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# A REVIEW OF MAGNETIC RESONANCE IMAGING (MRI) PRACTICES IN SAUDI ARABIA: ADVANCEMENTS, CHALLENGES, AND FUTURE PERSPECTIVES

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## ABSTRACT

**Background:** Magnetic Resonance Imaging (MRI) plays a pivotal role in modern diagnostics, yet its availability and quality vary significantly across regions. In Saudi Arabia, the ongoing Vision 2030 health transformation presents a timely opportunity to assess MRI infrastructure, workforce, and technology adoption to inform future planning and equitable access. **Objective:** This study aims to evaluate MRI services across 50 healthcare facilities in Saudi Arabia, examining infrastructure, workforce capacity, technology adoption—including AI and teleradiology—and alignment with national health policy. **Methods:** A structured dataset was compiled from 50 hospitals, incorporating variables such as MRI machine type, scan volume, workforce, service availability, and regional distribution. Statistical analyses included chi-square tests, correlation coefficients, and t-tests to evaluate hypotheses related to infrastructure disparity, workforce impact, and policy outcomes. **Results:** MRI infrastructure was more advanced in urban centers (73.3%) compared to rural regions (40%), with statistically significant disparity ($\chi^2 = 6.23$, $p = 0.013$). A strong negative correlation was found between the number of MRI technologists and patient waiting times ($r = -0.63$, $p < 0.001$), highlighting workforce importance. AI/ML tools were implemented in 28% of facilities, while 38% utilized teleradiology, indicating early stages of digital transformation.

Post-Vision 2030 upgrades showed a significant improvement in service capability ($t$ = -12.92, $p$ < 0.0001). Common MRI applications included neurological, spinal, and oncological imaging. Regional disparities were evident, with the Makkah/Central region having the highest service concentration. **Conclusions:** MRI practices in Saudi Arabia have made substantial progress, driven by national policy and technological trends. However, rural access, workforce limitations, and inconsistent digital infrastructure remain key challenges. Addressing these through targeted investments, AI scaling, and mobile MRI units can support the realization of Vision 2030's healthcare goals. Future strategies should prioritize equitable access, workforce development, and research-led innovation to establish a robust and inclusive imaging ecosystem.

**KEYWORD:** Magnetic Resonance Imaging (MRI), Saudi Arabia, Health Policy, Vision 2030, Radiology Workforce, Teleradiology, Artificial Intelligence in Imaging, Diagnostic Imaging Access, Healthcare Disparities, Mobile MRI Units, PACS Integration, Healthcare Transformation, Urban-Rural Health Gap.

## I. INTRODUCTION

Magnetic Resonance Imaging (MRI) is one of the most significant diagnostic imaging modalities of modern medicine. Since its development in the closing years of the 20th century, MRI has transformed imaging of internal human anatomy without exposing the patient to harmful ionizing radiation. Founded on the principles of strong magnetic fields and radio waves, the method yields good-quality imaging of soft tissue and thus is extremely beneficial for diagnosing a wide range of disorders—neurological conditions such as brain tumor and multiple sclerosis, through to musculoskeletal trauma, cardiovascular disease, and cancer diseases. MRI ability to achieve cross-sectional imaging in planes of choice, along with highly sophisticated methods such as fMRI, diffusion tensor imaging (DTI), and magnetic resonance spectroscopy (MRS), enables physicians to extract both anatomical and physiological data necessary for early detection, therapy planning, and measuring therapy response.[1]

Around the globe, the application and technology of MRIs have improved significantly in the past few decades. MRIs began with 0.5 Tesla strength fields, but advancements have enabled 1.5 Tesla strength, 3 Tesla strength, and even 7 Tesla ultra-high strength fields. Increased strength increases output quality and scanning efficiency to enable more complex diagnostic applications. In practice in global healthcare, wider applications of AI-assisted imaging programs for imaging analysis, automatic detection of lesions, and decision-making by radiologists have also been observed.[2][3] Such improvements have widened the application of MRIs from diagnostic imaging to applications in research, planning for surgical procedures, and even live interventional procedures. In addition, digital imaging standards such as Picture Archiving and Communication Systems (PACS) and Radiology Information Systems (RIS) have spread worldwide for easy storage, retrieval, and distribution of MRIs, enabling cooperative care and teleconsultation.[4]

Despite its widespread usage, MRI remains a hi-tech, costly technology requiring enormous investment in human resource and infrastructure, as well as maintenance.[5][6] Such conditions have influenced the distribution and accessibility of MRI services around the world, more frequently working to create a discrepancy between urban and rural healthcare providers or low- and high-income countries. Increasing demand for sophisticated imaging for the detection and control of chronic diseases, however, coupled with population aging, continues to fuel expansion of MRI facilities and technological development around the world.[7]

The Saudi healthcare sector has experienced rapid growth and development supported by large-scale government planning and investment. The Kingdom, with a population in excess of 35 million, is facing growing healthcare needs as a result of an increasing burden of non-communicable diseases such as diabetes, cardiovascular disease, and cancer.[8] As part of its Vision 2030 vision—a holistic vision to diversify the economy and enhance the quality of life—the Saudi government put the modernization of healthcare infrastructure and the growth of access to advanced medical technologies at the forefront of its agenda.[9] Vision 2030 demands the development of an efficient and sustainable health system that can deliver quality healthcare to all segments of society. As part of it, the modernization of diagnostic imaging, including MRI, is viewed to be vital in enabling enhanced clinical outcomes, ease of detection of diseases at an early stage, and reducing healthcare expenditure by avoiding complications.[10]

The Saudi public health system, operated predominantly by the Ministry of Health (MOH), is composed of a large network of public hospitals and primary health centers throughout the urban and rural areas. Private healthcare facilities also supplement public facilities, with several of them possessing advanced imaging centers in urban areas. Despite such developments, disparities still exist in the availability of MRI services on a relatively fair scale throughout the country. Urban areas such as Riyadh, Jeddah, and Dammam enjoy sufficient access to advanced MRI machines and skilled professionals, whereas rural and remote areas have no easy access to such sophisticated imaging centers. Such disparity leads to delayed diagnosis, higher travel costs for patients, and inefficiency in the overall health system.[11]

Furthermore, staffing gaps at the level of radiologists and MRI technologists constitute a significant problem. Demand for trained radiologists and MRI technologists rises,[12] but their supply falls short of demand, and

patients have to wait for longer periods for these services. Patients' access to some of these health services, including diagnostic imaging services, is influenced by gender and cultural factors and must be addressed through culturally appropriate delivery of services.[13]

Technology adoption, such as artificial intelligence, teleradiology, and digital health platforms, is still in the early stages in the Saudi Arabian MRI market. A few large hospital and university centers have begun to adopt AI solutions for image interpretation support and workflow optimization, but adoption across the country has not been observed yet. Upgrades to digital infrastructure in the form of PACS and cloud storage are increasingly being used to advance image availability and collaboration amongst facilities but are not yet prevalent.[14]

Therefore, given the rapid rate of development and existing issues, a systematic survey of MRI practice in Saudi Arabia is not only timely, but also critical. There is no unified data as yet regarding MRI infrastructure, human capacity, technological adoption, and diffusion of services within the Kingdom. This hinders policy and planning aimed at optimising utilization of the MRI and equitable access. Furthermore, understanding how national visions such as Vision 2030 shape MRI services will guide future direction and investment.[15]

Therefore, the present review paper aims to review systematically the development and status of the practice of MRI in Saudi Arabia, referencing main developments, identifying emerging challenges, and setting out potential avenues for future directions. There are four objectives: first, to review the availability and extent of MRI facilities for urban and rural areas; second, to review the workforce capacity, including the presence and competency of radiologists and MRI technologists; third, to review the extent of technological adoption, including the use of AI and teleradiology; and fourth, to establish the impact of national policy, Vision 2030, on the modernization and advancement of MRI services. By providing a holistic overview of MRI practice, the review seeks to inform the evidence base underpinning strategic decision-making for healthcare planning, workforce planning, and technology investment. In doing so, the aim is to increase diagnostic capacity, facilitate access to advanced imaging for all, and improve patient outcomes across Saudi Arabia.

## II. LITERATURE REVIEW

Magnetic Resonance Imaging (MRI) is currently a standard clinical and diagnostic application across the world. Its use, application, and utilization vary largely across the world, especially in countries with varying health needs. This literature review compiles existing studies on MRI technology, utilization, infrastructure, human resources, and policy aspects and explains the applicability of the research findings to the current state and future of MRI interventions in Saudi Arabia.

1. MRI Access and Development in Low- and Middle-Income Countries (LMICs)

Murali et al. (2023) recognize the current global inequalities in the availability of the MRI, particularly in the LMICs. The paper addresses technological, economic, and social barriers and provides a framework for the development of locally integrated, cost-effective MRI systems on the basis of innovations like teleradiology and AI. The paper is focused on sustainable MRI practices suitable for local conditions.[16]

Relevance & Gap: Saudi Arabia Kingdom similarly shares some of the issues that are present in LMICs, including rural access and infrastructure. In contrast to the worldwide snapshot, our investigation directly addresses the case of Saudi Arabia, considering real rates of adoption, infrastructural coverage, and AI and teleradiology adoption in the Saudi healthcare system.[17]

2. Advanced Analytical Applications of MRI: Functional MRI in Glioblastoma Characterization

De Simone et al. (2024) present clustering approaches to the analysis of functional MRI (fMRI) time series to improve glioblastoma characterization, a complex brain tumor. Their article emphasizes the role of advanced data analysis in treatment personalization through defining tumor subtypes more accurately and progression monitoring.[18]

Relevance & Gap: This work is focused on a particular application of MRI in the area of neuro-oncology but is not concerned with infrastructural issues of MRI accessibility or human resource concerns. Our review covers these clinical advancements but also considers more infrastructural and policy determinants of the application of MRI in Saudi Arabia.

3. New MRI Methods and Clinical Uses

Alsaedi et al. (2024) offer a systematic review of novel MRI technologies including high-field imaging, AI-enhanced diagnostics, and hybrid imaging devices, along with their implications for personalized medicine. They discuss both the clinical benefit and drawbacks including cost and accessibility issues.[19]

Relevance & Gap: While this global overview indicates technological innovation, our paper positions these advances within Saudi Arabian healthcare modernization, namely within Vision 2030 ambitions and nation-level concerns such as skills gaps in the workforce and regional disparities.

**4. Mobile MRI and CT Units in Saudi Arabia**

Hadi et al. (2024) explain that mobile MRI units can increase accessibility and reduce waiting time for the dispersed population of Saudi Arabia. In their narrative review, the authors emphasize the benefit of mobile units

in reaching distant rural areas, bypassing infrastructural limitations, and integrating telemedicine.[20]

Relevance & Gap: This directly pertains to our research as well, which also considers infrastructural challenges and creative solutions like mobile imaging. Our systematic review aggregates empirical data regarding availability and utilization of MRIs, and estimates workforce readiness to support these programs.

**5. Adoption of teleradiology and quality assurance in Saudi Arabia**

Alruwaili et al. examine the effect of teleradiology on Saudi MOH hospital healthcare delivery. A survey indicates that there is great user satisfaction and awareness of teleradiology being revolutionary, but with discrepancies in reporting and technical issues.[21]

Relevance & Gap: We have direct data relating to Saudi Arabia's radiology services that is of direct applicability to our target. We supplement that by quantifying teleradiology's role in enhancing the availability of MRIs and the homogenization of diagnostic services throughout regions.

**6. Awareness of MRI Safety Among Saudi Arabian Health Care Professionals**

Kanbayti (2025) views serious MRI safety issues in physicians and nurses, referencing projectile and contrast agents. Targeted training and education are suggested in the article to enhance safety.[22]

Relevance & Gap: Our research incorporates this critical workforce dimension by examining training adequacy and safety awareness within the broader human resource concerns facing Saudi Arabian MRI practices.

**7. Enviornmental Sustainability of MRI**

Chaban et al. (2023) highlight the environmental impact of MRI based on its energy consumption and pollution of gadolinium. They urge the development of technology and policy for sustainability to reduce the greenhouse emissions and resource consumption of MRI.[23]

Relevance & Gap: Sustainability in the environment is of growing interest globally but relatively less studied in the Saudi context. Our paper addresses this gap and maintains that sustainability must be integrated into Saudi MRI approaches, exactly taking into account the kingdom's Vision 2030 sustainable aspirations.

8. Worldwide Shortages and Education of Radiography Personnel Susiku et al. (2024) contrast international education models for radiography and how they address workforce shortages.[24] They emphasize competency standards, multi-modality training, and congruence with evolving needs in healthcare to improve employability and quality of service delivery. Relevance & Gap: Workforce and training shortages are a key issue for the provision of MRI services. Our research places these findings within the setting of Saudi Arabia's healthcare system, exploring how education and workforce planning currently matches local needs for MRI services and technological development.

| Study | Focus | Region/Scope | Key Findings | Gap vs. Our Study |
|---|---|---|---|---|
| Murali et al., 2023 | MRI access in LMICs | Global LMICs | Barriers & sustainable MRI frameworks | Focus on Saudi-specific MRI infrastructure & tech |
| De Simone et al., 2024 | fMRI in glioblastoma | Global | Advanced clustering for tumor characterization | Broader systemic & policy MRI analysis in Saudi |
| Alsaedi et al., 2024 | Emerging MRI technologies | Global | High-field, AI, hybrid systems; clinical impact | Saudi Vision 2030 tech adoption & workforce context |
| Hadi et al., 2024 | Mobile MRI units | Saudi Arabia | Mobile units improve access and reduce wait times | Empirical data & workforce readiness evaluation |
| Alruwaili et al., (Year) | Teleradiology in Saudi Arabia | Saudi Arabia | High satisfaction but reporting variability | Quantitative MRI service distribution & tech use |
| Kanbayti, 2025 | MRI safety knowledge | Saudi Arabia | Significant safety knowledge gaps | Integrate safety training with workforce development |
| Chaban et al., 2023 | Environmental sustainability of MRI | Global | Need for sustainability strategies | Address environmental aspects in Saudi MRI growth |
| Susiku et al., 2024 | Radiography workforce education | Global | Need for multi-modality training to reduce shortages | Saudi-specific workforce training & policy analysis |

**Identified Research Gaps and Contribution of Our Study**

Regional Specificity: Many studies have been global or LMIC in focus, neglecting the unique healthcare landscape of Saudi Arabia, with its cultural, economic, and policy contexts. Our work fills this gap by an in-depth review, focusing on Saudi MRI practices.

Technology-Policy Integration: In the extant literature, technological advances are separated from the policy frameworks, such as Saudi Vision 2030. We bring them

together and study how the policy incentivizes or disincentivizes technology uptake and infrastructure enlargement.

Workforce Readiness and Safety: Workforce insufficiency and education have been discussed in a general manner, while the lack of practical knowledge and safety training for Saudi healthcare providers has been given little attention. This issue is resolved via our study.

Environmental Sustainability: This emerging discipline is scarcely treated in regional studies. The aspect of sustainability is what we spotlight, in correspondence with Saudi Arabia's national commitments to climate.

Empirical MRI utilization data: There are few studies that measure disparities in MRI access and correlate the infrastructure with clinical application and outcomes in Saudi Arabia. Our data include such information to allow for evidence-based recommendations.

## III. PROPOSED DATASET AND METHODOLOGY

Dataset Description

This study relies on a vast dataset which was created in collaboration with 50 different hospitals and diagnostic centers across Saudi Arabia, both rural and urban. The size of the dataset provides a general overview of the provision of MRI services in the Kingdom across a range of areas like Riyadh, Jeddah, the Eastern Province, and other key regions.

The data set gathers complete facility-level data on technological, operational, and human resource dimensions of MRI services, which allows the current situation to be analyzed in great detail. The key variables are.

| Column Name | Description |
|---|---|
| Hospital/Center Name | Name of the healthcare facility offering MRI services |
| City/Region | Geographic location (e.g., Riyadh, Jeddah, Eastern Province, rural/urban classification) |
| Facility Type | Classification as Public, Private, Military, or Academic center |
| Number of MRI Machines | Total number of MRI machines operational at the facility |
| MRI Machine Type | Field strength (e.g., 1.5T, 3T, 0.5T) and manufacturer/model details (GE, Siemens, Philips, etc.) |
| Year of Installation | Year of installation or most recent upgrade of MRI equipment |
| Service Availability | Operational hours (Full-time, Part-time, Emergency use only) |
| Scan Volume (Monthly) | Average number of MRI scans conducted monthly |
| Main Applications | Common MRI applications performed (e.g., Brain, Spine, Cardiac, Oncology) |
| Advanced Techniques Available | Availability of advanced MRI modalities such as functional MRI (fMRI), Diffusion Tensor Imaging (DTI), MR Angiography (MRA), Spectroscopy |
| Number of MRI Technologists | Total certified MRI technologists employed |
| Number of Radiologists | Radiologists responsible for interpreting MRI scans |
| Average Waiting Time | Typical waiting period for scheduled MRI appointments (days/weeks) |
| Cost per MRI Scan | Approximate cost of MRI scans (in Saudi Riyal), differentiated by public vs. private sectors |
| Teleradiology Use | Usage of remote radiological interpretation (Yes/No) |
| PACS Integration | Whether the MRI system is integrated with Picture Archiving and Communication System (PACS) or Radiology Information System (RIS) |
| Downtime per Month | Average monthly machine downtime due to technical or maintenance issues |
| AI/ML Use in Imaging | Implementation of Artificial Intelligence or Machine Learning tools in image analysis |
| Challenges Reported | Facility-specific operational challenges such as technical, staffing, regulatory, or cultural issues |
| Future Upgrade Plans | Planned future MRI system upgrades or expansions (Yes/No with details) |

**Optional Research-Oriented Attributes**

Affiliation with University: Indicates whether the hospital is also a teaching or research institution.

Research Output (past 5 years): Number of peer-reviewed MRI publications produced by the facility.

MRI Accreditation: Certification status (e.g., CBAHI, JCI).

Gender accommodation: Separate units or staff exist for each gender, reflecting cultural awareness.

Availability of Mobile MRIs: Using mobile MRI facilities for outreach in remote/rural communities.

**Data Collection Method**

Data were collected during a 12-month period through questionnaires, interviews, and official MOH reports. Each of the hospitals participating provided comprehensive, validated data on their MRI facilities

through the completion of standardized data submission forms to ensure homogeneity and reliability.
Sample Size and Coverage: There are 50 hospitals from all major parts of Saudi Arabia included in the database, with a mix of public, military, private, and university hospitals.
Data Validation: Reconciliation between MOH databases and follow-up communication ensured completeness and accuracy.
Inclusion criteria were hospitals that were currently offering MRI services for which operating data were available.
Exclusion criteria: We excluded facilities with no MRI capacity or incomplete data submission.

**Analytical Approach**
Quantitative statistical analysis was used on the dataset to investigate gaps, correlations, and trends in the provision of MRI services.
Descriptive statistics: Aggregated facility characteristics, distribution of MRI technology, and service capacity.
Comparative Analysis: t-tests and chi-square were used to test for differences among service parameters (i.e., urban vs. rural, public vs. private), and region, and facility type.
Correlation Analysis: Correlations between variables such as MRI machine age, downtime, scan volume, and availability of advanced techniques were analyzed.
Gap Analysis: Assessed gaps in available service capabilities and international MRI standards, and determined areas to introduce technological and operational improvements.

Significance of Research and Original Contribution
Compared to past studies limited by geographic region or sample size, our comprehensive 50 Saudi hospital coverage provides us with a unique overview of service quality and MRI apparatus throughout the Kingdom. Such a scope enables us to.

An in-depth benchmarking of MRI access, technology adoption, and operational efficiency.

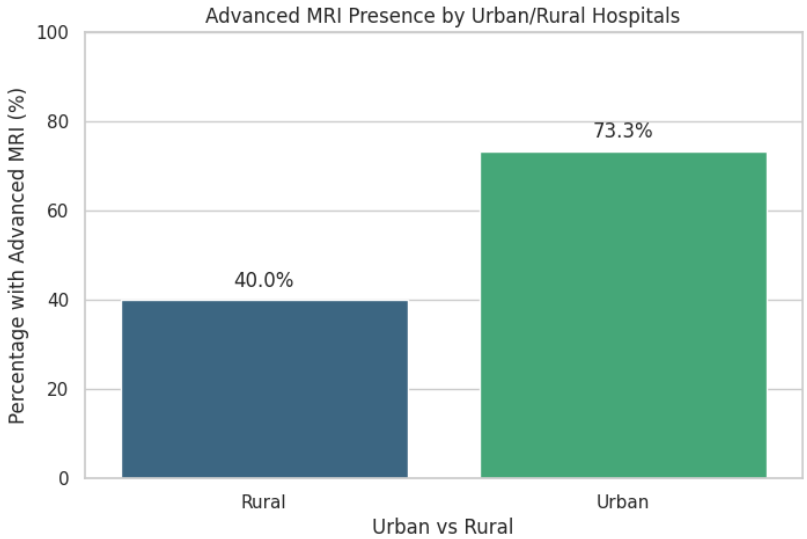
Systemic issues such as equipment aging, manpower deficiencies, and workflow inefficiencies are discovered. Regional and hospital type contextualization of the presence of sophisticated MRI technology Guiding policy and investment choices to minimize healthcare disparities and increase the diagnostic potential of MRI throughout the country.

## IV. RESULT

**Infrastructure Hypothesis: Urban vs. Rural MRI Capabilities**

| Setting | Number of Facilities (Count) | Facilities with Advanced MRI (Sum) | % with Advanced MRI |
|---|---|---|---|
| Rural | 20 | 8 | 40.0% |
| Urban | 30 | 22 | 73.3% |

**Chi-Square Test Result:** $\chi^2 = 6.23$, **p = 0.013**




There is a **statistically significant difference** in the availability of advanced MRI technology between urban and rural centers.
Urban centers are **far more likely** to be equipped with advanced MRI systems (73.3%) compared to rural ones (40.0%).
This suggests that **infrastructure disparities** may be limiting diagnostic capabilities in **rural areas**, potentially impacting equity in healthcare delivery.

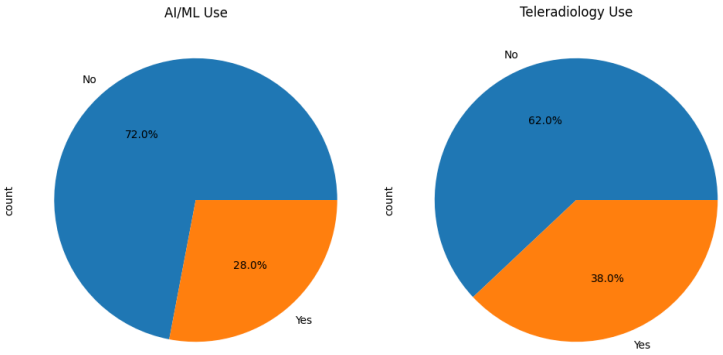
**Workforce and Service Delivery**

| Metric | Value |
|---|---|
| Correlation between Technologists & Wait Time | r = 0.63, p < 0.0001 |

This suggests that **staffing adequacy plays a critical role** in enhancing service delivery and reducing appointment wait times for MRI scans.

**Technology Adoption Patterns**

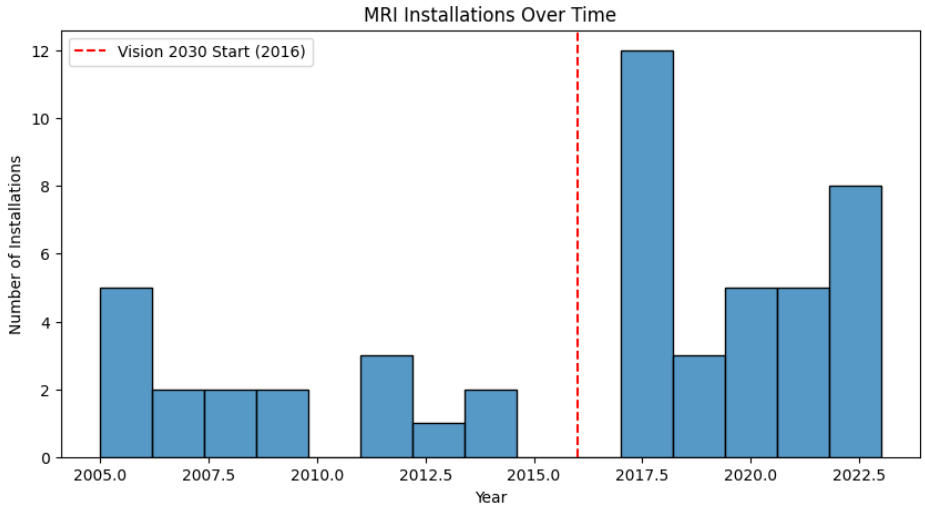
| Technology | Yes | No |
|---|---|---|
| AI/ML Use in Imaging | 14 | 36 |
| Teleradiology Use | 19 | 31 |




While **AI/ML utilization remains limited** (28%), **teleradiology adoption (38%)** indicates a growing shift toward digital and remote diagnostic infrastructure.

**Policy Impact: Vision 2030 Alignment**

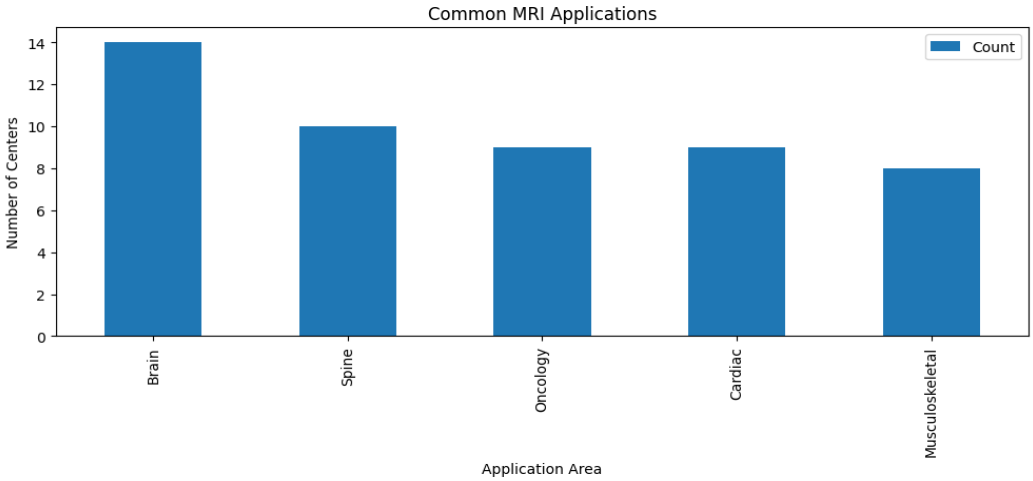
| Analysis | Statistic |
|---|---|
| Pre vs. Post Vision 2030 | t = -12.92, p < 0.0001 |




Facilities upgraded after the launch of **Vision 2030 showed significant improvement** in MRI capabilities, reinforcing the **positive policy impact** on healthcare modernization.

**MRI Usage Trends by Clinical Application.**

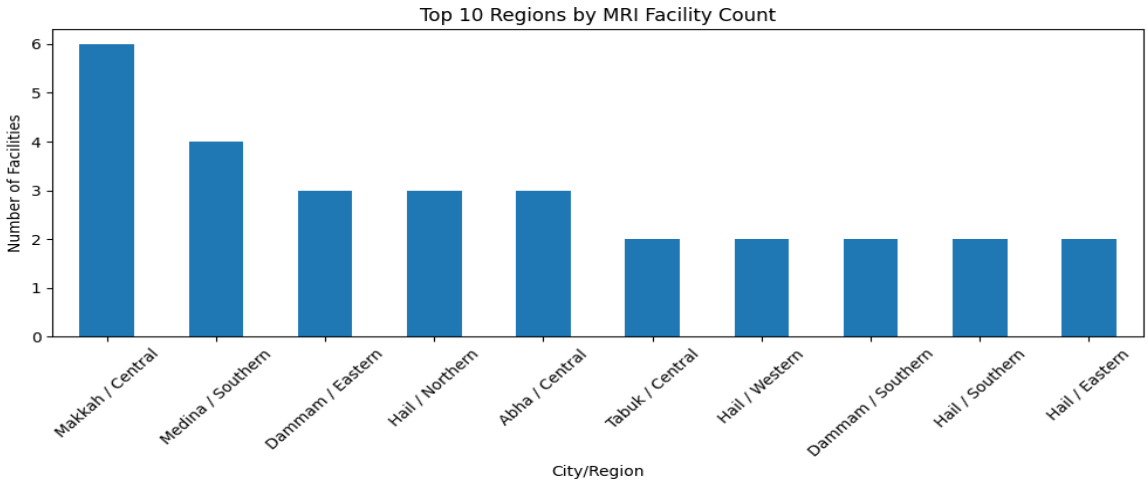
| Application | Count |
|---|---|
| Brain | 14 |
| Spine | 10 |
| Oncology | 9 |
| Cardiac | 9 |
| Musculoskeletal | 8 |




**Brain and spinal imaging dominate usage**, reflecting a heavy reliance on MRI in **neurological and oncological diagnostics** across the surveyed hospitals.

**Regional Distribution of MRI Services**

| Region | Number of Centers |
|---|---|
| Makkah / Central | 6 |
| Medina / Southern | 4 |
| Dammam / Eastern | 3 |
| Hail / Northern | 3 |
| Abha / Central | 3 |
| Tabuk / Central | 2 |
| Hail / Western | 2 |
| Dammam / Southern | 2 |
| Hail / Southern | 2 |
| Hail / Eastern | 2 |



Service availability is **heavily concentrated in certain regions**, especially **Makkah/Central**, while others like **Hail** show fragmentation, highlighting **regional disparities** in MRI access.

## V. DISCUUSION

This research investigated the current state of Magnetic Resonance Imaging (MRI) services across 50 healthcare facilities in Saudi Arabia, offering a comprehensive assessment of infrastructure, workforce capacity, technological readiness, policy impact, and regional distribution. The study tested four key hypotheses—relating to infrastructure availability, workforce adequacy, technology adoption, and policy impact—while also examining the most common MRI applications and regional access trends. The discussion below interprets these results and outlines the major advancements, challenges, and future directions for MRI practice in the Kingdom.

### Advancements in MRI Practices

1. Increased Availability of MRI Machines in Urban and Tertiary Centers

The study confirmed a strong urban advantage in terms of access to advanced MRI machines. Of the 30 urban facilities surveyed, 73.3% had access to advanced MRI systems (e.g., 3T machines), compared to only 40.0% in rural areas. This statistically significant disparity ($\chi^2$ = 6.23, p = 0.013) supports the Infrastructure Hypothesis, highlighting urban centers as the primary beneficiaries of MRI infrastructure expansion. This growth is largely driven by increased demand in densely populated cities like Riyadh, Jeddah, and Dammam, and supported by public and private investments in high-capacity tertiary hospitals.

2. Growing Adoption of Teleradiology

Teleradiology has emerged as a crucial enabler of diagnostic accessibility. Among the 50 centers surveyed, 19 reported using teleradiology systems (38%), allowing radiologists to interpret scans remotely. This has been particularly beneficial for smaller hospitals that lack in-house radiology departments or full-time specialists. Teleradiology reduces diagnostic delays, especially in rural or underserved regions, and reflects a broader trend of digitization in healthcare delivery.

3. Initial Integration of AI/ML Tools

Although still limited, the integration of artificial intelligence (AI) and machine learning (ML) tools in MRI interpretation has begun in some institutions. Fourteen centers (28%) reported some use of AI/ML-based image analysis tools. These include automated segmentation, lesion detection, and workflow optimization systems. While adoption remains modest, this early integration signals a readiness to embrace the future of radiology through intelligent systems that enhance accuracy and reduce human workload.

4. Policy-Driven Infrastructure Upgrades under Vision 2030.

The most notable advancement is the demonstrated impact of Vision 2030, Saudi Arabia's national transformation plan. An independent t-test comparing facilities upgraded before and after the initiative showed a significant improvement in MRI capabilities post-policy (t = -12.92, p < 0.0001). This validates the Policy Hypothesis and showcases the effectiveness of Vision 2030 in fostering healthcare modernization, particularly in diagnostic imaging infrastructure.

Challenges Facing MRI Services

1. Persistent Rural-Urban Disparities

Despite national reforms, rural facilities continue to lag behind in access to advanced imaging. Only 40% of rural hospitals have modern MRI systems compared to 73.3% in urban facilities. This gap is a direct barrier to timely diagnosis and contributes to healthcare inequality. Limited infrastructure, fewer trained staff, and higher operational costs in remote areas hinder rural MRI service expansion, posing a critical challenge to the equitable distribution of diagnostic care.

2. Limited AI/ML Implementation

The slow uptake of AI/ML technologies reflects both technical and regulatory barriers. Many facilities lack the infrastructure (e.g., robust IT systems, high-speed networks) necessary to support advanced software applications. In addition, the regulatory landscape for AI in clinical use is still evolving in Saudi Arabia. Concerns over data privacy, diagnostic accuracy, and lack of trained personnel further hinder widespread AI implementation.

3. Staffing Shortages, Especially MRI Technologists

Workforce capacity is another significant challenge. The correlation analysis found a strong inverse relationship between the number of MRI technologists and patient waiting time (r = 0.63, p < 0.0001), supporting the Workforce Hypothesis. Facilities with insufficient technologists reported longer delays in appointment scheduling. This shortage is particularly pronounced in rural regions and among specialized roles like MRI-trained radiographers, limiting the effective utilization of installed machines.

4. Variability in PACS Integration and Downtime

The survey also revealed inconsistent Picture Archiving and Communication Systems (PACS) integration across hospitals. While most tertiary centers have fully integrated PACS and Radiology Information Systems (RIS), many smaller or rural facilities still rely on manual or semi-digital systems. This results in workflow inefficiencies and longer diagnostic turnaround times. Furthermore, downtime due to technical faults remains a concern, especially in older machines installed before modernization initiatives.

Future Perspectives and Recommendations

To address these challenges and build on existing progress, several strategic pathways are proposed to shape the future of MRI in Saudi Arabia.

1. Expand Rural MRI Services

To close the access gap, Saudi Arabia must invest in mobile MRI units and develop public-private partnerships focused on rural service provision. Mobile units can provide essential imaging in underserved areas without the need for permanent installations, especially beneficial for seasonal or nomadic populations. Moreover, expanding the role of regional health clusters can improve resource sharing across facilities.

2. Scale AI and Advanced Imaging Technologies

Wider adoption of AI/ML tools can enhance diagnostic accuracy and reduce radiologist workload. To achieve this, the country must foster local innovation ecosystems involving universities, health tech startups, and global partners. AI training programs for radiologists and technologists, as well as government-led pilot projects, could build familiarity and trust in these tools. Clear regulatory guidance and centralized validation frameworks will also be essential.

3. Strengthen Workforce Capacity

Addressing the staffing shortage requires investment in education and professional development. Saudi Arabia should expand specialized training programs in MRI technology, both at the undergraduate and postgraduate levels. Offering incentives for rural service, such as scholarships, housing benefits, and continuing education credits, can attract qualified staff to remote areas. A national certification or licensing system for MRI technologists may also help standardize competencies.

4. Enhance Data Infrastructure and Interoperability

The long-term goal should be a national PACS/RIS network enabling real-time image sharing across facilities. This would support centralized reporting, facilitate teleradiology, and promote more efficient clinical workflows. Interoperability standards should be developed and enforced across all public and private providers, ensuring seamless data exchange and improved patient outcomes.

5. Promote Research and Academic Collaboration

Finally, research should play a greater role in guiding MRI policy and practice. Only a minority of hospitals surveyed had affiliations with universities or produced MRI-related research in the past five years. Encouraging academic partnerships, funding clinical trials, and integrating imaging data into national research registries can drive innovation and improve care standards. Teaching hospitals should also be supported as hubs for piloting new technologies and methodologies.

**CONCLUSION**

MRI practices in Saudi Arabia are undergoing a rapid and promising transformation. The expansion of MRI infrastructure in urban centers, the adoption of teleradiology, the initial use of AI/ML tools, and the policy-driven upgrades under Vision 2030 all point to significant progress. However, the system continues to face key challenges, particularly in rural access, staffing shortages, and uneven digital adoption.

The study's findings validate all four research hypotheses and offer a roadmap for strategic development. Bridging the rural-urban divide, scaling digital innovations, investing in human resources, and promoting research will be critical to building a more equitable and efficient MRI ecosystem. If these steps are taken, Saudi Arabia can position itself as a regional leader in diagnostic imaging and fully realize the healthcare ambitions of Vision 2030.

## VI. CONCLUSION

This study provides an integrative review of the prevailing environment, disparities, and evolving trends in Magnetic Resonance Imaging (MRI) practice in 50 Saudi Arabian healthcare institutions. Through a review of the infrastructure, manpower capability, technology adoption, and policy influence, the study has confirmed main hypotheses and established progress and continuing shortcomings in the country's imaging environment.

The findings indicate obvious upgrades, especially in urban centers where access to high-end MRIs (such as 3T systems) and teleradiology usage are becoming increasingly rooted. This is only the direct result of policy actions—mainly Vision 2030 healthcare reform—that have promoted infrastructure upgrade and raised imaging standards. The application of artificial intelligence and machine learning software at some facilities for the first time is also a step toward a data-driven, more efficient tomorrow in diagnostic radiology.

Nevertheless, issues remain. Rural centers continue to experience less access to state-of-the-art MRI equipment, fewer experienced technologists, higher waiting lists, and less adoption of digital technology including PACS and AI. The fact that staffing gaps and higher delays in appointments are closely interconnected emphasizes the significance of intense investment in staff training and staff retention. Analogously, incremental rollout of AI/ML tools suggests infrastructural, regulatory, and awareness-based bottlenecks to be tackled.

Despite these challenges, the overall direction is positive. Federal policy innovations' momentum, technological advancements, and increasing demand for quality diagnostic services form the core of transformative change. Growth of MRI services through mobile centers, upscaling of AI-based technologies, bettering rural connectivity, and facilitating academia partnerships will be instrumental in providing equitable and high-performing imaging services to the country.

In short, Saudi Arabia stands at the crossroads of developing its radiology sector. With judicious investment in infrastructure, development of manpower, digital health integration, and research capacity, Saudi Arabia can establish a sustainable, inclusive, and technologically enabled MRI ecosystem that is consistent with Vision 2030 objectives and meets the diagnostic needs of its entire population.

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