A review of MRI studies in Africa with special focus on quantitative MRI: Historical development, current status and the role of medical physicists

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https://doi.org/10.1016/j.ejmp.2022.09.016
Received 13 May 2022; Received in revised form 13 September 2022; Accepted 28 September 2022
Available online 8 October 2022
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1. Introduction

The utility of nuclear magnetic resonance in distinguishing between normal and tumoral tissues, making it a tool for cancer diagnosis, was first described by Raymond V. Damadian in 1971. This was followed two years later by the first MR imaging success by Paul C. Lauterbur [1]. Peter Mansfield developed mathematical algorithms to aid rapid MR imaging which subsequently led to the first acquisition of in vivo MRI in 1977 [2].

By 1984, the first two articles [3,4] on MR imaging of brain tumors were published in Radiology. Both studies were conducted at a field strength of 0.35 T using 7 mm-thick slides, which offered images of poor resolution to identify very small tumors and calcifications, as well as differentiation of tumors from surrounding edema [5]. In recent times, MRI systems have seen increased availability, especially in high-income countries and tremendous improvement which has revolutionized clinical care and research outcomes.

This systematic scoping review focuses on MRI in Africa by providing an overview on the historical and major developments, current status, quantitative and qualitative MR studies and the role of national and regional medical physics bodies in the region.

2. Historical and major developments in MRI applications in Africa

MRI came into wide clinical use in the 1980s, but remained largely in the developed countries. Only South Africa installed its first MR system as early as 1986 in Cape Town by the Medical Research Council [6]. The installation of MRIs in Algeria began at the end of the 1980s with the installation of the first MRI at the Central Hospital of the Army in 1989. The first MRI (0.2 T low-field) in the public sector was installed in 1997 at the CHU Bab El Oued while the first unit installation in the private sector was made in 1994 at the Medical Imaging Center of Algiers (CIMA) [7]. From the 2000s and with the renewal of the health sector equipment program, the number of MRIs installed, both in the public and private sectors, increased significantly [7]. The early 2000s saw the installation of the first 1.5 T MRIs mostly in the Northern African countries, including Algeria, Morocco and Egypt. Most other African countries began to use MRI only in the last two decades, with some countries in West Africa yet to install MR systems [8]. In the West African sub-region, Nigeria led this revolution in diagnostic imaging by installing the first MR system in 1999 at the National Hospital in Abuja. By September 2016, eighty-four (84) MR systems were installed in West Africa, with fifty-eight (58; 69%) of them installed nation-wide in Nigeria by 2018, accounting for more than two-thirds of the MRI systems in the sub-region [8].

In Ghana, the first MR system was installed in 2006 at the Radiology Department of the Korle-Bu Teaching Hospital in Accra, and by 2010, two more MR systems were installed in two other teaching hospitals in the country [9]. In June 2008, Malawi commissioned its first-ever MR system at Queen Elizabeth Central Hospital in Blantyre [10]. This very first installed MR system was to serve not only Malawi but also neighboring Mozambique and Zambia, neither of which had MR systems at that time [10]. By July 2010, Zambia also commissioned its first MR system at the University Teaching Hospital in Lusaka [11].

In African countries where MRI are available, most of the MRI facilities are cited in urban areas, directing MRI services mostly to an urban population. Investments in MRI installations in Africa have largely been through the private sector [8,9]. For example, in Kenya, the German Medical Centre installed an MR system to serve the urban population of Kenya [12]. In contrast to private sector investment to MRI installations, the Government of Morocco in May 2018 instituted the National Healthcare Plan 2025 with an investment of $1.5 billion for the improvement of hospital capacity and another $1 billion to strengthen various national health and disease-control programs, citing MR imaging as one of the leading sub-sectors to benefit from this investment [13].

Almost all MR systems installed in Africa are of low-field strength (<1.5 T) and stand-alone systems (non-hybrid). However, the first 3 T MRI in Algeria was installed in 2014 at the El Farabi Clinic in Annaba. In 2015, South Africa launched Africa’s first research-dedicated full-body 3 T MR system at the Cape Universities Body Imaging Centre, University of Cape Town [14]. The MISR Radiology Center in Cairo, Egypt is reported to be the first institute in Africa and the Arab countries to install a PET/MRI hybrid scanner [15].

In developed countries, MRI applications have increased exponentially alongside significant improvements every year in pulse sequences, field strength, and expertise of MRI physicists. MRI utilization in Africa is however limited due to its cost, lack of infrastructure to support its application (such as stable electricity), and limited expertise to manage and run the MRI systems [7]. It is however refreshing to note that a project known as the Consortium for Advancement of MRI Education and Research in Africa (CAMERA) has been commissioned to establish a sustainable MRI training and mentorship programme in African countries. CAMERA is a network of African MRI experts and global partners who seek to reach out to underrepresented MRI physicists in African countries and provide them with up-to-date expertise to champion MRI research, provide innovation in MRI applications, and expand the applications of MRI to meet the healthcare needs of Africa [16].

These developments show that Africa holds prospects for increased MRI utilization if current efforts at both investments and training of more MRI physicists are sustained through the governments and national medical physics societies of the respective countries.

Given the historical timelines of MRI availability in the various...
countries, from the literature available, it was instructive to review trends in quantitative MRI applications from 2016 to the current year of the review, 2022. Within that period, it was expected that MRI would have been incorporated in the healthcare systems of those countries, and well-positioned to be used in clinical research. This thus offered a wider scope of inclusion of more relevant studies in Africa in the review, even though most studies did not meet the inclusion criteria and fewer countries had published MRI studies.

3. Availability of MRI facilities

Availability of MR systems and medical physicists serving in MRI centres in Africa were surveyed through Google Form online questionnaire between 17th – 31st March 2022. The questionnaire contained 10 questions focusing on (i) number available MR systems (ii) how many of the scanners are in public and private hospitals and (iii) number of

Table 1
Geographical regions and countries studied.

<table>
<thead>
<tr>
<th>Geographical region</th>
<th>No. of countries in geographical region</th>
<th>No. of countries studied</th>
<th>Percentage of countries studied per geographical region (%)</th>
<th>Percentage of countries studied per entire African region (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>7</td>
<td>4</td>
<td>57.1</td>
<td>7.4</td>
</tr>
<tr>
<td>Southern</td>
<td>5</td>
<td>3</td>
<td>60.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Eastern</td>
<td>18</td>
<td>10</td>
<td>55.6</td>
<td>18.5</td>
</tr>
<tr>
<td>Western</td>
<td>16</td>
<td>13</td>
<td>81.3</td>
<td>24.1</td>
</tr>
<tr>
<td>Central</td>
<td>8</td>
<td>2</td>
<td>25.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td>32</td>
<td>59.3</td>
<td>59.3</td>
</tr>
</tbody>
</table>

Fig. 1. MR system per million population.
distributed through email and WhatsApp platforms to medical physicists serving in MRI centres. The questionnaire was reviewed as part of the study, totaling 32 (59 %) of the 54 countries in Africa (Table 1).

3.1. MR system to population ratios

The density of diagnostic imaging units has been one of the measurable indices for defining the quality of a country’s healthcare infrastructure. Level of access to MR systems in Africa is analyzed through equipment to population ratios, summarized in the regional map of Fig. 1 and detailed data presented in Table 2. South Africa and Egypt, 2 of the 3 countries in Africa with highest nominal gross domestic product (GDP) in the region of 400 billion USD [17], have the most MR systems in absolute terms. Nigeria, which is considered the continent’s wealthiest country in nominal GDP terms, had the fifth highest number of installed MR systems. Nigeria’s radiation medicine industry is rapidly growing in recent times and is envisaged to see the installation of more MRI systems in coming years. Less than one-third of the studied countries (n = 10, 31 %) have more than one MR system per million population. These are Libya, Mauritius, South Africa, Algeria, Morocco, Namibia, Botswana, Egypt, Gabon and Cape Verde. Fig. 2.

The number of MR systems in the 4 northern countries (Egypt, Morocco, Algeria and Libya) alone constitute 53 % of the total number of machines in the studied countries. The northern sector of the African region is an economically prosperous area, generating one-third of Africa’s total GDP [17]. The wealth of this geographical region correlates with the number of MR systems recorded in the study. Medical imaging infrastructural outlook is generally better in the northern and southern sections of the region relative to the eastern, western and central parts. Amongst the surveyed countries, Libya has the most MR systems per million population. A wide disparity in availability of MR systems per population (0.076 – 6.549 m/mp) exists and this affirms the assertion of uneven distribution of medical imaging infrastructure across the region. Of the countries with less than 1 machine per million population, 54 % are from the west, 41 % from the east and 5 % from central Africa.

The MRI data from Cote d’Ivoire, Guinea, Togo, Mauritania and Cape Verde were retrieved from a 2017 survey and published by Ogbole et al (2018) [7]. Number of MR systems in the 6 countries may have changed at present, however, if numbers were to remain same since the 2018 study [7], Cote d’Ivoire and Guinea will each be seen to have over 13 million inhabitants having access to a single MR system. A preponderance of African countries belongs to the class of low- and lower-middle-income countries (LMICs) and have challenges of limited availability of MRI and other medical imaging equipment, unlike high-income countries [18].

Overall, the 32 studied African countries have combined population of 1.039 billion and 1,108 MR systems, yielding an average of 1 machine

Table 2

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (mil) [World Bank, 2020]</th>
<th>No. of MR systems</th>
<th>MR system to mil population ratio</th>
<th>MR system per mil population (s/mp)</th>
<th>Nominal GDP (bil USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egypt</td>
<td>102.33</td>
<td>277</td>
<td>1: 0.37</td>
<td>2.71</td>
<td>396.33</td>
</tr>
<tr>
<td>Namibia</td>
<td>2.54</td>
<td>7</td>
<td>1: 0.36</td>
<td>2.76</td>
<td>12.21</td>
</tr>
<tr>
<td>Morocco</td>
<td>36.91</td>
<td>119</td>
<td>1: 0.31</td>
<td>3.22</td>
<td>126.04</td>
</tr>
<tr>
<td>Algeria</td>
<td>43.85</td>
<td>150</td>
<td>1: 0.29</td>
<td>3.42</td>
<td>163.81</td>
</tr>
<tr>
<td>South Africa</td>
<td>59.31</td>
<td>243</td>
<td>1: 0.24</td>
<td>4.10</td>
<td>415.32</td>
</tr>
<tr>
<td>Mauritius</td>
<td>1.27</td>
<td>7</td>
<td>1: 0.18</td>
<td>5.50</td>
<td>11.00</td>
</tr>
<tr>
<td>Libya</td>
<td>6.87</td>
<td>45</td>
<td>1: 0.15</td>
<td>6.55</td>
<td>27.30</td>
</tr>
<tr>
<td>Total</td>
<td>1,039.92</td>
<td>1,108</td>
<td>1: 0.94</td>
<td>1.07</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (mil) [World Bank, 2020]</th>
<th>No. of MR systems</th>
<th>MR system to mil population ratio</th>
<th>MR system per mil population (s/mp)</th>
<th>Nominal GDP (bil USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cote d’Ivoire</td>
<td>26.38</td>
<td>*2</td>
<td>1: 13.19</td>
<td>0.08</td>
<td>68.84</td>
</tr>
<tr>
<td>Guinea</td>
<td>13.13</td>
<td>*1</td>
<td>1: 13.13</td>
<td>0.08</td>
<td>16.72</td>
</tr>
<tr>
<td>Burundi</td>
<td>11.89</td>
<td>1</td>
<td>1: 11.89</td>
<td>0.08</td>
<td>8.49</td>
</tr>
<tr>
<td>Togo</td>
<td>8.28</td>
<td>*1</td>
<td>1: 8.28</td>
<td>0.12</td>
<td>8.49</td>
</tr>
<tr>
<td>Mozambique</td>
<td>31.26</td>
<td>4</td>
<td>1: 7.81</td>
<td>0.13</td>
<td>15.83</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>115.00</td>
<td>16</td>
<td>1: 7.19</td>
<td>0.14</td>
<td>92.76</td>
</tr>
<tr>
<td>Mali</td>
<td>20.250</td>
<td>3</td>
<td>1: 6.75</td>
<td>0.15</td>
<td>19.56</td>
</tr>
<tr>
<td>Uganda</td>
<td>45.74</td>
<td>7</td>
<td>1: 6.53</td>
<td>0.15</td>
<td>43.24</td>
</tr>
<tr>
<td>Malawi</td>
<td>19.13</td>
<td>3</td>
<td>1: 3.68</td>
<td>0.16</td>
<td>12.15</td>
</tr>
<tr>
<td>Benin</td>
<td>12.12</td>
<td>2</td>
<td>1: 6.06</td>
<td>0.17</td>
<td>18.07</td>
</tr>
<tr>
<td>Niger</td>
<td>24.21</td>
<td>5</td>
<td>1: 4.84</td>
<td>0.21</td>
<td>15.64</td>
</tr>
<tr>
<td>Zambia</td>
<td>18.38</td>
<td>5</td>
<td>1: 3.68</td>
<td>0.27</td>
<td>21.70</td>
</tr>
<tr>
<td>Tanzania</td>
<td>59.73</td>
<td>17</td>
<td>1: 3.51</td>
<td>0.29</td>
<td>69.24</td>
</tr>
<tr>
<td>Senegal</td>
<td>16.74</td>
<td>5</td>
<td>1: 3.35</td>
<td>0.30</td>
<td>27.58</td>
</tr>
<tr>
<td>Cameroon</td>
<td>26.55</td>
<td>8</td>
<td>1: 3.32</td>
<td>0.30</td>
<td>44.81</td>
</tr>
<tr>
<td>Rwanda</td>
<td>12.95</td>
<td>5</td>
<td>1: 2.59</td>
<td>0.39</td>
<td>10.33</td>
</tr>
<tr>
<td>Gambia</td>
<td>2.42</td>
<td>*1</td>
<td>1: 2.42</td>
<td>0.41</td>
<td>2.04</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>20.90</td>
<td>9</td>
<td>1: 2.32</td>
<td>0.43</td>
<td>19.93</td>
</tr>
<tr>
<td>Nigeria</td>
<td>206.14</td>
<td>100</td>
<td>1: 2.06</td>
<td>0.49</td>
<td>480.48</td>
</tr>
<tr>
<td>Kenya</td>
<td>53.77</td>
<td>32</td>
<td>1: 1.68</td>
<td>0.60</td>
<td>109.49</td>
</tr>
<tr>
<td>Ghana</td>
<td>31.07</td>
<td>19</td>
<td>1: 1.64</td>
<td>0.61</td>
<td>75.49</td>
</tr>
<tr>
<td>Mauritania</td>
<td>4.65</td>
<td>*3</td>
<td>1: 1.55</td>
<td>0.65</td>
<td>9.16</td>
</tr>
<tr>
<td>Cape Verde</td>
<td>0.56</td>
<td>*1</td>
<td>1: 0.56</td>
<td>1.80</td>
<td>1.89</td>
</tr>
<tr>
<td>Gabon</td>
<td>2.23</td>
<td>5</td>
<td>1: 0.45</td>
<td>2.25</td>
<td>18.29</td>
</tr>
<tr>
<td>Botswana</td>
<td>2.35</td>
<td>6</td>
<td>1: 0.39</td>
<td>2.55</td>
<td>15.78</td>
</tr>
<tr>
<td>Egypt</td>
<td>102.33</td>
<td>277</td>
<td>1: 0.37</td>
<td>2.71</td>
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<tr>
<td>Total</td>
<td>1,039.92</td>
<td>1,108</td>
<td>1: 0.94</td>
<td>1.07</td>
<td></td>
</tr>
</tbody>
</table>

*Data from Ogbole et. al, 2018 [7] (Data may have changed at present).
per million population. This presents an improved representation of MRI availability in Africa. Relative to other published works in the region, this is the first of such wide-scale study comprising approximately 60% of African countries. The study of Ogbole et al (2018) [7] which is the next wide-scaled study focused only on West Africa, where 84 MRI units serving a population of 370 million was realized. Other studies, such as Ofori et al (2021), focused on availability of the MR systems at the national level [20]. All the studies have highlighted the inadequacy of MRI availability in Africa, primarily caused by the significant capital investment needed for the acquisition, installation and operation of MR systems. Human resource expertise, infrastructural and maintenance limitations are reported to also constitute a major impediment to the use of MR systems in this part of the world [7]. For example, the availability and cost of liquid helium for the imaging system refill is a big challenge in some countries. This has often created problems of extended downtimes for MRI systems and resulted in long waiting periods stretching into several months in parts of the region. Patients without immediate access to MR systems have to travel far, in some cases over 500 km, to access this important health service when needed.

3.2. MR scanner density in Africa vs other geographic regions

The Global Atlas of medical imaging devices, published by the World Health Organization (WHO), provides country survey on medical devices like MRI. The Atlas points out how medical devices support or hinder the accomplishment of the Sustainable Development Goals (SDGs) and contribute to the progress of the country-specific Universal Health Coverage (UHC) path. Data from the Atlas indicates that Africa has the least MRI density (machine per million population) among the six other continents of the world. Regional data from the 2017 version of the Atlas indicates that proportion of countries which have at least one MRI unit per million population are European Region (89%), Region of the Americas (64%), Eastern Mediterranean Region (62%), South-East Asian Region (50%), Western Pacific Region (41%) and African Region
3.3. Public and private sector contributions to MRI availability

Africa possesses a huge market potential for MRI services if challenges of infrastructure, health service reforms and lack of properly trained personnel should be adequately addressed. Generally, problems in the health sector in Africa are centered around inadequate funding resulting in under-resourced infrastructure, unstable electricity supply, shortage of healthcare personnel, and lack of capacity in the available workforce. These have pushed the private sector to the forefront in the development of the African health sector.

The contribution of public and private sector to MRI availability in Africa was analyzed based on data from 26 of the 32 studied countries (Table 3). The private sector by far dominates in the number of installed MR systems across the region, making up about two-thirds (64.3 %) of the distribution. This implies twice as much investment in MRI services by the private sector relative to government’s contribution. The private sector in Africa has generally seen increased investment in medical imaging services and healthcare provision in recent times. Given the competing interests from other healthcare needs, budget allocation for upgrading and expanding the medical imaging sector in Africa is mostly inadequate in relative terms. Most of the public sector dominance is observed in the northern and western parts of Africa, while only two countries from the eastern geographical areas observed same. Benin is the only country from the survey that had equal numbers of MR systems in both public and private sector.

MR systems are mostly concentrated in the large cities of Africa. Most rural communities do not have appreciable level of health infrastructure to support MRI operations and hence dwellers either have to travel to access the service elsewhere or resort to other available complementary diagnostic modalities for their healthcare needs. Ofori et al (2020) published that all installed MR systems in Ghana are concentrated in just 5 of the 16 national geographic regions [20]. Similar observation is reported by Ogbole et al (2018) where greater portion of the installed MR systems in Nigeria are in Lagos and Abuja [7]. In rural towns, where most inhabitants live below the poverty line, cost of MRI examination alone is enough to turn installed MRI systems into ‘white elephants’, if healthcare insurance is not available to provide support packages to cover such services. Contribution of the private sector as an engine of growth is thus highly important towards rapidly expanding and improving access to MRI and other medical imaging services in rural towns. Increased public–private sector collaboration is needed in this direction to improve geographical spread of MRI facilities across the African region.

4. Engagement of medical physicists in MRI services

The engagement of medical physicists (MPs) in MRI facilities is recommended to ensure improved image quality, efficient functioning of
the MRI imaging system, optimization of protection for patients, staff and the public, among others. Table 4 presents the number of available MPs in the studied countries and percentages of same who are engaged in MRI facilities. The total number of MPs of 1,103 from 26 countries in this study is 6 % more than the 2020 estimated data of MPs in Africa (Ige et al, 2020) [21]. Nineteen of the countries, representing 73 %, have no MPs offering services in MRI facilities. Average of 2.9 % of MPs in the surveyed countries are engaged in MRI work. The very few numbers of MPs in MRI is a reflection of the findings from the staffing level survey performed for Africa using the International Atomic Energy Agency (IAEA) developed staffing algorithm, where it was observed that the number of clinically qualified imaging medical physicists (CQIMPs) engaged in health centres is largely inadequate, at least by a factor of 20 in almost all countries in the region [22]. The limited MP personnel with knowledge and access to MRI facilities remain a major predicament for Africa. Breakdown and extended downtimes of many MRI systems could be avoided if regular quality control and maintenance checks were performed or supervised by qualified MPs.

5. Review of MRI published studies

5.1. Scope of review

The review includes quantitative MRI studies performed in Africa and published between 2016 and 2022. Search for relevant publications was primarily conducted in PubMed and Google Scholar using the keywords “quantitative magnetic resonance imaging or MRI in Africa”. This phrase returned 31 and 17,800 studies in PubMed and Google Scholar respectively. The search phrase was subsequently refined to replace “Africa” with the names of 24 African countries, one after the other based on data on availability of MRI systems in those countries. After carefully reviewing the titles and subsequently the abstracts of published studies found from each search, a total of 27 studies from 9 countries (Fig. 3) were selected for this review. Seven (7) out of the 27 published studies were quantitative.

Published studies with the following characteristics were excluded: strictly in vitro or non-human studies, review papers, publications in any language other than in English language, and studies that used nuclear magnetic resonance (NMR) techniques other than structural MRI.

Twelve (12) studies were retrospective while fifteen (15) studies were prospective by study type, focusing on various anatomical

![Fig. 3. Distribution of studies by country.](image)

![Fig. 4. Anatomies of interest in the various studies.](image)
Table 5
Brain MRI studies (n = 16).

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Study Objective(s)</th>
<th>Study Participants</th>
<th>Study Type</th>
<th>Pulse Sequence(s)</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ezeala-Adikaike et al.</td>
<td>Nigeria</td>
<td>To describe the pattern and frequency of occurrence of brain lesions in MRI of seizure patients</td>
<td>Seizure patients without clinical evidence of focal neurologic deficits</td>
<td>Retrospective</td>
<td>T1, T2, gradient-echo, FLAIR</td>
<td>MRI showed focal lesions in two-thirds, and normal findings in a third of the patients</td>
</tr>
<tr>
<td>Ogolodom et al.</td>
<td>Nigeria</td>
<td>To evaluate MRI findings in patients presenting with headache</td>
<td>Patients referred for MRI investigation with headache as clinical indication</td>
<td>Retrospective</td>
<td>Not stated</td>
<td>Out of 150 cases assessed, 48 % (n = 72) had normal MRI finding, 21.34 % (n = 32) had sinusitis, 1.33 % (n = 2) had pituitary mass, and 1.33 % (n = 2) had meningitis</td>
</tr>
<tr>
<td>Samia et al.</td>
<td>Kenya</td>
<td>To describe MRI findings in children with epilepsy</td>
<td>Children aged 0–18 years with epilepsy diagnosis</td>
<td>Retrospective</td>
<td>T1, T2, FLAIR, diffusion-weighted imaging (DWI), post-contrast T1</td>
<td>Ninety-five (53 %) children had abnormal findings on imaging. The most common findings were encephalomalacia related to chronic infants (n = 18: 6.3 %), cerebral atrophy (n = 11: 3.8 %), disorders of neuronal migration (n = 11: 3.8 %), periventricular leukomalacia (n = 9: 3.1 %), and hippocampal sclerosis (n = 8: 2.8 %).</td>
</tr>
<tr>
<td>Potchen et al.</td>
<td>Zambia</td>
<td>To identify pathophysiological mechanisms underlying cerebral edema in pediatric cerebral malaria</td>
<td>Comatose children (mean age 6.4 years) with retinopathy-confirmed cerebral malaria</td>
<td>Prospective</td>
<td>Susceptibility-weighted imaging (SWI), T2, T1 pre- and post-gadolinium, diffusion-weighted imaging (DWI) with apparent diffusion coefficients, T2-fluid attenuated inversion recovery sequences (FLAIR)</td>
<td>Gray matter appeared normal on DWI suggesting vasogenic edema with viable tissue rather than cytotoxic edema; while matter changes were consistent with vascular congestion. SWI findings were consistent with microhemorrhages. Children who subsequently recovered showed posterior reversible encephalopathy syndrome on MRI.</td>
</tr>
<tr>
<td>Benzagmout et al.</td>
<td>Morocco</td>
<td>1) To investigate emotional processing organization in the brain of patients with Parkinson’s disease 2) To explore whether there are differences between recognition of different types of emotions in Parkinson’s disease</td>
<td>Patients with Parkinson’s disease with no history of neurological or psychiatric comorbidities</td>
<td>Prospective</td>
<td>Single-shot echo-planar imaging</td>
<td>The occipito-temporal cortices, insula, orbitofrontal cortex, basal ganglia, and parietal cortex which are involved in emotion processing, were activated during the functional control. Also, positive emotions activated larger volumes of the same anatomical entities than neutral and negative emotions. Parkinson’s disease associated with emotional disorders are increasingly recognized as disabling as classic motor symptoms.</td>
</tr>
<tr>
<td>Ikubor et al.</td>
<td>Nigeria</td>
<td>To determine the prevalence, site, and type of abnormalities in the paranasal sinus using MRI of suspected intracranial diseases and unrelated sinus disease</td>
<td>Patients referred for brain MRI for suspected intracranial disease</td>
<td>Prospective</td>
<td>T1, T2, diffusion-weighted imaging (DWI), short-T1 inversion recovery (STIR), T2-fluid attenuated inversion recovery (FLAIR) and time of flight (TDoF)</td>
<td>Prevalence of sinus disease was 26.7 %, maxillary sinus most frequent, and the commonest abnormality was fluid collection with air-fluid level</td>
</tr>
<tr>
<td>Ogbole et al.</td>
<td>Nigeria</td>
<td>To identify the presence and frequency of ventricular CSF pulsation artifact (VCSFA) on FLAIR axial brain MRI at a low-field</td>
<td>Patients referred for brain MRI for various conditions</td>
<td>Retrospective</td>
<td>FLAIR</td>
<td>VCSFA occurred in at least one ventricular cavity among 16.3 % of the patients. The 4th ventricle was the commonest site of VCSFA (n = 10), followed by the 3rd ventricle (n = 8) and the lateral ventricles (n = 7). CSF pulsation of VCSFA did not occur across the brain parenchyma in the phase encoding direction. Cortical surface area and thickness within frontal regions were associated with cognitive development, and in temporal and frontal regions with language development. It is feasible to carry out a neuroimaging study of young children during natural sleep in sub-Saharan Africa.</td>
</tr>
<tr>
<td>Wedderburn et al.</td>
<td>South</td>
<td>1) To investigate the feasibility of paediatric multimodal MRI at age 2–3 years without sedation; 2) To explore the relationship between cortical structure and neurocognitive development at age 2–3 years in a sub-Saharan African setting</td>
<td>Healthy children aged 2–3 years</td>
<td>Prospective</td>
<td>T1-Multi-Echo Magnetization Prepared Rapid Acquisition Gradient Echo (T1-MEMPRAGE), T2, functional MRI (fMRI), diffusion tensor imaging (DTI), magnetic resonance spectroscopy (MRS)</td>
<td>(continued on next page)</td>
</tr>
</tbody>
</table>
structures (Fig. 4).

5.2. Trends in MRI studies in Africa

MRI is a fairly new diagnostic tool in most African countries and expertise in its applications may be very limited in most regions of Africa. The review (Tables 5 – 9) showed that current trends in quantitative MRI applications in Africa include protocol assessment studies [23], evaluation of the utility of MRI as a diagnostic tool in disease conditions [24–33], disease prevalence studies [24,32,33], establishment of normal range of measurements of some anatomical and physiological parameters [34–36], establishment of associations between quantitative MRI parameters and measured disease physiological parameters in healthy and diseased populations [28,37–40], image processing studies [41,42], and most recently, the development of artificial intelligence models using MR images in diagnosis [43,44]. Most of these studies are still within the range of basic applications of quantitative MRI. However, in some regions of Africa, functional connectivity inversely correlated with global deficits scores (worse performance) was observed in brain MRI of more than half of the children. Findings included dilated periventricular white matter (28 %), subcortical deep white matter (34 %), sub-cortical lacunar infarcts in gray matter (16 %), and caudate in the cyanotic group. Local reductions in cortical thickness were observed in the frontal, parietal and temporal lobes. Three types of color maps were calculated using the acquired DWI and DTI. Data in the color maps compared with the fiber directions of known anatomical structures (e.g., corpus callosum and gray matter).

Table 5 (continued)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Study Objective(s)</th>
<th>Study Participants</th>
<th>Study Type</th>
<th>Pulse Sequence(s)</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idro et al. (2016) [38]</td>
<td>Uganda</td>
<td>To assess structural brain changes associated with cerebral malaria or severe malaria anaemia</td>
<td>Children aged 18 months to 12 years diagnosed with cerebral malaria or severe malaria anaemia</td>
<td>Prospective</td>
<td>T1, T2, Fluid Attenuated Inversion Recovery (FLAIR), diffusion weighted imaging (DWI)</td>
<td>Small vessel ischaemic neural injury was observed in the brain MRI of more than half of the children.</td>
</tr>
<tr>
<td>du Plessis et al. (2017) [39]</td>
<td>South Africa</td>
<td>To investigate the effect of HIV on neurocognitive function during resting-state functional MRI</td>
<td>Treatment-naive adult HIV patients</td>
<td>Prospective</td>
<td>Gradient-echo planar imaging (EPI), T1 magnetization-prepared rapid gradient echo (T1-MPRAGE)</td>
<td>In ten regions of six resting-state networks, functional connectivity inversely correlated with global deficit scores (worse performance).</td>
</tr>
<tr>
<td>Salama et al. (2016) [40]</td>
<td>Egypt</td>
<td>1) To assess brain volumetrics and ischemic brain lesions in children with cyanotic congenital heart disease (CCHD) 2) To determine the correlation between MRI findings, oxygen saturation and some laboratory measures</td>
<td>Children with cyanotic congenital heart disease (CCHD) and a mean oxygen saturation of 83 ± 2.2 %</td>
<td>Prospective</td>
<td>Single-shot diffusion-weighted echo-planar imaging (DW-EPI)</td>
<td>Findings included dilated ventricles (28 %), subcortical deep white matter hyperintensity (46 %), periventricular white matter hyperintensity (46 %), subcortical deep white matter (34 %), sub-cortical lacunar infarcts in gray matter (16 %), and caudate in the cyanotic group.</td>
</tr>
<tr>
<td>Boujraf (2018) [41]</td>
<td>Morocco</td>
<td>To perform a comparative study of visualized diffusion anisotropy in the human brain anatomical entities using three different color-mapping techniques based on diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI)</td>
<td>Healthy adult volunteers</td>
<td>Prospective</td>
<td>T1-weighted Magnetization Prepared Rapid Gradient Echo (MP-RAGE)</td>
<td>Structural similarity (SSIM) index and DICE coefficients between the pseudo-CT image and the corresponding real CT image showed that the proposed stereo-matching approach outperforms a registration one.</td>
</tr>
<tr>
<td>Chaibi &amp; Nourine (2018) [42]</td>
<td>Algeria</td>
<td>To generate a pseudo-CT image from an MR image</td>
<td>Sample MR images obtained from the Vanderbilt database, called the Retrospective Image Registration Evaluation Project (RIRE)</td>
<td>Retrospective</td>
<td>T1-Fluid Attenuated Inversion Recovery (T1-FLAIR)</td>
<td>T1 images had the most discriminative features with 0.9513 accuracy, 0.907 sensitivity, and 0.9487 specificity. The developed model outperformed other models with 0.9975 accuracy, 0.9894 sensitivity, and 1 specificity. Agreement of clinical staging with MR spectroscopy (76.67 %) was higher than with MRI (66.67 %). MRS had higher sensitivity, accuracy, positive and negative predictive values than MRI, but they had equal specificity.</td>
</tr>
<tr>
<td>Fettah, Goumidi, &amp; Daho (2022) [43]</td>
<td>Algeria</td>
<td>To develop an automated system of diagnosing Glioma by classifying brain tumors into High-Grade Glioma (HGG) and Low-Grade Glioma (LGG).</td>
<td>Sample MR images from institutional database</td>
<td>Retrospective</td>
<td>T1, T2, Fluid Attenuated Inversion Recovery (T2-FLAIR)</td>
<td>Abnormal and normal MRI findings were 52 % and 48 %, respectively. Commonest neoplastic and non-neoplastic abnormalities were pituitary macroadenoma (4 %) and sinusitis (21.3 %) respectively.</td>
</tr>
<tr>
<td>Mansour et al. (2017) [45]</td>
<td>Egypt</td>
<td>To compare the performances of MRI and MR Spectroscopy (MRS) in diagnosis and staging of hypoxic-ischemic encephalopathy (HIE)</td>
<td>Full-term neonates in first 2 weeks with hypoxic-ischemic encephalopathy (HIE)</td>
<td>Prospective</td>
<td>Spin-echo (SE), T2 fast spin-echo (FSE), FLAIR</td>
<td>Abnormal and normal MRI findings were 52 % and 48 %, respectively. Commonest neoplastic and non-neoplastic abnormalities were pituitary macroadenoma (4 %) and sinusitis (21.3 %) respectively.</td>
</tr>
<tr>
<td>Itanyi et al. (2020) [46]</td>
<td>Nigeria</td>
<td>To evaluate the utility of cranial MRI in identifying intracranial lesions among patients with chronic headache</td>
<td>Patients presenting with chronic headache (or history of headache lasting up to 3 months)</td>
<td>Retrospective</td>
<td>T1, Gd-DTPA-enhanced T1, FLAIR, MR Angiography</td>
<td>Abnormal and normal MRI findings were 52 % and 48 %, respectively. Commonest neoplastic and non-neoplastic abnormalities were pituitary macroadenoma (4 %) and sinusitis (21.3 %) respectively.</td>
</tr>
</tbody>
</table>
reported in seven studies [30,34,35,36,40,41,48], employing some of the sophisticated MRI pulse sequences and image post-processing methods. This trend is expected because MRI was introduced in the healthcare settings of these countries relatively earlier than in their counterparts. Basic MRI applications thus commenced in these countries earlier, resulting in their current advancements in research and clinical applications. Table 10.

5.3. MRI protocols

During MRI, a series of radiofrequency pulses are applied to the anatomy of interest and characteristic signals are collected from the anatomy by receiver coils to be processed into the desired images. Multiple pulses are often applied in sequence at set time periods; a collection of these pulses, how long they are applied, and the time intervals between pulses constitute a pulse sequence which is programmed into the MR system. A choice of pulse sequence for a particular study is the MRI protocol of that study. Basic MRI protocols often include T1, T2 and proton density sequences.

A range of MRI protocols were used by the studies. Inversion recovery, IR (T1-weighting) and gradient-echo, GE (T2-weighting) techniques were the most widely used MRI protocols; proton density was rarely used except in one study [29]. Various modified forms of the IR and GE sequences were applied across all studies, some of which included the use of contrast media [23,26,27,31,43,46,48] and fat saturation techniques particularly for breast MRI [47,48].

Highly specialized MRI protocols such as diffusion-weighted imaging (DWI) [26,27,30,32,38,41,48], susceptibility-weighted imaging (SWI) [27], and diffusion tensor imaging (DTI) [37,41] were used in studies focusing on assessing permeability of brain tissues under various conditions; MR angiography (MRA) and time of flight (TOF) techniques were used to assess the integrity of vessels and blood flow in vessels of the brain [32], whereas single-shot echo planar imaging techniques were used to study neuronal responses to stimuli or in resting state happening within specified times in functional MRI studies [28,39].

The range of MRI protocols used in the various studies reflects the

---

### Table 6

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Study Objective(s)</th>
<th>Study Participants</th>
<th>Study Type</th>
<th>Pulse Sequence(s)</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mensah et al.</td>
<td>Ghana</td>
<td>To determine the MRI utilization trend and its policy implications in Ghana</td>
<td>Patients with degenerative diseases</td>
<td>Retrospective</td>
<td>Not stated</td>
<td>Significant association and correlation were obtained between the number of body parts evaluated and examination year as well as the variety of clinical conditions requested and examination year for degenerative bone disease was the commonest finding, which can otherwise be diagnosed by plain radiography</td>
</tr>
<tr>
<td>Gorlek et al.</td>
<td>Ghana</td>
<td>To evaluate the local lumbar spine MRI protocol, clinical indications, referral sources, imaging findings and the appropriateness of the request using the Appropriateness Criteria (AC)</td>
<td>Adult patients with degenerative bone disease</td>
<td>Retrospective</td>
<td>T1 FSE, T2 FSE, STIR FSE, T2 FSE post-contrast, T1-FatSat, post-contrast T1-FatSat</td>
<td>Degenerative bone disease was the commonest finding, which can otherwise be diagnosed by plain radiography</td>
</tr>
<tr>
<td>Stutterheim &amp; Goodier</td>
<td>South Africa</td>
<td>To assess the reliability of a mechanism-based approach to complex post-trauma knee MRI interpretation among different observers</td>
<td>Post-trauma knee patients undergoing MRI</td>
<td>Retrospective</td>
<td>T1, short tau inversion recovery (STIR), T2, proton density with fat saturation, spectral pre-saturation with inversion recovery (SPIR)</td>
<td>The independent radiologists agreed that 62 % of cases were not classifiable by mechanism, 26 % because of highly complex injury and 26 % because of non-specific findings.</td>
</tr>
</tbody>
</table>

### Table 7

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Study Objective(s)</th>
<th>Study Participants</th>
<th>Study Type</th>
<th>Pulse Sequence(s)</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abd El-Aal, H. et</td>
<td>Egypt</td>
<td>To use apparent diffusion coefficient (ADC) estimates from diffusion-weighted-MRI (DW-MRI) for characterization of malignant and benign breast lesions</td>
<td>Adult females with breast masses</td>
<td>Prospective</td>
<td>T1, T2-spectral pre-saturation with inversion recovery (T2-SPRIR), EPI-DW, T1 High-Resolution Isotropic Volume Excitation (THRIVE), short tau inversion recovery (STIR)</td>
<td>Mean ADC values of the malignant and benign lesions were 0.93 ± 0.42 × 10^{-3} mm²/s and 1.54 ± 0.43 × 10^{-3} mm²/s respectively. The receiver operating characteristic (ROC) curve could identify an ADC of 1.26 × 10^{-3} mm²/s as a cut-off value to differentiate between benign and malignant lesions with sensitivity and specificity of 89 % and 94.7 % respectively. Breast Imaging-Reporting and Data System (BI-RADS) and the Kaiser scoring system showed statistically significant correlation with each other and with histopathology results for each lesion</td>
</tr>
<tr>
<td>Cloete et al.</td>
<td>South Africa</td>
<td>To assess the reliability of breast MRI (bMRI) to characterize lesions resembling fibroadenomas on ultrasound</td>
<td>Patients with breast masses</td>
<td>Prospective</td>
<td>T2, T2-fat saturation, DWI, dynamic contrast-enhanced (DCE) imaging</td>
<td></td>
</tr>
<tr>
<td>Ramaema &amp; Hift</td>
<td>South Africa</td>
<td>To evaluate the accuracy of diffusion-weighted, T2-weighted and dynamic contrast-enhanced MR (DCE-MR) imaging in differentiating breast cancer (BCA) from breast tuberculosis (BCT).</td>
<td>Patients with BCA who had undergone preoperative MRI and those with pathologically proven BCT who underwent DCE-MRI</td>
<td>Retrospective</td>
<td>DWI, pre-contrast T1, T1-fat saturated, T2-short tau inversion recovery (STIR), T2-turbo spin echo (TSE)</td>
<td>Mean values of apparent diffusion coefficient and T2-weighted signal intensity were significantly lower in BCA compared to BCT</td>
</tr>
</tbody>
</table>

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5.4. Field strengths

MRI physicists in African countries in this regard. Field strengths of the MR systems used in the studies ranged between 0.2 T and 3.0 T (Table 9). Only 5 studies used magnets below 1.5 T, which appears to be skewed in favor of few countries. There is therefore the gradual understanding and incorporation of advanced MRI applications - [25,42 – 44]. One study [26] was conducted at both 1.5 T and 3.0 T, while 4 studies [8,23,26-32,36,38,40,41,45,47,48] were conducted at 3.0 T, which was the maximum field strength reported. It has been reported elsewhere [49] that both 1.5 T and 3.0 T do not differ significantly in diagnostic quality of images they produce; however, 3.0 T may have safety concerns in its application due to large fringe magnetic effects, especially in a setting where expertise in its use is limited.

While ultra-high field MRI is becoming common in European countries, mostly in research settings, same cannot be said about African countries mainly due to lack of adequate financial support for MRI applications. It thus appears that the 3.0 T remains the highest magnetic field strength in Africa, with most countries using 1.5 T MR systems.

### Table 8

Ocular MRI studies (n = 3).

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Study Objective(s)</th>
<th>Study Participants</th>
<th>Study Type</th>
<th>Pulse Sequence(s)</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aiyekomogbon &amp; Rafindadi (2017) [34]</td>
<td>Nigeria</td>
<td>To use MRI to establish the normal ocular axial length of the eyeball</td>
<td>Normal adults</td>
<td>Prospective</td>
<td>T1, slices planned at the level of the lens</td>
<td>Averages of ocular axial lengths of right/left globes were 23.32 ± 1.34 mm; 23.29 ± 1.22 mm and of the inter-zygomatic line was 103 ± 4.78 mm. Measurements in males were higher than in females. Normal position of the posterior pole of the right and left globes were 6.34 ± 0.99 mm and 6.56 ± 0.93 mm respectively from IZL. The position of the right globe within the orbit was significantly different from that of the left.</td>
</tr>
<tr>
<td>Aiyekomogbon et al. (2016) [35]</td>
<td>Nigeria</td>
<td>To determine inter-zygomatic distance, distance between the anterior and posterior borders of the globes and the inter-zygomatic line (IZL), and then using these parameters to determine the normal position of the ocular globes within the orbits</td>
<td>Adult individuals 18-80 years who did not have clinical or radiological evidence of proptosis or epiphthalmas, referred for MRI of the brain and/or paranasal sinuses.</td>
<td>Prospective</td>
<td>T1- and T2-weighted spin echo sequence in the axial, coronal, and sagittal planes</td>
<td></td>
</tr>
<tr>
<td>Mncube &amp; Goodier (2019) [36]</td>
<td>South Africa</td>
<td>To establish normal measurements of the optic nerve (ON), optic nerve sheaths (ONS) and optic chiasm (OC)</td>
<td>Normal adults</td>
<td>Prospective</td>
<td>T2-turbo spin echo (T2-TSE)</td>
<td>No statistical differences in the measurements between gender and age correlation. Interobserver agreement was best for larger structures (OC width and intracranial ON width, respectively)</td>
</tr>
</tbody>
</table>

### Table 9

MRI studies of the heart (n = 1) and lungs (n = 1).

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Study Objective(s)</th>
<th>Study Participants</th>
<th>Study Type</th>
<th>Pulse Sequence(s)</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mncube &amp; Goodier (2019) [36]</td>
<td>South Africa</td>
<td>To investigate early myocardial disease and its progression in antiretroviral therapy naive patients</td>
<td>Antiretroviral therapy naive adults without known cardiovascular disease</td>
<td>Prospective</td>
<td>Post-contrast T1 mapping, T2 mapping, extracellular volume (ECV) mapping, and late gadolinium enhancement (LGE) imaging</td>
<td>All patients had non-dilated left ventricular volumes (LV). No patient had overt systolic dysfunction. Non-trivial pericardial effusions were present in 71 % of cases. Indexed LV mass measured normal. Late gadolinium enhancement imaging showed 71 % of abnormalities associated with midmyocardial enhancement of the inferior septum.</td>
</tr>
<tr>
<td>Isizoh et al. (2021) [44]</td>
<td>Nigeria</td>
<td>To develop diagnostic system for coronavirus using MRI.</td>
<td>Patients with normal pneumonia and those with COVID-19 pneumonia</td>
<td>Retrospective</td>
<td>Not stated</td>
<td>The developed deep learning network took about 9 min to be trained, detect and predict COVID-19 diagnosis with a prediction accuracy of 99.37 %</td>
</tr>
</tbody>
</table>

### Table 10

Distribution of magnetic field strengths of the MR systems used in the studies.

<table>
<thead>
<tr>
<th>References</th>
<th>Field strength (T)</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>[34,35]</td>
<td>0.2</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td>[32,46]</td>
<td>0.3</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td>[24]</td>
<td>0.25</td>
<td>1</td>
<td>4.2</td>
</tr>
<tr>
<td>[8,23,26-32,36,38,40,41,45,47,48]</td>
<td>1.5</td>
<td>16</td>
<td>66.7</td>
</tr>
<tr>
<td>[26,37,39]</td>
<td>3.0</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>Total number of systems</td>
<td>24</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

One study [26] was conducted at both 1.5 T and 3.0 T, while 4 studies [25,42-44] did not provide information about field strength.

### 5.4. Field strengths

Field strengths of the MR systems used in the studies ranged between 0.2 T and 3.0 T (Table 9). Only 5 studies used magnets below 1.5 T, which is becoming the most common clinical field strength in most centres and offers a range of quantitative applications. Three (3) studies were conducted at 3.0 T, which was the maximum field strength reported. It has been reported elsewhere [49] that both 1.5 T and 3.0 T do not differ significantly in diagnostic quality of images they produce; however, 3.0 T may have safety concerns in its application due to large fringe magnetic effects, especially in a setting where expertise in its use is limited.

While ultra-high field MRI is becoming common in European countries, mostly in research settings, same cannot be said about African countries mainly due to lack of adequate financial support for MRI applications. It thus appears that the 3.0 T remains the highest magnetic field strength in Africa, with most countries using 1.5 T MR systems.

### 5.5. Quantitative MRI studies

Out of the 27 published studies reviewed, 7 were quantitative MRI studies [30,34,35,36,40,41,48]. By anatomy of interest, these quantitative MRI studies focused on the brain [40,41], breast [30,48] and ocular structures [34–36]. One brain study measured volumes of brain structures and investigated the correlations between these measurements and oxygen saturation and other laboratory measurements [40]. The other study calculated three color maps from diffusion-weighted...
and diffusion-tensor images and used the maps to estimate fiber directions of selected anatomical structures [41]. In breast studies, apparent diffusion coefficient (ADC) estimates from diffusion-weighted images were used to characterize malignant and benign breast lesions [30], while ADC and T2-weighted signal intensity estimates were used elsewhere [48] for differentiation between breast cancer and breast tuberculosis. The quantitative ocular MRI studies involved the establishment of the normal ocular axial length of the eyeball [34], determination of the normal position of the ocular globes within the orbits using zygomatic measurements [35], and establishment of the normal measurements of the optic nerve, optic nerve sheath and optic chiasm.

6. Roles of national and regional MP bodies towards improving MRI clinical services and research in Africa

There are currently no MRI physics societies in Africa; however, there are discussions around starting an African chapter of the International Society for Magnetic Resonance in Medicine (ISMRM). In addition, funding was secured for the CAMERA consortium [50] which is committed to establishing a sustainable MRI training and mentorship programme in African countries [51]. Only twelve African countries have a medical physics society, all of whom belong to the Federation of African Medical Physics Organizations (FAMPO), which in turn is the African chapter of the International Organization for Medical Physics (IOMP) [52]. Imaging medical physicists are a scarce resource in Africa, and of the 251 imaging medical physicists on the continent, 137 work in diagnostic radiology and 124 in nuclear medicine [21]. In 2011, the International Labour Organization (ILO) classified medical physics as an integral part of the health workforce, with one of the listed tasks being “ensuring the safe and effective delivery of radiation (ionizing and non-ionizing) to patients to achieve a diagnostic or therapeutic result as prescribed by a medical practitioner” [53], and so it is clear that medical physicists have a crucial role to play in clinical MR imaging and research. With such a small number of medical physicists on the continent, maybe national and/or regional bodies can be leveraged to create more awareness.

The aims and functions of FAMPO include the promotion of improved quality service to patients and the community in the region, to promote the co-operation, communication and the profession and practice of medical physics, to promote and improve the training of medical physicists, to promote research and development, to promote the appropriate use of technology and to collaborate with other scientific bodies [21].

All of these are applicable to the expansion of MR imaging in Africa. The role of a national and regional medical physics body is very important for the development of MRI through education, research, and training. In addition, societies can help to improve communication between stakeholders, make appropriate and applicable information available to professionals, patients and the public, or offer continuous professional development (CPD) events. National societies may be a valuable resource for regulatory bodies, especially in a region where MR systems for clinical care and research owing to low priority and investments in the health sector. The region possesses a big market potential for MR services and requires the cooperation of both governments and the private sector to address the major infrastructural challenges and impediments. The few MR systems available in Africa have found very useful needs to support diagnostic radiology services and many more of such systems are needed to further advance healthcare delivery.

Ethical clearance

N/A (No patient or animal data was used in the study).

Informed consent

All respondents to questionnaire indicated consent to participate in study.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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