the shape of internal body organs and systems, and practice surgeries, recognizing the possible problems in the process. It has been used in cardiology, orthopedics, and oncology to increase the accuracy of surgical operations and minimize intraoperative dangers (Mashoufi&Mashoufi, 2023).

Radiographers have also been overwhelmed by the introduction of another type of visualization, the virtual reality systems, that are modifying the way that radiologists use images. Through the use of VR, clinicians can more easily understand complex spatial relationship between structures as well as better visualize pathology in 3D. They are also using it in patient inpatient's education where people can learn more about their health state and ways to treat them. In medical education, VR provides an effective method of training for radiologists and other members of health care personnel, which offers the possibility of developing accurate models of diagnostic and interventional procedures (Lastrucci, Giansanti, 2024).

Although 3D printed prototypes and virtual reality provide a great deal of potential, there are challenges associated with these technologies with radiology practices including cost point, applicability, and personnel competencies. Strategies to design affordable options and incorporate these technologies into the practice will be equally significant to achieve these objectives (Olatunji et al., 2023).

Challenges and the Road Ahead

However, we have identified certain challenges that need to be overcome in order to successfully implement these emerging technologies in radiology field. Some concerns like, data privacy and bias in the system, which are very important while implementing AI and molecular imaging. Despite the advantages the discussed technologies bring into the healthcare industry, Ahmad (2024) noted that creating sound frameworks in data governance and data transparency will be the key to retaining the public's trust and achieving the fair distribution of these technologies.

Another challenging factor identified includes the cross functionality needed in research The final key challenge is the constant training needs in research. New techniques require the radiologists to learn new roles for the particular technology, and the engineers and computer science specialists alongside clinicians to innovate in their engineering for the solutions. Calling for cross sector training and research will be important to support innovative approaches and to ensure that developments in technology are relevant to clinical practice (Ahmad & Khan, 2024).

Last but not least concerns over equitable distribution of advanced imaging modalities constitute an important area that needs to be addressed. The barriers of health-care access in poorer regions may be further widened since technologies such as hybrid imageries and 3D printing are expensive. Measures for the creation of effective and affordable technologies and more access to such technologies are also recognized to be imperative for scaling up their influence globally (Hanna et al., 2021).

CONCLUSION

Radiology is on the verge of significant change that is being catalyzed by emergent technologies that are recasting the role and application of the field in medicine. New developments in machines like artificial intelligence, molecular imaging, hybrid imaging systems, interventional radiology, and 3D printing not only increase diagnostic accuracy but also add more therapeutic functionalities to radiology. Such progress is leading to better, proactive, and individualised treatment plans for patients and placing radiology as a cornerstone to current healthcare.

AI has clearly shown possible ways of changing how images are analyzed and making certain processes less time-consuming for radiologists to attend to significant clinical tasks. Molecular imaging also provides dramatic insights into the pathologic processes at the molecular and cellular levels, thus being a strong supporter of personalized medicine. Imaging systems have reached the point of combining both structural and functional images, and interventional radiology's progress opens up a world where procedures can be less invasive and heal faster. Also, techniques such as additive manufacturing and virtual reality are presenting state-of-the-art applications in the areas of surgery, education, as well as patient experience.

However, some issues like cost constraints, ethical issues, and interprofessional collaboration have not been addressed despite progress. The solutions to these problems will be of paramount importance in creating conditions for the equal dissemination of new technologies and their proper implementation in clinical care. Work on defining training programs, designing affordable approaches, and increasing global availability will significantly influence radiology's development.

As these technologies advance, radiology will augment its current missions in diagnosis and therapy, but it will also shape the future of health care. With innovation as an opportunity that comes with challenges on its way, the field of radiology has what it takes to reach its full potential and produce a positive impact for patients and on the practice of medicine in the years to come.

REFERENCES

Ahmad, G. (2024). Radiology Revolution: Emerging Technologies and Diagnostic Advancements. *Cosmic Journal of Chemistry*, *3*(1), 36-41.

Ahmad, W., & Khan, A. (2024).Navigating Emergency Medicine Challenges: The Confluence of Anesthesia and Radiology. *Cosmic Journal of Chemistry*, *3*(1), 151-157.

Alsubaiei, N. K. M., Almalki, F. R. M., Almutairi, T. R., Al Sharyah, S. H. A., Al Sharyah, H. S. F., Al Juraib, M. H. M., ... &Jali, H. M. A. (2023). Advancements In Imaging Technology: Revolutionizing Radiology Practice. *Journal of Namibian Studies: History Politics Culture*, *36*, 1953-1965.

Becker, M., &Garibotto, V. (Eds.). (2023). *Clinical Value of Hybrid PET/MRI, An Issue of Magnetic Resonance Imaging Clinics of North America, E-Book: Clinical Value of Hybrid PET/MRI, An Issue of Magnetic Resonance Imaging Clinics of North America, E-Book* (Vol. 31, No. 4). Elsevier Health Sciences.

Bhandari, A. (2024). Revolutionizing Radiology With Artificial Intelligence. *Cureus*, *16*(10), e72646.

Brock, K. K., Chen, S. R., Sheth, R. A., &Siewerdsen, J. H. (2023). Imaging in interventional radiology: 2043 and beyond. *Radiology*, *308*(1), e230146.

Cazzato, R. L., Garnon, J., Ramamurthy, N., Koch, G., Tsoumakidou, G., Caudrelier, J., ...&Gangi, A. (2016). Percutaneous image-guided cryoablation: current applications and results in the oncologic field. *Medical oncology*, *33*, 1-16.

Giovannini, E., Giovacchini, G., &Ciarmiello, A. (2016). Hybrid Imaging in Cerebrovascular Disease: Ischemic Stroke. *PET-CT and PET-MRI in Neurology: SWOT Analysis Applied to Hybrid Imaging*, 251-262.

Gupte, A. A., & Hamilton, D. J. (2016).Molecular imaging and precision medicine. *Cardiology*, *133*(3), 178-180.

Hanna, T. N., Friedberg, E., Dequesada, I. M., Chaves, L., Pyatt, R., Duszak, R., & Hughes, D. R. (2021). Disparities in the use of emergency department advanced imaging in Medicare beneficiaries. *American Journal of Roentgenology*, *216*(2), 519-525.

Hosny, A., Parmar, C., Quackenbush, J., Schwartz, L. H., &Aerts, H. J. (2018).Artificial intelligence in radiology. *Nature Reviews Cancer*, *18*(8), 500-510.

Kastelik-Hryniewiecka, A., Jewula, P., Bakalorz, K., Kramer-Marek, G., &Kuźnik, N. (2022).Targeted PET/MRI imaging super probes: a critical review of opportunities and challenges. *International Journal of Nanomedicine*, 8465-8483.

Kitson, S. L. (2024). Modern Medical Imaging and Radiation Therapy. *Cyber Security| Big Data| AI. Open Med Science*.

Lastrucci, A., &Giansanti, D. (2024). Radiological Crossroads: Navigating the Intersection of Virtual Reality and Digital Radiology through a Comprehensive Narrative Review of Reviews. *Robotics*, *13*(5), 69.

Lastrucci, A., &Giansanti, D. (2024). Radiological Crossroads: Navigating the Intersection of Virtual Reality and Digital Radiology through a Comprehensive Narrative Review of Reviews. *Robotics*, *13*(5), 69.

MacRitchie, N., Frleta-Gilchrist, M., Sugiyama, A., Lawton, T., McInnes, I. B., &Maffia, P. (2020).Molecular imaging of inflammation-Current and emerging technologies for diagnosis and treatment. *Pharmacology & Therapeutics*, *211*, 107550.

Mahajan, A., & Cook, G. (2017).Clinical applications of PET/CT in oncology. *Basic science of PET imaging*, 429-450.

Mandal, S., Greenblatt, A. B., &An, J. (2018). Imaging intelligence: AI is transforming medical imaging across the imaging spectrum. *IEEE pulse*, *9*(5), 16-24.

Mashoufi, R., &Mashoufi, R. (2023). Interventional radiology for disease management: a narrative review. *Cureus*, *15*(11).

Ming, Y., Wu, N., Qian, T., Li, X., Wan, D. Q., Li, C., ...& Wu, N. (2020). Progress and future trends in PET/CT and PET/MRI molecular imaging approaches for breast cancer. *Frontiers in oncology*, *10*, 1301.

Najjar, R. (2023). Redefining radiology: a review of artificial intelligence integration in medical imaging. *Diagnostics*, *13*(17), 2760.

Oladele, O. K. (2024). AI-Powered Medical Imaging: A Comprehensive Review of Applications, Benefits, and Challenges.

Olatunji, G., Osaghae, O. W., &Aderinto, N. (2023).Exploring the transformative role of 3D printing in advancing medical education in Africa: a review. *Annals of Medicine and Surgery*, *85*(10), 4913-4919.

Padmanabhan, P., Nedumaran, A. M., Mishra, S., Pandarinathan, G., Archunan, G., &Gulyás, B. (2017). The advents of hybrid imaging modalities: a new era in neuroimaging applications. *Advanced Biosystems*, *1*(8), 1700019.

Pinto-Coelho, L. (2023). How artificial intelligence is shaping medical imaging technology: A survey of innovations and applications. *Bioengineering*, *10*(12), 1435.

Recht, M. P., Dewey, M., Dreyer, K., Langlotz, C., Niessen, W., Prainsack, B., & Smith, J. J. (2020).Integrating artificial intelligence into the clinical practice of radiology: challenges and recommendations. *European radiology*, *30*, 3576-3584.

Saleh, G. A., Batouty, N. M., Gamal, A., Elnakib, A., Hamdy, O., Sharafeldeen, A., ...& El-Baz, A. (2023). Impact of imaging biomarkers and AI on breast cancer management: A brief review. *Cancers*, *15*(21), 5216.

Sarikaya, I., Schierz, J. H., &Sarikaya, A. (2021). Liver: glucose metabolism and 18F-fluorodeoxyglucose PET findings in normal parenchyma and diseases. *American journal of nuclear medicine and molecular imaging*, *11*(4), 233.

Tarighatnia, A., Mahmoudi, G., Kiani, M., & Nader, N. D. (2023).Current challenges and new opportunities of hybrid nanoparticles for diagnosis and treatment of cancer. *Frontiers in Biomedical Technologies*.

Varghese, K., &Adhyapak, S. (2017). *Therapeutic Embolization* (No. 25561). Cham, Switzerland: Springer International Publishing.

Vāvere, A. L., & Scott, P. J. (2017, September). Clinical applications of small-molecule PET radiotracers: current progress and future outlook. In *Seminars in Nuclear Medicine* (Vol. 47, No. 5, pp. 429-453). WB Saunders.