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The Role of Magnetic Resonance Imaging in Early Detection of Cancer: Present and Prospective Challenges for Future Research

Yvanne Komenan [a*]

[a] *Kennesaw State University, Georgia.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

Aim: Records have been reported on the inflicting attributes of cancer in society and how early detection is necessary for preventive measure and as a proactive step. The use of Magnetic Resonance Imaging (MRI) has been proved as an effective and proficient diagnostic method for the early detection of cancer. This paper is an eye-opener for future researchers willing to investigate the use of magnetic resonance imaging in early detection of cancer. It critically discusses the present and prospective challenges in this area.
Objectives: In this paper, historical records of cancer and the application of MRI in the early detection of cancer are presented. The mechanism of MRI operation together with comprehensive concepts behind its application for early cancer detection are also presented. Recent challenges regarding the subject matter are presented for the benefits of future researchers.
Methodology: Literature review on recent studies conducted between 2009 and 2024 on using MRI for early cancer detection was discussed revealing the objectives, methodologies, results and conclusions from various studies.

**Corresponding author: Email: ykomenan@gmail.com;*

Conclusions: Several limitations and constraints from previous studies and those perceived are presented in this paper for future consideration of research studies in this area. In conclusion, twenty research limitations are stated therein which are gaps that should be bridged by future researchers.

Keywords: Cancer; magnetic resonance imaging; diagnosis tests; biochemical; treatment.

1. INTRODUCTION

"Cancer is a major problem afflicting human society currently. Cancers are one of the leading causes of death worldwide. On annual basis, over 9.5 million people die from cancer-related deaths and this number is expected to rise to 16.4 million by 2040 due to increased factors such as pesticides, air pollution and unhealthy lifestyle choices, including alcohol, processed foods consumption and so on" [1]. Cancer occurs with oncogenes that develop into cancerous cells which divide uncontrollably. These cancer cells sometimes clump together to form harmful tumors known as malignant tumors, which take nutrients and space from healthy functioning cells, and this causes the healthy cells to be unable to convert energy to function and sustain the body for life. It is estimated that over 19 million individuals were diagnosed with cancer in 2020. By 2040, it is expected that the number of new diagnoses annually will be 29.5 million [2]. Men are 19% more likely to develop cancer than women. Furthermore, 1 in 8 men who are diagnosed die due to cancer, and 1 in 11 diagnosed women die due to cancer. Early development of cancer is a crucial stage for patients because the mortality rate can be greatly decreased during this period if diagnosed and treatment is initiated because the earlier the diagnosis, the easier to prevent the metastasizing and growth of cancer [3].

Currently, most cancer diagnosis tests can be placed under two categories. Imaging or biochemical. Imaging and biochemical diagnostic tests are invaluable advancements because doctors can diagnose cancer without needing to wait for symptoms to develop [4]. Once cancer reaches the stage where symptoms would develop, this would be more difficult to treat, and thus treatment might be less successful if left to this stage. This can prevent the regression of the tumour since the mutated can be limited to a confined area of the body. Biochemical examples of cancer diagnosis tests include biopsy, sputum cytology, urinalysis, complete blood count testing, etc [5]. The biochemical diagnosis examines a sample from the body, for example, the blood, mucus, or urine, at a microscopic level, searching for its biomarker, usually mutated cells or abnormal fragments of DNA. The second type of cancer diagnosis test is imaging. Examples of imaging diagnostics are CT scans, X-rays, MRIs, PET scans, Ultrasounds and so on. Imaging tools can detect anomalies and physical abnormalities, such as density, electronegativity, and other irregular body properties. Two main diagnostic tests that dominate the imaging field are X-rays and MRIs [6].

Common diagnostic tests for cancer have been identified. A biopsy is done by removing a piece of tissue from the tumor and examining it under a microscope for cancer cells. There are several ways to perform a biopsy, such as with a long hollow needle, or as part of a surgical procedure. A biopsy is typically the only way to confirm a cancer diagnosis [7]. Endoscopy is a procedure that's done by inserting a thin tube with a camera and a light on the end into your body through an opening, such as your mouth, or through an incision. The tube is gently fed to the appropriate area, and the camera connects to a computer screen. This allows doctors to get an up-close look at organs, tissues, veins, and any tumor growth. In urinalysis the levels of substances like blood and proteins in urine are measured. It can help doctors measure how well kidneys and liver are functioning, which can be affected by some types of cancer. Genetic testing is done to look for the genetic markers of cancer [8]. In the case of some cancers, this may help doctors identify the type of cancer present in the body. Lastly, in addition to an MRI, additional imaging tests such as X-rays, CT scans, and PET scans can be conducted to help doctors visualize tumors. However, MRIs are useful imaging tests that can help detect cancer. Because an MRI is able to see soft tissue, it can create detailed images of tumor growth. They're helpful for detecting many types of cancer. However, MRIs can't detect all cancers. They're best at seeing tumor growth in organs and tissues. This means they're not the best tool for detecting blood or bone cancers. They have some challenges that call for future and further research studies. Research has

shown that MRI scans are 77% accurate when distinguishing between malignant (cancerous) and benign (non-cancerous) tumors. This is one reason why it is the preferred modality for imaging and evaluating soft-tissue tumors [9].

MRI was first used on a human subject in 1977. In 1980, it became commercially available to the public and is now widely used for examining the interior of the body and for cancer diagnosis. X-rays were utilized much earlier than MRI, first used by clinics in 1986 in the United States of America [10]. “X-rays were initially used to examine the skeletal system and organs. Magnetic Resonance Imaging (MRI) is a non-invasive medical imaging technique which utilizes powerful magnetic fields and radio waves to generate detailed images of the body's internal structures. Unlike other medical imaging tests such as X-rays or CT scans, MRI does not use ionizing radiation which makes it safer for patients. The images produced by an MRI machine are incredibly detailed, providing physicians with a comprehensive view of the body's tissues and organs. This makes it particularly useful in detecting and monitoring cancer, as well as other conditions affecting the organs, soft tissues, and bones. MRI scanners are particularly proficient at visualizing tumors and identifying their precise locations within the body. This is largely due to the use of a contrast dye, which is injected via IV to enhance the appearance of abnormal tissues” [11]. “When the patient is placed into the MRI scanner, the contrast dye in the abnormal tissues reacts differently to the process than the healthy tissues. This creates a clear distinction between normal and abnormal tissues in the resulting images. The MRI scan meticulously captures detailed images of these structures, highlighting these areas of concern and allowing doctors to make an accurate diagnosis” [12].

“This advanced imaging capability of MRI allows doctors to not only detect the presence of a tumor but also accurately determine its size, location, and potential impacts on surrounding tissues. This critical information forms the foundation of an effective cancer treatment plan, positioning MRI as an indispensable tool in the initial diagnosis of cancer. MRI scans play a pivotal role in monitoring disease progression in cancer patients, as these images allow changes in tumor size over the course of cancer treatment to be monitored accurately” [13]. “For example, imagine a brain cancer patient who is going through radiation therapy. After an initial scan and a few weeks of treatment, an additional MRI scan can be used to determine the effectiveness of the radiation on the tumor's size. By comparing MRI images taken before and after treatment, doctors can determine whether the tumor has shrunk, grown, or remained the same. This critical evaluation helps in making informed decisions about whether to continue with the current treatment or consider other therapeutic options” [14].

“MRI also plays a crucial role in detecting the recurrence of cancer after treatment, or the return of cancer after an apparent period of remission. Identifying the onset of cancer recurrence as soon as possible is vital in ensuring prompt intervention and improving the patient's prognosis. MRI's detailed imaging capabilities make it an excellent tool for this task. For post-treatment, patients are typically scheduled for regular MRI scans at intervals decided by their health care team. A usual schedule might call for a scan every 3-6 months during the first couple of years, and then less frequently as time goes on. MRI scans can help detect subtle changes in the body's tissues and organs that may indicate the return of cancer. By comparing current images with those taken directly post-treatment, physicians can identify any new growths at their earliest stage and initiate immediate intervention” [15]. “MRI technology has transformed the landscape of cancer detection, treatment, and monitoring. This advanced, non-invasive imaging technique allows doctors to accurately visualize tumors, track their progress, and identify recurrence early on. An MRI scan is a common method used in the diagnosis, assessment and treatment of many different types of cancer. It can be used to determine whether a tumor is cancerous or not, and helps doctors to understand whether cancer has spread” [16].

“An MRI scanner is a long cylinder or tube that holds a large, very strong magnet. The patient lies on a table that slides into the tube, and the machine surrounds him/her with a powerful magnetic field. The machine uses a powerful magnetic force and a burst of radiofrequency waves to pick up signals from the nuclei (centers) of hydrogen atoms in the body. A computer converts these signals into a black and white picture. Many pictures are created during the test. A specific kind of MRI can be used to look inside the breast. An MRI with contrast dye is the best way to see certain types of tumors, such as brain and spinal cord tumors” [17]. “Contrast is a

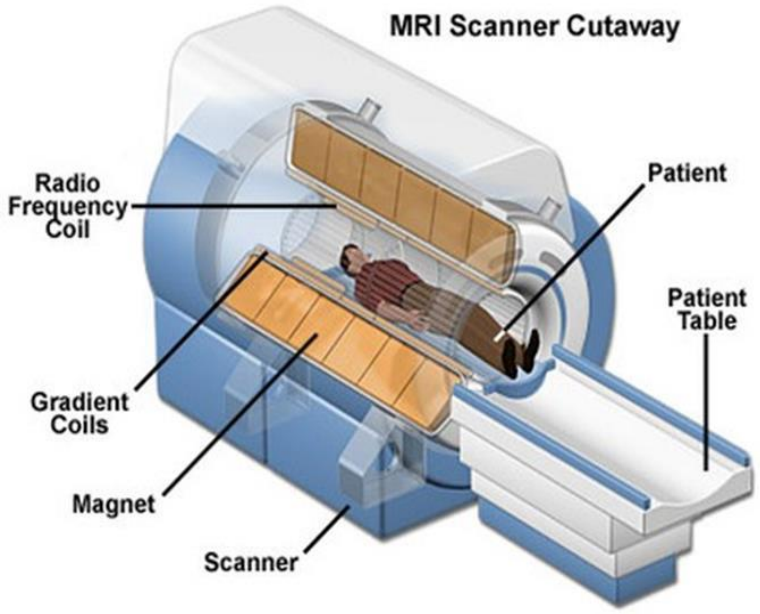

Fig. 1. Magnetic Resonance Imaging machine

dye that is put into the body through a vein to make the MRI images clearer. Once absorbed by the body, the contrast speeds up the rate at which tissues in the body respond to the magnetic and radio waves of the MRI. These stronger signals give clearer pictures. MRI scans are most often done on an outpatient basis" [12]. "If being in a small, enclosed space is a problem, the patient might need to take medicine to help relax while in the scanner. Sometimes talking with the technologist or a patient counselor, or seeing the MRI machine before the test can help. Sometimes a contrast dye material is used for MRI imaging. The patient may have to swallow the contrast, or may have an intravenous (IV) catheter put in a vein in the arm so the contrast can be given into the bloodstream. The contrast material used for an MRI exam is called gadolinium" [10]. Fig. 1 is the diagram of an MRI machine.

2. LITERATURE REVIEW: RECENT STUDIES ON USING MRI FOR EARLY CANCER DETECTION

Researchers around the globe have used MRI as a diagnostic method for early detection of different forms of cancer. Enriquez et al. [18] investigated "the role of MRI in breast cancer management. It was resolved that magnetic resonance imaging is highly sensitive for cancer staging, problem-solving, posttreatment surveillance, and other indications. It can detect primary breast cancers and additional foci of cancer that are occult to standard imaging. They concluded that continued improvements in technology and studies to assess outcomes would help to better define MRI's role in breast cancer. However, there were some limitations in their study for future research investigations. MRI was sensitive but not so specific for the task. The overall sensitivity of MRI for breast cancer was relatively high, with estimates ranging from 85% to 100%. In invasive ductal carcinoma, its sensitivity approached 100%. Sensitivities for invasive lobular carcinoma and ductal carcinoma in situ were lower and not yet well defined. In contrast, MRI's specificity for breast cancer is much more variable, ranging from 37% to 100%. The discrepancies among estimates of specificity were attributed to multiple confounding methodologic factors in the studies to date, such as differences in imaging protocols, patient selection criteria, patient ages, interpretation criteria, and the level of experience of the interpreting radiologist".

Wu et al. [19] investigated "magnetic resonance imaging for lung cancer detection referencing a population of more than 10,000 healthy individuals. A retrospective chart review was performed on images of lung parenchyma, which were extracted from whole-body MRI examinations between October 2000 and December 2007. 11,766 consecutive healthy individuals (mean age, 50.4 years; 56.8% male) were scanned using one of two 1.5-T scanners

(Sonata and Sonata Maestro, Siemens Medical Solutions, Erlangen, Germany). The standard protocol included a quick whole-lung survey with T2-weighted 2-dimensional half Fourier acquisition single shot turbo spin echo (HASTE) and 3-dimensional volumetric interpolated breath-hold examination (VIBE). Total examination time was less than 10 minutes, and scanning time was only 5 minutes. Prompt referrals and follow-ups were arranged in cases of suspicious lung nodules. A total of 559 individuals (4.8%) had suspicious lung nodules. A total of 49 primary lung cancers were diagnosed in 46 individuals: 41 prevalence cancers and 8 incidence cancers. The overall detection rate of primary lung cancers was 0.4%. For smokers aged 51 to 70 years, the detection rate was 1.4%. TNM stage I disease accounted for 37 (75.5%). The mean size of detected lung cancers was 1.98 cm (median, 1.5 cm; range, 0.5-8.2 cm). The most histological types were adenocarcinoma in 38 (77.6%). In conclusion, rapid zero-dose MRI can be used for lung cancer detection in a healthy population. However, consideration was given to smokers majorly in this study".

In another study, Lehman et al. [20] investigated "MRI screening in women with a personal history of breast cancer. Case-series registry data, collected at time of MRI and at 12-month follow-up, from our regional Clinical Oncology Data Integration project were analyzed. MRI performance was compared in women with personal history (PH) with those with genetic risk or family History (GFH). Chi-square testing was used to identify associations between age, prior history of MRI, and clinical indication with MRI performance; logistic regression was used to determine the combined contribution of these variables in predicting risk of a false-positive exam. All statistical tests were two-sided. The result revealed that 1521 women who underwent screening MRI from July 2004 to November 2011, 915 had PH and 606 had GFH of breast cancer. Overall, MRI sensitivity was 79.4% for all cancers and 88.5% for invasive cancers. False-positive exams were lower in the PH vs GFH groups (12.3% vs 21.6%, P < .001), specificity was higher (94.0% vs 86.0%, P < .001), and sensitivity and cancer detection rate were not statistically different (P > .99). Age (P < .001), prior MRI (P < .001), and clinical indication (P < .001) were individually associated with initial false-positive rate; age and prior MRI remained statistically significant in multivariable modeling (P = .001 and P < .001, respectively). In conclusion, MRI performance is superior in women with PH compared with women with GFH. Screening MRI warrants consideration as an adjunct to mammography in women with a PH of breast cancer".

The objective of the study conducted by Callender et al [21] was to evaluate "the benefit-harm profiles and cost-effectiveness associated with MRI before biopsy compared with biopsy-first screening for prostate cancer using age-based and risk stratified screening strategies. A decision analytical model was used as a life-table approach and was conducted between December 2019 and July 2020. A hypothetical cohort of 4.48 million men in England aged 55 to 69 years were analyzed and followed-up to 90 years of age. Age-based screening consisted of screening every 4 years with prostate-specific antigen between the ages of 55 and 69 years. Risk-stratified screening used age and polygenic risk profiles. The benefit-harm profile (deaths from prostate cancer, quality-adjusted life-years, overdiagnosis, and biopsies) and cost-effectiveness (net monetary benefit, from a health care system perspective) were analyzed. Both age-based and risk-stratified screening were evaluated using a biopsy-first and an MRI-first diagnostic pathway. Results were derived from probabilistic analyses and were discounted at 3.5% per annum. The hypothetical cohort included 4.48 million men in England, ranging in age from 55 to 69 years (median, 62 years). Compared with biopsy-first age-based screening, MRI-first age-based screening was associated with 0.9%(1368; 95% uncertainty interval [UI], 1370-1409) fewer deaths from prostate cancer, 14.9% (12 370; 95%UI, 11 100-13 670) fewer over diagnoses, and 33.8% (650 500; 95%UI, 463 200-907 000) fewer biopsies. At 10-year absolute risk thresholds of 2% and 10%, MRI-first risk-stratified screening was associated with between 10.4% (7335; 95%UI, 6630-8098) and 72.6%(51 250; 95% UI, 46 070-56 890) fewer over diagnosed cancers, respectively, and between 21.7% fewer MRIs (412 100; 95% UI, 411 400-412 900) and 53.5% fewer biopsies (1 016 000; 95% UI, 1 010 000-1 022 000), respectively, compared with MRI-first age-based screening. The most cost-effective strategies at willingness-to-pay thresholds of £20 000 (US $26 000) and £30 000 (US $39 000) per quality-adjusted life-year gained were MRI-first risk stratified screening at 10-year absolute risk thresholds of 8.5% and 7.5%, respectively. In this decision analytical model of a hypothetical cohort, an MRI-first diagnostic pathway was

associated with an improvement in the benefit-harm profile and cost-effectiveness of screening for prostate cancer compared with biopsy-first screening. These improvements were greater when using risk-stratified screening based on age and polygenic risk profile and may warrant prospective evaluation".

A critical review was conducted by Petralia et al. [22] on recommendations for "the use of whole-body magnetic resonance imaging (WB-MRI) for cancer screening in adult and pediatric subjects with cancer predisposition syndromes, representing a substantial aid for prolonging health and survival with a high oncological risk. It was stated that the number of studies exploring the use of WB-MRI for cancer screening in asymptomatic subjects from the general population is growing. The primary aim of their review was to analyze the acquisition protocols found in the literature, in order to identify common sequences across published studies and to discuss the need of additional ones for specific populations. The secondary aim was to provide a synthesis of current recommendations regarding the use of WB-MRI for cancer screening".

Zhang [23] compared the efficacies of magnetic resonance imaging and X-ray technologies as the currently mainstream and generally applicable means of early cancer detection. However, there was a lack of unified comparison and interpretation for their respective applicable cancer detection types. A comprehensive comparison and explanation of the working principles of the two technologies, as well as their advantages and disadvantages were presented. Further, the application of MRI and X-ray technology in the early detection of different common cancer types, including lung, breast, and brain cancers was explained. The study found that MRI is crucial in the early detection of brain cancer, and X-ray is a common method for lung cancer screening. With further advances in technology, cancer-related deaths can be further curbed.

Lubinski et al. [24] investigated "MRI surveillance and breast cancer mortality in women with BRCA1 and BRCA2 sequence variations. Women with a BRCA1 or BRCA2 sequence variation were identified from 59 participating centers in 11 countries. Participants completed a baseline questionnaire between 1995 and 2015 and a follow-up questionnaire every 2 years to document screening histories, incident cancers, and vital status. Women who had breast cancer, a screening MRI examination, or bilateral mastectomy prior to enrollment were excluded. Participants were followed up from age 30 years (or the date of the baseline questionnaire, whichever was later) until age 75 years, the last follow-up, or death from breast cancer. Data were analyzed from January 1 to July 31, 2023. Cox proportional hazards modeling was used to estimate the hazard ratios (HRs) and 95% CIs for breast cancer mortality associated with MRI surveillance compared with no MRI surveillance using a time-dependent analysis. The result revealed a total of 2488 women (mean [range] age at study entry 41.2 [30-69] years), with a sequence variation in the BRCA1 (n = 2004) or BRCA2 (n = 484) genes were included in the analysis. Of these participants, 1756 (70.6%) had at least 1 screening MRI examination and 732 women (29.4%) did not. After a mean follow-up of 9.2 years, 344 women (13.8%) developed breast cancer and 35 women (1.4%) died of breast cancer. The age-adjusted HRs for breast cancer mortality associated with entering an MRI surveillance program were 0.20 (95% CI, 0.10-0.43; P < .001) for women with BRCA1 sequence variations and 0.87 (95% CI, 0.10-17.25; P = .93) for women with BRCA2 sequence variations. In conclusion, results of this cohort study suggest that among women with a BRCA1 sequence variation, MRI surveillance was associated with a significant reduction in breast cancer mortality compared with no MRI surveillance. Further studies of women with BRCA2 sequence variations are needed to ascertain these women obtain the same benefits associated with the surveillance of MRI".

In another recent study, Patel et al. [25] compared "magnetic resonance imaging–based risk calculators to predict prostate cancer risk. The objective of the study was to externally validate and compare MRI-based PCa risk calculators (Prospective Loyola University Multiparametric MRI [PLUM], UCLA [University of California, Los Angeles]-Cornell, Van Leeuwen, and Rotterdam Prostate Cancer Risk Calculator–MRI [RPCRC-MRI]) in cohorts from Europe and North America. This multi-institutional, external validation diagnostic study of 3 unique cohorts was performed from January 1, 2015, to December 31, 2022. Two cohorts from Europe and North America used MRI before biopsy, while a third cohort used an advanced serum biomarker, the Prostate Health Index (PHI), before MRI or biopsy. Participants included adult men without a PCa diagnosis receiving MRI

before prostate biopsy. A total of 2181 patients across the 3 cohorts were included, with a median age of 65 (IQR, 58-70) years and a median prostate-specific antigen level of 5.92 (IQR, 4.32-8.94) ng/mL. All models had good diagnostic discrimination in the European cohort, with AUCs of 0.90 for the PLUM (95% CI, 0.86-0.93), UCLA-Cornell (95%CI, 0.86-0.93), Van Leeuwen (95%CI, 0.87-0.93), and RPCRC-MRI (95%CI, 0.86-0.93) models. All models had good discrimination in the North American cohort, with an AUC of 0.85 (95%CI, 0.80-0.89) for PLUM and AUCs of 0.83 for the UCLA-Cornell (95%CI, 0.80-0.88), Van Leeuwen (95%CI, 0.79-0.88), and RPCRC-MRI (95%CI, 0.78-0.87) models, with somewhat better calibration for the RPCRC-MRI and PLUM models. In the PHI cohort, all models were prone to underestimate clinically significant PCa risk, with best calibration and discrimination for the UCLA-Cornell (AUC, 0.83 [95%CI, 0.81-0.85]) model, followed by the PLUM model (AUC, 0.82 [95%CI, 0.80-0.84]). The Van Leeuwen model was poorly calibrated in all 3 cohorts. On decision curve analysis, all models provided similar net benefit in the European cohort, with higher benefit for the PLUM and RPCRC-MRI models at a threshold greater than 22% in the North American cohort. The UCLA-Cornell model demonstrated highest net benefit in the PHI cohort. In conclusion, in this external validation study of patients receiving MRI and prostate biopsy, the results support the use of the PLUM or RPCRC-MRI models in MRI-based screening pathways regardless of European or North American setting".

3. FUTURE AND PROSPECTIVE CHALLENGES: BRIDGING THE RESEARCH LOOP-HOLES

So far, the previous studies conducted on using MRI for early-stage cancer detection have proven the efficiency of this diagnosis method. However, some of these past researches conducted lack some limitations which have not been thoroughly addressed. These are imperative for future research studies to fill the loop holes and also enhance the advancement of this diagnosis technique.

- In the past study, factors which account for the discrepancies among estimates of specificity of MRI have been identified to include studies to date, patient selection criteria, imaging protocols, patient ages, interpretation criteria, and interpreting radiologist level of experience. Not only this, study has proved that the application of MRI for early breast cancer detection was sensitive but not so specific for the task. Thus, there is need for further investigation. A study that varies these factors using a software that optimizes processes such as design expert can be utilized. Investigating this will give the optimum factors that give the maximum sensitivity and specificity.
- Also, study has shown that "false-positive results may be caused by benign conditions such as fibro adenomas, inframammary lymph nodes, proliferative and non-proliferative fibrocystic changes, and mastitis, as well as by radial scars, a typical ductal hyperplasia, and lobular carcinoma in situ. In premenopausal women, the menstrual cycle may bring about regional physiologic variation in enhancement of the normal breast parenchyma, which may either simulate the appearance of a lesion or obscure a true lesion. Thus, breast MRI may detect cancer that is occult to mammography, but it also carries the risk of worrisome incidental findings that may only be resolved by biopsy. Such uncertain findings are troubling for both the radiologist and the patient when mammography, ultrasonography, and the physical examination are all normal. Clearly, breast MRI cannot be counted on to reassure the "worried well" patient. This also is calling for future studies". [26]
- Furthermore, MRI is not for screening in the general population in relation to early breast cancer detection. While its high sensitivity for invasive ductal carcinoma would seem to make breast MRI attractive for breast cancer screening, it has the disadvantages of lower sensitivity for invasive lobular carcinoma and ductal carcinoma in situ, as well as the potential to raise suspicions of breast cancer that may be difficult to resolve. For these reasons, MRI is not suitable for routine breast cancer screening in asymptomatic women, although it is recommended for patients in some high-risk groups. These are strong limitations for future research studies.
- It has been proved that improved MRI scanners can show structures as small as 0.5 mm, which helps the radiologist discern lesion morphology. Also, contrast-enhanced and temporally resolved imaging

provides estimates of spatially localized enhancement patterns and kinetics, which in turn may offer clues as to whether a lesion is benign or malignant. However, future studies are required on improving the quality of MRI to detect structures lesser than 0.5 mm.

- Numerous reports have shown that MRI can detect additional foci of breast cancer in a substantial number of women with a new diagnosis of breast cancer. While some argue that detecting these additional lesions should improve outcomes after the first operation and, hopefully, lead to lower rates of recurrence, the long-term consequences of MRI-directed changes in treatment have not been fully studied.
- "In the 1980s, mastectomy was the routine treatment for breast cancer until the arrival of breast conservation surgery combined with radiation therapy which offered major advantages with similarly low recurrence rates. Based on the results of controlled clinical trials with mortality as the end point, breast conservation therapy and mastectomy confer equivalent risk to the patient. Any increase in the rate of mastectomy prompted by MRI findings would represent a setback in the standard of care. And since radiation therapy is presumed to eradicate or delay progression of residual disease in most women who undergo conservation therapy, preoperative MRI would have little or no impact on rates of recurrence or death. Thus, MRI should not be used routinely in the workup of new breast cancers. This is of major concern too". [26]
- "The detection rate of MRI for clinically suspected cancer to a screened hypothetical cohort has been extrapolated" [21]. "Magnetic resonance imaging has been shown to distinguish between clinically significant and insignificant cancers. However, the proportion of cancers deemed clinically insignificant that will progress to become clinically significant and the implications of an MRI-first diagnostic pathway for long-term prostate cancer outcomes remain unknown". [21]
- There is also serious argument about the preoperative MRI. The upper threshold amount of residual disease that can be eradicated by radiation therapy is not yet well established. There are as yet no MRI criteria for assessing the likelihood of standard treatment failure in individual patients with multifocal or multicentric disease, or with occult cancer in the contralateral breast. Further investigation in this regard is necessary.
- Knowledge of the extent of disease at presentation will help the patient to make a more informed decision when presented with treatment options. A staging MRI examination showing only a single cancer lesion may permit the patient to choose conservation therapy with a high degree of confidence that no macroscopic disease will be missed at surgery.
- As MRI is making inroads into functional assessment, response to treatment and treatment guidance for a variety of cancers, including brain and prostate, MRI use in lung cancer has lagged behind because of inherent barriers arising from the physics of the lung itself. This also calls for further and future investigation.
- Current data on MR-guided stereotactic body radiation therapy in early lung cancer are limited, but early results are promising, opening the door for dose escalation, improved normal tissue visualization and normal tissue sparing, improved motion management, and potentially improved outcomes for patients with early-stage lung cancer treated with radiotherapy.
- Despite magnetic resonance imaging being a mainstay in the oncologic care for many disease sites, it has not routinely been used in early lung cancer diagnosis, staging, and treatment. This is critically needed to be looked into.
- The study conducted by Petralia et al. [22] suggested a "core protocol" that includes T1-weighted GRE, T2-weighted TSE and DWI sequences for the evaluation of head, neck, chest, abdomen and pelvis. Additional sequences and sub-protocols was recommended to be performed as extensions to the core protocol, in order to adapt the WB-MRI examination to the specific risk profile of the population being evaluated. More intense research is still needed in this regard. There are limited studies to this recommendation.
- Recently, there are several limitations in the study conducted by Lubinski et al. [24]. Participants with breast cancer were followed up for a mean (range) of 5.3 (0.1-21) years after diagnosis. Overall, the women in the cohort were followed up until age 50 years; ideally, we should follow up

all women until age 75 years to establish the lifetime risks of breast cancer. The screening MRI examinations were carried out in several countries according to local protocols and image interpretation was not centralized. Most participants were White and there were too few women of other races or ethnicities to compare effectiveness in different racial and ethnic.

- Studies have been applying artificial intelligence (AI) as machine learning tool for Magnetic Resonance Imaging in early detection of cancer. However, the interpretability of AI and the ability to interrogate such methods for reasons behind a specific outcome, as well as the anticipation of failures are still challenging. This is a research gap that needs to be bridged.
- The models used by Patel et al. [25] was confirmed “effective for the comparison of magnetic resonance imaging–based risk calculators to predict prostate cancer risk. However, tools specific to screening pathways incorporating advanced biomarkers as reflex tests are needed due to under prediction”.
- With the increasing demand for CT201 and MR202 imaging, care providers are constantly generating large amounts of data. Standards, including the Picture Archiving and Communication System (PACS) and the Digital Imaging and Communications in Medicine (DICOM), have ensured that these data are organized for easy access and retrieval. However, such data are rarely curated in terms of labeling, annotations, segmentations, quality assurance, or fitness for the problem at hand. The curation of medical data represents a major obstacle in developing automated clinical solutions, because it requires trained professionals, making the process expensive in both time and cost.
- Although MRI does not expose patients to radiation, the strong magnetic field can stimulate the nerves and cause a twitching sensation which some may find uncomfortable.
- The MRI machine can also cause the medical instruments to malfunction because of their high radiofrequency; this can fail the medical instrument to perform its intended tasks. The strong magnetic field can disrupt medical instruments implanted in the body and cause it to heat up, leading to burns on surrounding tissues. This is because most medical instruments are made of conductive material (able to transmit heat and electricity), so when introduced to a high electromagnetic field, that results in more concentrated electrical currents. This allows energy to be transmitted through the insulator, which results in excess heating.
- Lastly, the presence of the medical instruments themselves can decrease the resolution of MRI images, so images may be uninformative or misleading and can lead to a misdiagnosis and inappropriate treatment. Because MRI detects physical properties of tumors they miss biochemical biomarkers such as DNA or cells, which other chemical biosensors could detect.

4. CONCLUSION

This paper has critically discussed the inflicting nature of different kinds of cancer. The tracking historical records of cancer and the application of MRI in the early detection of cancer were examined. The mechanism of MRI operation alongside comprehensive concepts of using MRI for early cancer detection are also presented. Recent studies conducted between 2009 and 2024 on using MRI for early cancer detection were reviewed. The objectives, methodologies, results and conclusions from previous studies were presented. Several limitations and constraints from previous studies and those perceived are presented in this paper for future consideration of research studies in this area. In conclusion, twenty research limitations are stated therein which are gaps that should be bridged by future researchers.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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