Driving Healthcare Forward: The Potential of Mobile MRI and CT Units in Streamlining Radiological Services in Saudi Arabia - A Narrative Review

Abstract

Background and purpose: This narrative review focuses on the role of mobile MRI and CT units in addressing the challenges of healthcare accessibility and patient wait times in Saudi Arabia. It underscores the growing demand for diagnostic imaging amid infrastructural and geographical barriers, emphasizing mobile units as innovative solutions for enhancing radiological services across diverse Saudi landscapes. The purpose of this study is to assess how these mobile technologies can mitigate service delays, improve patient outcomes, and support healthcare delivery in remote or underserved areas, reflecting on global trends towards more dynamic, patient-centered healthcare models.

Methods: This review utilizes an expanded database search and refined keywords to ensure comprehensive literature coverage. The study focused on peer-review articles and grey literatures that directly examined the impact of these mobile units on healthcare accessibility, wait times, and service delivery. A thematic analysis identified significant contributions to accessibility improvements, emergency responses, and rural healthcare, highlighting areas for further research and policy development.

Discussion: Mobile units have advanced technical specifications with high-field magnets and multi-slice CT scanners on par with fixed facilities. They prioritize patient comfort and safety with examination areas, control rooms, and waiting areas. Telemedicine capabilities allow real-time image transmission to specialists. Strategic deployment can address workforce shortages by distributing services equitably. Mobile units represent cost-effective solutions to expand healthcare access without fixed infrastructure.

Conclusion: Integration of mobile MRI and CT units in Saudi Arabia can transform access to diagnostic imaging by decentralizing services and directly reaching patients, including rural areas. Evidence shows mobile units reduce diagnostic delays and optimize resource use. Despite challenges, strategic investments and collaborations can overcome obstacles to make radiological services more equitable, flexible and patient-focused in Saudi Arabia.

Keywords: Mobile units | MRI | CT | Medical imaging | Healthcare | Saudi Arabia

Introduction

In the landscape of contemporary healthcare, the role of advanced diagnostic imaging, such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans, cannot be overstated. Innovations in medical technology have revolutionized the way healthcare professionals diagnose and treat patients, offering unprecedented precision and timeliness [1, 2]. Despite these advancements, equitable access to such essential services remains a significant challenge, particularly in areas marked by vast geographical distances or constrained by inadequate healthcare infrastructure [3]. This gap between the availability of advanced diagnostics tools and the need for them presents a global healthcare dilemma, starkly evident in the context of Saudi Arabia [4].

The demand for diagnostic imaging in Saudi Arabia is growing, with MRI and CT scans at the forefront. However, prolonged wait times have become a critical issue, adversely affecting patient care and clinical outcomes [5]. Although comprehensive statistics on wait times in Saudi Arabia are lacking, anecdotal evidence suggests significant delays [6]. In terms of resources, Saudi Arabia has 482 MRI units and 1,182 CT units distributed across various regions, with Riyadh having the highest number of both MRI (100 units) and CT (232 units) machines. The MRI rate per 10,000 population ranges from 0.09 in Makkah to 0.3 in the Northern Borders, while the CT rate per 10,000 population varies from 0.2 in Riyadh and Makkah to 0.7 in Al Jawf [7]. Notably, a substantial portion of the population lives outside major city centers, further exacerbating access issues. This situation is not unique to Saudi Arabia; for instance, Norway experienced significant fluctuations in MRI wait times from 2018 to 2021, peaking at an average of 20.3 weeks, underscoring a widespread challenge across public health systems [5].

Amidst this scenario, relocatable mobile MRI and CT units emerge as a beacon of innovation, offering a practical solution to improve access and reduce service delays. By bringing diagnostic imaging directly to the patient's doorstep, especially in remote or underserved communities, these mobile units not only enhance service efficiency but are also instrumental in achieving better patient outcomes through timely diagnosis [8, 9].

While mobile radiology is not a new concept, its application within Saudi Arabia offers unique insights and opportunities. The adoption of such technology signifies a shift towards more dynamic, patient-centered healthcare delivery models, echoing global trends aimed at increasing accessibility and quality of care [10]. Evidence from recent studies, including findings published in BMC Health Services Research, supports the positive impact of mobile diagnostic imaging on service utilization and care quality, particularly highlighting its role in areas equipped with mobile radiography units [11].

By tackling the geographical and infrastructural barriers to healthcare access, mobile radiology units stand to democratize the availability of crucial diagnostic services. This is particularly relevant for Saudi Arabia, a country characterized by its vast territory and uneven distribution of healthcare facilities. The deployment of mobile MRI and CT units across the nation promises an equitable approach to serving its diverse populations [12–15].

This review sets out to thoroughly examine the existing literature on the deployment and efficacy of mobile MRI and CT units, with a specific focus on their role within the healthcare delivery ecosystem. It aims to assess how these mobile units can contribute to mitigating wait times and enhancing the overall quality of radiological services, particularly within the Saudi Arabian healthcare context.

Methods

A comprehensive narrative review was conducted to assess the impact of mobile MRI and CT units on radiological services in Saudi Arabia. The search for this review extended beyond PubMed, Ovid, and Google Scholar to include Embase, Scopus, Web of Science, and OpenGrey, aiming for a wider capture of relevant literature. Keywords were expanded to encompass "Mobile MRI" OR " Mobile CT" AND "Radiological services" and related synonyms (**Table 1**). The search strategy employed Boolean "AND" and "OR" logic to effectively combine keywords, enhancing the precision of retrieved records.

Eligibility criteria were defined to include peer-reviewed articles and grey literature in English, with no time restrictions to encompass the inception of mobile imaging technology. Exclusion criteria were sharpened to omit studies not directly assessing the impact of mobile units on service accessibility, wait times reduction, or emergency and rural healthcare.

The synthesis of findings adopted a thematic analysis approach, categorizing the data into themes related to accessibility improvements, patient wait times reductions, emergency response enhancements, economic and financial implications, and rural healthcare delivery.

Employing a broad, inclusive search strategy and thematic analysis ensures a comprehensive capture and nuanced synthesis of the diverse literature on mobile MRI and CT units, highlighting their impact on radiological services in Saudi Arabia. This methodology facilitates a focused examination of key outcomes, providing a solid foundation for identifying actionable insights and guiding future research and policy interventions.

Discussion

Mobile Diagnostic Imaging in Saudi Arabia's Evolving Healthcare Landscape

The adoption of mobile radiography has significantly advanced healthcare accessibility and efficiency in Saudi Arabia. Portable diagnostic imaging machines, such as mobile X-ray, MRI, and CT units, overcome the logistical challenges of delivering medical imaging services to immobile populations, including nursing home residents, and expand healthcare reach to remote areas [11]. This progress supports the nation's shift toward a privatized healthcare model driven by population growth and rising costs [16–18].

Central to these developments are the Health Clusters and Seha Virtual Hospital initiatives. Health clusters unify diverse healthcare providers under a single management system, enhancing care coordination and service efficiency. Seha Virtual Hospital utilizes telemedicine to offer remote consultations and care, which is vital for patients in underserved areas [19]. Mobile radiological units play a crucial role in maintaining service continuity during emergencies or when stationary units are unavailable, ensuring uninterrupted access to essential diagnostics, especially in rural settings. Together, these initiatives strengthen the national healthcare system's ability to serve broader communities more effectively.

The Impact of Mobile MRI and CT Scanners on Accessibility and Efficiency

The introduction of mobile MRI and CT scanners has transformed the availability of advanced diagnostic imaging worldwide. These units are designed for durability and efficiency; they feature advanced suspension, climate control, and power systems to maintain functionality across various terrains, ensuring operational integrity and patient safety within a compact layout [20, 21].

In the USA, mobile MRI units have significantly increased accessibility for rural and remote communities. This has led to higher early diagnosis rates for neurological conditions and reduced travel costs for patients. Additionally, these units have shortened waiting times for MRI scans, improving patient satisfaction [22]. In the UK, mobile CT units have been effective in urban areas with high demand, reducing waiting times and enhancing lung cancer screening rates. This approach has proven cost-effective for the NHS and increased early detection rates of lung cancer, leading to earlier interventions [23].

These mobile units prioritize patient comfort and safety, incorporating a patient examination area, a control room, and sometimes a waiting area—all within a space-efficient layout. Equipped with telemedicine capabilities, they enable instant image transmission to specialists and promote remote diagnostics while adhering to radiation safety measures [24–27]. This innovation reduces the need for patients to travel to urban centers, alleviating wait times at local facilities, and is invaluable in disaster relief scenarios by providing essential imaging services [28–32]. The patient experience with mobile units is marked by convenience and accessibility, offering high-quality diagnostic imaging across diverse locations and enhancing participation among patients from lower socioeconomic backgrounds [33]. In Canada, mobile MRI units serving Indigenous communities in remote areas have significantly improved access, saving time and enhancing diagnosis rates for mental health and neurological conditions. Integrating these units with community health programs has also helped reduce overall healthcare costs and tailored services to lessen disparities in health outcomes [34].

Supported by various operational models—government-backed, public-private partnerships, or private entities—these mobile units exemplify flexible healthcare solutions [35]. Collaboration between a hospital and a private company to deploy mobile medical imaging units enhances healthcare services [36]. This partnership adds MRI and CT scanning capabilities to hospitals not originally equipped for such technologies, expanding capacities and reducing patient wait times. This practical alternative to the costly, space-consuming installation of fixed imaging devices serves as a case study in efficient healthcare resource management.

In Saudi Arabia, deploying mobile medical imaging units aligns with Saudi Vision 2030's goals of developing an accessible healthcare system capable of overcoming geographical barriers and enhancing service delivery in rural areas. This strategy supports healthcare reform by improving system efficiency and accessibility (**Table 2**) [7, 37]. It ensures timely services for a dynamic population, especially during Hajj and Ramadan when the population of Mecca and Medina swells to over four million pilgrims [7, 37–40]. Additionally, it offers strategic solutions for peak times and emergencies, providing gender-specific services that respect cultural norms while delivering essential care [12]. The global success of mobile MRI and CT scanners underscores their pivotal role in expanding access to advanced medical services and highlights their impact across various healthcare settings (**Table 3**) [22, 23, 34].

Revolutionizing Diagnostic Imaging: The Rise of Mobile MRI and CT Technology

Mobile radiology, powered by MRI and CT technologies, marks a significant advancement in diagnostic imaging, offering high-quality diagnostics to underserved regions [21, 41]. These mobile units feature advanced imaging capabilities: MRI systems with high-field magnets (1.5 T to 3 T) and mobile CT scanners with multi-slice capabilities (16 to 256 slices) and dose-reduction technologies, comparable to hospital-based scanners [9, 21, 42, 43]. Mobile MRI and CT services are popular for their convenience and cost-effectiveness. Contrary to misconceptions, the image quality of these units can rival in-house services, depending on the equipment and radiographer's expertise.

These mobile units expand healthcare access by delivering essential imaging services to remote locations, proving indispensable in emergencies for rapid injury assessments and immediate treatment [44–46]. Telemedicine integration allows swift image sharing with specialists, enhancing critical care through immediate consultations [47]. This approach promotes equitable healthcare by bridging gaps in service reach and infrastructure [13, 48].

This shift introduces radiography technologists to dynamic environments, demanding adaptability and a broad skill set for mobile operations [49, 50]. Radiologists adapt to interpreting diagnostics remotely, highlighting the shift toward flexible, community-centric healthcare [51]. When evaluating the feasibility of mobile units, it is crucial to consider patient satisfaction regarding space. Surveys from lung cancer screenings indicate that most patients felt they had adequate space at both mobile and stationary sites, suggesting space constraints in mobile imaging trailers may not significantly impact patient experience [32].

The future of mobile radiology is promising, with artificial intelligence (AI) and machine learning poised to improve diagnostic accuracy and efficiency, which is particularly beneficial for Saudi Arabia's expanding urban areas [21, 52]. Hybrid units that combine various imaging modalities into a single mobile setup represent the next wave of technological advancements in diagnostics, reducing the personnel needed for operation and image analysis [53, 54].

Embracing innovative technologies, mobile radiology is set to redefine healthcare accessibility, providing quality and cost-effective diagnostic services. This marks a new era in diagnostic imaging with broad implications for Saudi healthcare delivery and management.

Transforming Healthcare with Mobile Diagnostic Imaging: A Global Perspective

The introduction of mobile MRI and CT technology marks a revolutionary step in diagnostic imaging, significantly improving medical care in underserved communities and diverse healthcare settings. Real-world applications and case studies highlight the profound impact of mobile imaging in emergency care, rural healthcare delivery, pediatric imaging, sports medicine, large-scale screening programs, and clinical research.

In emergencies, mobile MRI and CT scanners provide rapid, accurate diagnostics, often tipping the balance between life and death. These units are crucial in managing mass casualties and facilitating prompt medical responses in disaster-prone areas [31] or during major events like the Hajj pilgrimage [9]. Their deployment provides essential, lifesaving interventions.

In rural settings, mobile diagnostic units shorten the time from diagnosis to treatment for critical conditions such as strokes, improving recovery probabilities and reducing long-term disability risks [55]. In regions like Saudi Arabia, this mobile strategy dramatically boosts healthcare accessibility and effectiveness, delivering essential services directly to remote communities.

For pediatric patients and individuals with chronic conditions, mobile imaging units offer a less intimidating alternative to traditional hospital visits, reducing anxiety and increasing comfort during scans [56]. This approach makes diagnostic procedures more accessible and child-friendly, even in remote areas of Saudi Arabia.

In sports medicine, mobile imaging technology provides immediate, comprehensive injury assessments, facilitating on-the-field diagnoses that inform quick treatment decisions and fitness evaluations [43, 57, 58]. For a country like Saudi Arabia, which is investing in its sports sector, the availability of mobile diagnostic units at sporting events ensures the health and performance of athletes.

Mobile imaging significantly enhances large-scale screening efforts, especially for lung cancer, by facilitating early detection and streamlined treatment initiation [59–62]. In Saudi

Arabia, deploying mobile units for national screening programs could markedly improve early diagnosis rates by offering screenings in convenient locations and beyond traditional hospital hours [33, 63].

The UK's introduction of mobile PET/CT technology illustrates the potential for improved access to advanced diagnostics in areas without fixed facilities. This model could transform cancer care in Saudi Arabia by providing high-quality imaging in remote or underserved areas [35, 64].

Mobile MRI and CT scanners have proven their worth in clinical trials, matching the performance of stationary units and ensuring consistent imaging quality across varied research sites [35]. This is particularly relevant for Saudi Arabia as it seeks to enhance its medical research and clinical trial infrastructure, supporting geographically diverse studies.

Case studies collectively underscore the versatility and profound impact of mobile MRI and CT units in healthcare delivery. Key outcomes include heightened patient satisfaction, reduced travel times, and notable improvements in health metrics, such as decreased hospital readmission rates.

Mitigating Health Human Resource Challenges with Mobile Imaging Units

Mobile imaging units have emerged as a crucial strategy in addressing radiology workforce shortages, especially in remote areas. By delivering advanced imaging services directly to patients, these units minimize the need for extensive staffing and infrastructure, significantly enhancing access to healthcare in underserved regions [65, 66]. They provide essential diagnostic services without location constraints, operated by rotating teams of technologists and support staff, efficiently utilizing limited human resources and alleviating staffing challenges.

The EQUI-ResHuS project in Mali exemplifies how telehealth and information and communication technology can reduce professional isolation for healthcare workers in remote locations, suggesting that integrating telehealth with mobile imaging could improve recruitment and retention across various medical fields [67]. This approach not only addresses radiology staff shortages but also enhances healthcare delivery, improving patient access and fostering interdisciplinary collaboration across different specialties.

Additionally, mobile units help alleviate the pressure on centralized radiology services by decentralizing diagnostics, leading to a more equitable distribution of workloads. This decentralization improves radiologists' work–life balance and job satisfaction, reduces patient travel to central facilities, and eases congestion, allowing these centers to focus on complex cases while mobile units handle routine diagnostics [13]. This shift contributes to a more balanced and responsive healthcare system, enhancing service delivery.

Economic and Financial Implications of Mobile Diagnostic Units

The deployment and operation of mobile diagnostic units, such as mobile MRI and CT scanners, are influenced by multiple factors, including the complexity of the technology, operational costs, and logistical challenges. The initial investment for a mobile diagnostic unit—which includes both the vehicle and the medical equipment—varies considerably. High-quality MRI machines are priced between $1.5 million and $2 million (USD), while CT systems cost approximately $1 million to $1.5 million, reflecting solely the price of the equipment [12, 35, 68].

Annual operating costs for these units, covering expenses like staffing, maintenance, fuel, and logistical support, range from $76,000 to $100,000 for MRI units and $120,000 to $150,000 for CT units. Additionally, the total fixed costs—including the vehicle, trailer, and other necessary supplies—are estimated at $1 million to $2.5 million for MRI and $0.5 million to $1 million for CT scanners, highlighting the substantial financial commitment required (**Figure 1**) [35, 50, 69].

Despite these significant costs, the strategic deployment of mobile units, particularly in regions like Saudi Arabia, offers considerable long-term financial and health benefits. Mobile units reduce the need for patients in remote areas to travel to distant diagnostic centers, significantly lowering travel-related expenses and inconveniences [35, 50]. Their operational flexibility and lower fixed overheads further enhance their cost-effectiveness over time. Moreover, these units help relieve the burden on centralized healthcare facilities, which often face capacity issues, thereby improving service availability and reducing diagnostic wait times [12, 26, 64, 70].

In Saudi Arabia, flexible funding strategies support the adoption and operation of these units, ranging from public funding and public–private partnerships to private ventures. Public funding focuses on broadening access to essential diagnostic services, which is in line with public health objectives [71]. Public–private partnerships leverage efficiencies to extend radiology services in a cost-effective manner [72], while private entities, although profit-driven, can innovate and provide specialized services, potentially subsidizing operational costs for public or remote deployments [73].

Economic analysis indicates that, despite higher initial setup costs, mobile diagnostic units are a cost-effective solution for expanding radiology services to underserved communities [12]. Their operational flexibility and lower fixed overheads contribute to their cost efficiency over the long term. The successful integration of these units within Saudi Arabia's health ecosystem is poised to enhance healthcare access and efficiency, leading to improved health outcomes and overall savings for the national healthcare system.

Overcoming Deployment Challenges for Mobile Healthcare in Saudi Arabia

In the vast and diverse landscape of Saudi Arabia, deploying mobile diagnostic units presents significant logistical challenges. Transporting sophisticated diagnostic tools such as mobile MRI and CT units to remote and underserved areas involves navigating long distances across potentially rugged terrains and ensuring a consistent power supply in regions where infrastructure is still developing. These logistical complexities are critical barriers that must be addressed, as mobile units are essential for delivering healthcare services to the communities most in need.

Further complicating these logistical issues are regulatory and policy hurdles. The deployment of mobile diagnostic units across the Kingdom is subject to stringent standards and approval processes by the Saudi Ministry of Health and other regulatory bodies [74]. This regulatory environment underscores the importance of compliance with healthcare standards and requires a nuanced approach to ensure that mobile diagnostic services meet the high standards set for patient care.

Additionally, technical limitations, particularly in terms of network connectivity, pose a significant challenge. These limitations can restrict access to essential patient data, hindering the delivery of tailored healthcare solutions. Mobile units also face challenges in providing immediate care for rare but severe reactions to contrast media, highlighting the need for robust emergency response protocols. Despite these challenges, technological advancements have enabled the delivery of diagnostic services in a variety of settings. However, the pursuit of improved imaging quality and safety standards continues to drive technological innovation and adaptation in the realm of mobile healthcare services [50]. Diagnostic equipment must undergo repeated testing to ensure its robustness and stability after transportation and during mobile usage.

To address the complex logistical and technical challenges of potentially rolling out mobile healthcare across Saudi Arabia's varied terrain, a comprehensive and collaborative strategy is essential. This initiative would focus on deploying advanced mobile units designed for easy transportation and effective operation across challenging landscapes equipped with alternative energy sources, such as solar power, to ensure a reliable power supply [21]. Enhancing infrastructure and implementing detailed logistical planning—including optimizing travel routes and establishing local partnerships—would be vital for overcoming physical and geographical obstacles.

To address connectivity issues, the proposal includes using satellite communications and mobile internet devices to ensure continuous access to healthcare data and networks. Incorporating telehealth technology could further bridge the gap between patients and specialists, facilitating real-time consultations. The ongoing drive for technological enhancements in mobile healthcare equipment, coupled with the development of reliable diagnostic tools that operate independently of the high-speed internet, would ensure the durability and dependability of mobile diagnostics.

Crucially, training mobile unit personnel and establishing a technical support system are necessary to ensure the smooth operation of mobile healthcare services. By implementing these innovative and cooperative measures, Saudi Arabia could significantly advance the accessibility of essential diagnostic imaging services, thereby delivering vital healthcare to its most underserved communities.

Transforming Healthcare in Saudi Arabia with Mobile Diagnostic Units

The deployment of mobile diagnostic units is a transformative step in Saudi Arabia's healthcare landscape, particularly in MRI and CT imaging. This innovation impacts healthcare policy, service delivery, and accessibility, driving significant changes across the sector.

Policy and Strategic Implications

The introduction of mobile MRI and CT units necessitates crucial policy considerations. One key aspect is the decentralization of radiology services, which extends diagnostic capabilities to less accessible areas, thereby alleviating the pressure on urban healthcare facilities. This decentralization requires a strategic approach to workforce development, focusing on the training and deployment of technicians across a broader geographic area [75, 76]. Economically, these units provide a cost-effective means to enhance access to care, indicating a shift in funding priorities toward more flexible, mobile radiology services [11]. Such a shift could redefine healthcare investment, emphasizing flexibility and widespread access.

Integrating these units with telemedicine requires robust digital health policies to ensure data security, privacy, and standardized practices [77]. In situations such as the COVID-19 pandemic, mobile units have proven essential in bolstering healthcare resilience by providing decentralized diagnostic services. This not only eases the burden on urban centers but also ensures broader, timely access to crucial imaging services [78, 79].

There is a potential risk of exacerbating healthcare disparities if mobile services are more readily accessible to affluent communities or if barriers arise for those less familiar with digital health technologies. Ethical and equitable deployment strategies are vital to democratize healthcare effectively. This entails targeted outreach and education to ensure widespread and fair access, fostering a healthcare system that benefits all segments of the population.

Future Directions

As Saudi Arabia advances the implementation of mobile MRI and CT units, several key areas will be crucial for the ongoing evolution of radiology services. At the forefront is workforce development. The need for specialized training programs for radiographers is increasing, focusing on equipping professionals with the necessary skills for proficient use of mobile imaging technologies and accurate diagnostic interpretation [80].

The integration of mobile diagnostic services with telemedicine also represents a significant opportunity to enhance healthcare delivery. Through telemedicine, specialists can provide remote consultations, which improves both the efficiency and accuracy of diagnoses and extends the reach of expert care.

Looking to the future, the potential incorporation of AI and machine learning into mobile radiology practices is particularly promising. These technologies could fundamentally transform preliminary image analysis, offering healthcare professionals advanced tools for decision-making and diagnosis [81].

Conclusion

The integration of mobile MRI and CT units in Saudi Arabia is set to revolutionize access to diagnostic imaging by decentralizing services and extending reach directly to patients, including those in remote areas. This initiative aligns with national healthcare reforms aimed at enhancing efficiency, accessibility, and quality. Global case studies highlight the effectiveness of mobile units in reducing diagnostic delays, improving patient outcomes, and optimizing resource utilization. In Saudi Arabia, these units are especially valuable for managing demand spikes and providing care that respects cultural norms.

Despite facing logistical, regulatory, and technical challenges, strategic investments and collaborations are essential for overcoming these barriers. Thoughtful implementation of mobile imaging services, with careful consideration of costs, workforce needs, and technological advancements, is key to transforming radiological care in Saudi Arabia into a more equitable, flexible, and patient-centered system.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used *ChatGPT/Creative Writing Coach* in order to improve readability and language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

References

1. Phelan A, Broughan J, McCombe G, et al (2023) Impact of enhancing GP access to diagnostic imaging: A scoping review. PLoS One 18:e0281461. https://doi.org/10.1371/JOURNAL.PONE.0281461

2. Smith-Bindman R, Kwan ML, Marlow EC, et al (2019) Trends in Use of Medical Imaging in US Health Care Systems and in Ontario, Canada, 2000-2016. JAMA 322:843–856. https://doi.org/10.1001/JAMA.2019.11456

3. Borges do Nascimento IJ, Abdulazeem H, Vasanthan LT, et al (2023) Barriers and facilitators to utilizing digital health technologies by healthcare professionals. npj Digital Medicine 2023 6:1 6:1–28. https://doi.org/10.1038/s41746-023-00899-4

4. Saeed A, Bin Saeed A, AlAhmri FA (2023) Saudi Arabia Health Systems: Challenging and Future Transformations With Artificial Intelligence. Cureus 15:. https://doi.org/10.7759/CUREUS.37826

5. Hofmann B, Brandsaeter IØ, Kjelle E (2023) Variations in wait times for imaging services: a register-based study of self-reported wait times for specific examinations in Norway. BMC Health Serv Res 23:1287. https://doi.org/10.1186/s12913-023-10284-2

6. O. AlRowaili M, Ahmed AE, Areabi HA (2016) Factors associated with No-Shows and rescheduling MRI appointments. BMC Health Serv Res 16:1–7. https://doi.org/10.1186/S12913-016-1927-Z/TABLES/5

7. Saudi Arabia: hospital number by region | Statista. https://www.statista.com/statistics/608528/number-of-hospitals-in-saudi-arabia-by-region/. Accessed 19 Feb 2024

8. Deoni SCL, Medeiros P, Deoni AT, et al (2022) Development of a mobile low-field MRI scanner. Scientific Reports 2022 12:1 12:1–9. https://doi.org/10.1038/s41598-022-09760-2

9. John S, Stock S, Masaryk T, et al (2016) Performance of CT Angiography on a Mobile Stroke Treatment Unit: Implications for Triage. Journal of Neuroimaging 26:. https://doi.org/10.1111/jon.12346

10. Juhnke C, Mühlbacher AC (2013) Patient-centredness in integrated healthcare delivery systems - needs, expectations and priorities for organised healthcare systems. Int J Integr Care 13:. https://doi.org/10.5334/ijic.1114

11. Kjelle E, Lysdahl KB, Olerud HM (2019) Impact of mobile radiography services in nursing homes on the utilisation of diagnostic imaging procedures. BMC Health Serv Res 19:. https://doi.org/10.1186/s12913-019-4276-x

12. Malone NC, Williams MM, Smith Fawzi MC, et al (2020) Mobile health clinics in the United States. Int J Equity Health 19:1–9. https://doi.org/10.1186/S12939-020-1135-7/FIGURES/6

13. Toppenberg MD, Christiansen TEM, Rasmussen F, et al (2020) Mobile X-ray outside the hospital: A scoping review. BMC Health Serv Res 20:1–12. https://doi.org/10.1186/S12913-020-05564-0/TABLES/4

14. Dollard J, Edwards J, Yadav L, et al (2023) Mobile X-ray services in nursing homes as an enabler to healthcare-in-place for residents: informal carers' views. BMC Geriatr 23:1–11. https://doi.org/10.1186/S12877-023-04130-7/TABLES/1

15. Al Saffer Q, Al-Ghaith T, Alshehri A, et al (2021) The capacity of primary health care facilities in Saudi Arabia: infrastructure, services, drug availability, and human resources. BMC Health Serv Res 21:1–15. https://doi.org/10.1186/S12913-021-06355-X/TABLES/5

16. Almalki M, Fitzgerald G, Clark M (2011) Health care system in Saudi Arabia: an overview. Eastern Mediterranean Health Journal 17:. https://doi.org/10.26719/2011.17.10.784

17. Walston SL, Al-Harbi Y, Al-Omar B (2008) The changing face of healthcare in Saudi Arabia. Ann Saudi Med 28:. https://doi.org/10.5144/0256-4947.2008.243

18. Asmri M Al, Almalki MJ, Fitzgerald G, Clark M (2020) The public health care system and primary care services in Saudi Arabia: A system in transition. Eastern Mediterranean Health Journal 26

19. Yu SWY, Hill C, Ricks ML, et al (2017) The scope and impact of mobile health clinics in the United States: A literature review. Int J Equity Health 16

20. Hirschorn DS, Choudhri AF, Shih G, Kim W (2014) Use of mobile devices for medical imaging. Journal of the American College of Radiology 11:. https://doi.org/10.1016/j.jacr.2014.09.015

21. Mollura DJ, England RW, Harvey SC, et al (2018) Mobile strategies for global health radiology. In: Radiology in Global Health: Strategies, Implementation, and Applications

22. Shoghli A, Chow D, Kuoy E, et al Current role of portable MRI in diagnosis of acute neurological conditions. ncbi.nlm.nih.govA Shoghli, D Chow, E Kuoy, V YaghmaiFrontiers in Neurology, 2023•ncbi.nlm.nih.gov

23. NHS England » NHS to rollout lung cancer scanning trucks across the country. https://www.england.nhs.uk/2019/02/lung-trucks/. Accessed 19 Feb 2024

24. Emery D, Forster A, Shojania K, et al (2009) Management of MRI Wait Lists in Canada. Healthc Policy 4:. https://doi.org/10.12927/hcpol.2009.20537

25. CADTH (2023) Wait List Strategies for CT and MRI Scans. Canadian Journal of Health Technologies 3:. https://doi.org/10.51731/cjht.2023.557

26. Caffery LJ, Farjian M, Smith AC (2016) Telehealth interventions for reducing waiting lists and waiting times for specialist outpatient services: A scoping review. J Telemed Telecare 22:. https://doi.org/10.1177/1357633X16670495

27. Merriel SWD, Lee L, Neal R (2021) Community diagnostic centres: Bringing diagnostics closer to home. British Journal of General Practice 71

28. Gibney BT, Roberts JM, D'Ortenzio RM, et al (2021) Preventing and mitigating radiology system failures: A guide to disaster planning. Radiographics 41:. https://doi.org/10.1148/rg.2021210083

29. Yang Q, Xu H, Tang X, et al (2020) Medical imaging engineering and technology branch of the chinese society of biomedical engineering expert consensus on the application of emergency mobile cabin CT. Quant Imaging Med Surg 10:. https://doi.org/10.21037/QIMS-20-980

30. Latif S, Rana R, Qadir J, et al (2017) Mobile Health in the Developing World: Review of Literature and Lessons from a Case Study. IEEE Access 5

31. Rutty GN, Biggs MJP, Brough A, et al (2020) Remote post-mortem radiology reporting in disaster victim identification: experience gained in the 2017 Grenfell Tower disaster. Int J Legal Med 134:637–643. https://doi.org/10.1007/S00414-019-02109-X/METRICS

32. Bartlett EC, Kemp S V., Ridge CA, et al (2020) Baseline Results of the West London lung cancer screening pilot study – Impact of mobile scanners and dual risk model utilisation. Lung Cancer 148:12–19. https://doi.org/10.1016/j.lungcan.2020.07.027

33. Crosbie PA, Balata H, Evison M, et al (2019) Implementing lung cancer screening: baseline results from a community-based 'Lung Health Check' pilot in deprived areas of Manchester. Thorax 74:405–409. https://doi.org/10.1136/THORAXJNL-2017-211377

34. Portable MRI machine could revolutionize health care, Ontario doctors say | CBC News. https://www.cbc.ca/news/canada/toronto/portable-mri-machine-health-care-ontario-1.6416123. Accessed 19 Feb 2024

35. Mohammadshahi M, Alipouri Sakha M, Esfandiari A, et al (2019) Cost-effectiveness of mobile versus fixed computed tomography and magnetic resonance imaging: A systematic review and economic evaluation. Iran J Public Health 48

36. Illemann NM, Illemann TM (2024) Mobile imaging trailers: A scoping review of CT and MRI modalities. Radiography 30:431–439. https://doi.org/10.1016/J.RADI.2023.12.008

37. Portal | Open Data Portal. https://od.data.gov.sa/en. Accessed 19 Feb 2024

38. Alasiri AA, Mohammed V (2022) Part of the Health Policy Commons, and the International Public Health Commons Original Publication Citation Original Publication Citation Alasiri. Health Serv Insights 15:1–7. https://doi.org/10.1177/11786329221121214

39. Rahman R, Qattan A (2021) Vision 2030 and Sustainable Development: State Capacity to Revitalize the Healthcare System in Saudi Arabia. Inquiry (United States) 58

40. Craven P, Hansroth J, Quedado KD, et al (2021) Lessons on Mass Gatherings Learned From the 2019 Union Cycliste Internationale Mountain Bike World Cup. Cureus. https://doi.org/10.7759/cureus.14275

41. Deoni SC, Deoni AT, Burton P, et al (2021) Residential MRI: Development of A Mobile Anywhere-Everywhere MRI Lab. https://doi.org/10.21203/RS.3.RS-1121934/V1

42. Parakh A, Kortesniemi M, Schindera ST (2016) CT radiation dose management: A comprehensive optimization process for improving patient safety. Radiology 280:. https://doi.org/10.1148/radiol.2016151173

43. Miyasaka T, Kajiwara M, Kawasaki A, et al (2023) Development of a Car-mounted Mobile MR Imaging System for Diagnosis of Sports-related Wrist Injury. Magnetic Resonance in Medical Sciences 22:. https://doi.org/10.2463/mrms.tn.2021-0158

44. Burdorf BT (2022) Comparing magnetic resonance imaging and computed tomography machine accessibility among urban and rural county hospitals. J Public Health Res 11:. https://doi.org/10.4081/jphr.2021.2527

45. Reyes-Santias F, Antelo M (2021) Explaining the adoption and use of computed tomography and magnetic resonance image technologies in public hospitals. BMC Health Serv Res 21:. https://doi.org/10.1186/s12913-021-07225-2

46. Huang X, Wen L, Hao P, et al (2023) [Research and Practice of Vehicle-mounted Mobile CT Based on Emergency Medical Rescue]. Zhongguo Yi Liao Qi Xie Za Zhi 47:66–69. https://doi.org/10.3969/J.ISSN.1671-7104.2023.01.011

47. Perera CM, Chakrabarti R (2015) A review of m-health in medical imaging. Telemed J E Health 21:132–137. https://doi.org/10.1089/TMJ.2013.0330

48. Vang S, Margolies LR, Jandorf L (2019) Mobile Mammography Participation Among Medically Underserved Women: A Systematic Review. Prev Chronic Dis 15:. https://doi.org/10.5888/PCD15.180291

49. Postels D, Seydel K, Taylor Chetcuti TK, et al Environment: Our Experience in Malawi Scanner in a Resource-Constrained Implementation of a Low-Field Portable MRI Implementation of a Low-Field Portable MRI Scanner in a Resource-Constrained Environment: Our Experience in Malawi. AJNR Am J Neuroradiol PRACTICE PERSPECTIVES 43:670–674. https://doi.org/10.3174/ajnr.A7494

50. Toppenberg MD, Christiansen TEM, Rasmussen F, et al (2020) Mobile X-ray outside the hospital: A scoping review. BMC Health Serv Res 20:1–12. https://doi.org/10.1186/S12913-020-05564-0/TABLES/4

51. Morozov S, Guseva E, Ledikhova N, et al (2018) Telemedicine-based system for quality management and peer review in radiology. Insights Imaging 9:337–341. https://doi.org/10.1007/S13244-018-0629-Y/FIGURES/1

52. Alowais SA, Alghamdi SS, Alsuhebany N, et al (2023) Revolutionizing healthcare: the role of artificial intelligence in clinical practice. BMC Medical Education 2023 23:1 23:1–15. https://doi.org/10.1186/S12909-023-04698-Z

53. Padmanabhan P, Nedumaran AM, Mishra S, et al (2017) The Advents of Hybrid Imaging Modalities: A New Era in Neuroimaging Applications. Adv Biosyst 1:. https://doi.org/10.1002/ADBI.201700019

54. Shao J, Wang G, Yi L, et al (2022) Deep Learning Empowers Lung Cancer Screening Based on Mobile Low-Dose Computed Tomography in Resource-Constrained Sites. Frontiers in Bioscience - Landmark 27:212. https://doi.org/10.31083/J.FBL2707212/8B82625F11CEEF9154F93A1928A2B6D3.PDF

55. Mathur S, Walter S, Grunwald IQ, et al (2019) Improving Prehospital Stroke Services in Rural and Underserved Settings With Mobile Stroke Units. Front Neurol 10

56. Everts R, Muri R, Leibundgut K, et al (2021) Fear and discomfort of children and adolescents during MRI: ethical consideration on research MRIs in children. Pediatric Research 2020 91:4 91:720–723. https://doi.org/10.1038/s41390-020-01277-6

57. Crema MD, Yamada AF, Guermazi A, et al (2015) Imaging techniques for muscle injury in sports medicine and clinical relevance. Curr Rev Musculoskelet Med 8:154–161. https://doi.org/10.1007/S12178-015-9260-4

58. Nakagomi M, Kajiwara M, Matsuzaki J, et al (2019) Development of a small car-mounted magnetic resonance imaging system for human elbows using a 0.2 T permanent magnet. Journal of Magnetic Resonance 304:. https://doi.org/10.1016/j.jmr.2019.04.017

59. Headrick JR, Morin O, Miller AD, et al (2020) Mobile Lung Screening: Should We All Get on the Bus? In: Annals of Thoracic Surgery

60. Pua BB, O'Neill BC, Ortiz AK, et al (2023) Results from Lung Cancer Screening Outreach Utilizing a Mobile CT Scanner in an Urban Area. J Am Coll Radiol. https://doi.org/10.1016/J.JACR.2023.10.025

61. Sone S, Takashima S, Li F, et al (1998) Mass screening for lung cancer with mobile spiral computed tomography scanner. Lancet 351:. https://doi.org/10.1016/S0140-6736(97)08229-9

62. Sone S, Li F, Yang ZG, et al (2001) Results of three-year mass screening programme for lung cancer using mobile low-dose spiral computed tomography scanner. Br J Cancer 84:. https://doi.org/10.1054/bjoc.2000.1531

63. Hamaguchi M, Tsubata Y, Tanino A, et al (2022) Results of 10-year mobile low-dose computed tomography screenings for lung cancer in Shimane, Japan. Respir Investig 60:215–220. https://doi.org/10.1016/J.RESINV.2021.10.001

64. Chua SC, Perkins AC, Pearson D, Ganatra RH (2008) Mobile pet in the uk: Legislative, regulatory and cost-effectiveness considerations. Nucl Med Commun 29

65. Tan BS, Dunnick NR, Gangi A, et al (2021) RSNA international trends: A global perspective on the COVID-19 pandemic and radiology in late 2020. Radiology 299:E193–E203. https://doi.org/10.1148/RADIOL.2020204267/ASSET/IMAGES/LARGE/RADIOL.2020204267.FIG7.JPEG

66. Dickerson TC (2014) AN INTEGRATED DELIVERY MODEL FOR PROVIDING ON-SITE AND REMOTE RADIOLOGY SERVICES TO RURAL MIDWEST HOSPITALS

67. Bagayoko CO, Gagnon MP, Traoré D, et al (2014) E-Health, another mechanism to recruit and retain healthcare professionals in remote areas: Lessons learned from EQUI-ResHuS project in Mali. BMC Med Inform Decis Mak 14:1–6. https://doi.org/10.1186/S12911-014-0120-8/TABLES/7

68. Dhoot R, Humphrey JM, O'Meara P, et al (2018) Implementing a mobile diagnostic unit to increase access to imaging and laboratory services in western Kenya. BMJ Glob Health 3:e000947. https://doi.org/10.1136/BMJGH-2018-000947

69. García Sánchez C, Botella Juan G, Ayuso Márquez F, et al (2013) Implementation of a low-cost mobile devices to support medical diagnosis. Comput Math Methods Med 2013:. https://doi.org/10.1155/2013/287089

70. Ebinger M, Fiebach JB, Audebert HJ (2015) Mobile computed tomography: Prehospital diagnosis and treatment of stroke. Curr Opin Neurol 28:4–9. https://doi.org/10.1097/WCO.0000000000000165

71. Ezat Wan Puteh S, Noor Aizuddin A, Abdullah Al Salem A (2020) Renewal of Healthcare Funding Systems by National Health Insurance in the Kingdom of Saudi Arabia (NHI). https://doi.org/10.36348/sjls.2020.v05i11.001

72. Joudyian N, Doshmangir L, Mahdavi M, et al (2021) Public-private partnerships in primary health care: a scoping review. BMC Health Serv Res 21:1–18. https://doi.org/10.1186/S12913-020-05979-9/TABLES/4

73. Tynkkynen LK, Vrangbæk K (2018) Comparing public and private providers: A scoping review of hospital services in Europe. BMC Health Serv Res 18:1–14. https://doi.org/10.1186/S12913-018-2953-9/TABLES/3

74. Saudi Arabia Diagnostic Imaging Market, By Type (X-Ray Imaging Solutions, Ultrasound Systems, MRI Systems, CT Scanners, Nuclear Imaging Solutions, Mammography, Others), By Mobility, By Source, By Application, By End User, By Region, Competition Forecast & Opportunities, 2027. https://www.researchandmarkets.com/reports/5562161/saudi-arabia-diagnostic-imaging-market-by-type. Accessed 17 Feb 2024

75. Dhoot R, Humphrey JM, O'Meara P, et al (2018) Implementing a mobile diagnostic unit to increase access to imaging and laboratory services in western Kenya. BMJ Glob Health 3:e000947. https://doi.org/10.1136/BMJGH-2018-000947

76. Liew C (2018) The future of radiology augmented with Artificial Intelligence: A strategy for success. Eur J Radiol 102:152–156. https://doi.org/10.1016/j.ejrad.2018.03.019

77. Rezaeibagha F, Mu Y (2018) Practical and secure telemedicine systems for user mobility. J Biomed Inform 78:24–32. https://doi.org/10.1016/J.JBI.2017.12.011

78. Liu X, Sun Z, Wang X, et al (2021) Application of Mobile Helical Computed Tomography in Combatting COVID-19. Iranian Journal of Radiology 2021 18:1 18:1–7. https://doi.org/10.5812/IRANJRADIOL.106204

79. Stramare R, Carretta G, Capizzi A, et al (2020) Radiological management of COVID-19: structure your diagnostic path to guarantee a safe path. Radiologia Medica 125:691–694. https://doi.org/10.1007/S11547-020-01231-W/FIGURES/1

80. Bartholmai BJ, Erickson BJ, Hartman TE, et al (2002) The electronic imaging technology specialist: the role of a new radiology subspecialty for the 21st century. J Digit Imaging 15 Suppl 1:184–8. https://doi.org/10.1007/S10278-002-5024-Y

81. Shen D, Wu G, Suk H Il (2017) Deep Learning in Medical Image Analysis. https://doi.org/101146/annurev-bioeng-071516-044442 19:221–248. https://doi.org/10.1146/ANNUREV-BIOENG-071516-044442

Figures and Tables

Table 1: Example of the PubMed database's detailed search strategy and outcome.

Database	PubMed
Date search was conducted	20th October 2023
Search Strategy	(((("Mobile MRI"[All Fields] OR "Portable MRI"[All Fields] OR "Mobile Magnetic Resonance"[All Fields] OR "Mobile Imaging"[All Fields] OR (("mobile"[All Fields] OR "mobiles"[All Fields]) AND ("diagnostic imaging"[MeSH Subheading] OR ("diagnostic"[All Fields] AND "imaging"[All Fields]) OR "diagnostic imaging"[All Fields] OR "diagnostic imaging"[MeSH Terms])) OR (("portability"[All Fields] OR "portable"[All Fields] OR "portables"[All Fields]) AND ("diagnostic imaging"[MeSH Subheading] OR ("diagnostic"[All Fields] AND "imaging"[All Fields]) OR "diagnostic imaging"[All Fields] OR "diagnostic imaging"[MeSH Terms]))) AND ("loattrfull text"[Filter] AND "english"[Language])) OR (("Mobile CT"[All Fields] OR "Portable CT"[All Fields] OR "Mobile Computed Tomography"[All Fields] OR (("mobile"[All Fields] OR "mobiles"[All Fields]) AND ("tomography, x ray computed"[MeSH Terms] OR ("tomography"[All Fields] AND "x ray"[All Fields] AND "computed"[All Fields]) OR "x-ray computed tomography"[All Fields] OR "tomography x ray computed"[All Fields]))) AND ("loattrfull text"[Filter] AND "english"[Language]))) AND (("Radiological services"[All Fields] OR "Imaging Services"[All Fields] OR "Radiologic Services"[All Fields] OR "Medical Imaging"[All Fields] OR "Diagnostic Radiology"[All Fields]) AND ("loattrfull text"[Filter] AND "english"[Language]))) AND ((fft[Filter]) AND (english[Filter]))
Years searched	1987 – 2023
Number of results retrieved	467

Table 2: A table with the number of hospitals, MRI and CT units, population, and total area of each region in Saudi Arabia.

Region	Number of Hospitals	Population	Number of MRI Units	MRI Rate/10000 population	Number of CT Units	CT Rate/10000 population	Total Area (sq km)
Riyadh	110	8216284	100	0.1	232	0.2	380000
Makkah	99	8557766	83	0.09	232	0.2	137000
Eastern Province	63	4900325	70	0.1	157	0.3	540000
Asir	47	2211875	42	0.1	99	0.4	80000

Medina	32	2132679	36	0.1	98	0.4	150000
Qassim	28	1423935	33	0.2	86	0.6	73000
Tabuk	19	910030	25	0.2	58	0.6	136000
Jazan	23	1567547	24	0.1	57	0.3	13000
Hail	16	699774	19	0.2	45	0.6	120000
Najran	14	582243	15	0.2	36	0.6	130000
Al Bahah	9	476172	9	0.1	21	0.4	12000
Northern Borders	11	365231	11	0.3	25	0.6	104000
Al Jawf	14	508475	15	0.2	36	0.7	85000
Total	**485**	**32552336**	**482**	**-**	**1182**	**-**	**1950000**

Table 3: A comparative table of global case studies showing the impact of mobile MRI and CT units in different countries.

Country	Type of Unit	Target Population	Impact on Access to Care	Impact on Diagnosis Rates	Impact on Healthcare Cost	Key Outcomes
USA	MRI	Rural and remote communities	Increased accessibility	Higher early diagnosis rates for neurological conditions	Reduced travel costs for patients	Shortened waiting times for MRI scans, improved patient satisfaction
UK	CT	Urban areas with high demand	Reduced waiting times	Improved lung cancer screening rates	Cost-effective for the NHS compared to stationary units in the long term	Increased early detection rates of lung cancer, leading to earlier interventions
Canada	MRI	Indigenous communities in remote areas	Greatly increased access and saves time	Improved mental health and neurological condition diagnosis	Reduced overall healthcare costs by integrating with community health programs	Tailored healthcare services, reduced disparities in health outcomes

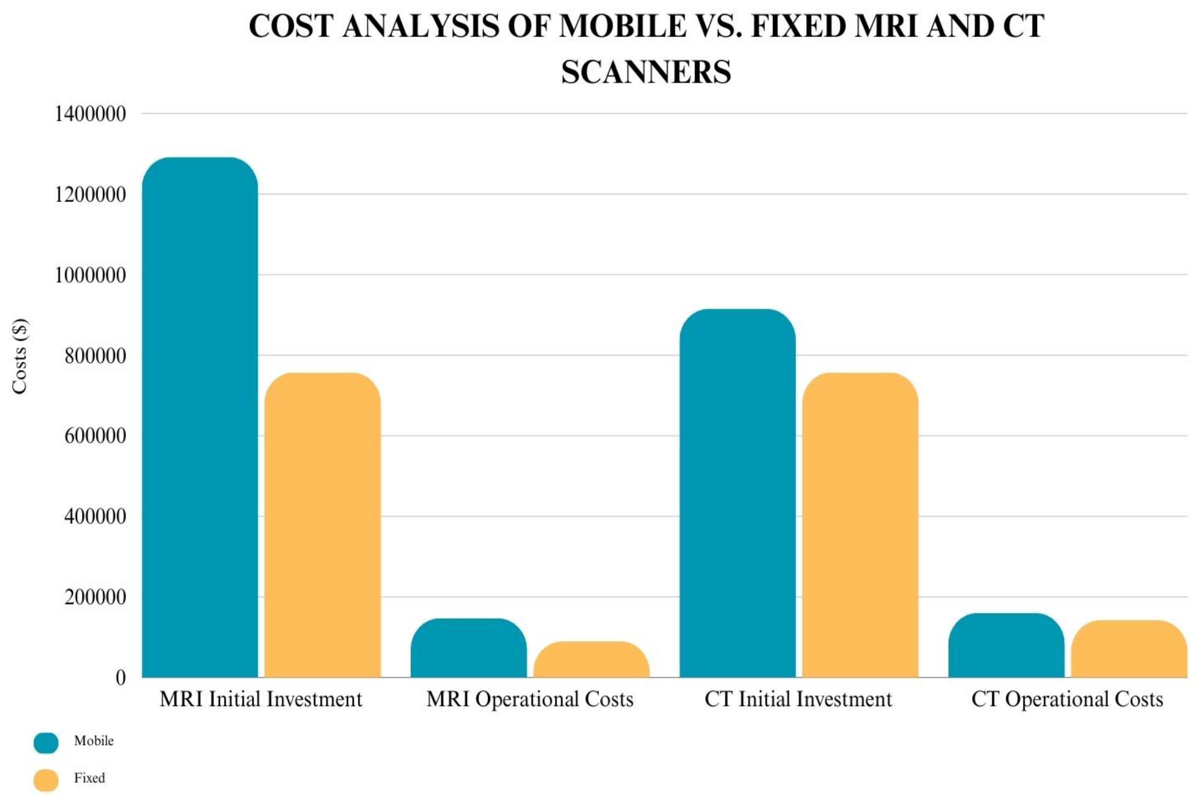

Figure 1: A bar graph compares the costs of mobile units versus fixed units.