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An audit of clinical practice, referral patterns, and appropriateness of clinical indications for brain MRI examinations: A single-centre study in Ghana

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A B S T R A C T

Introduction: The aim of this study was to investigate current brain MRI practice, pattern of brain MRI requests, and their appropriateness using the American College of Radiology (ACR) Appropriateness Criteria.
Material and methods: We used direct observation and questionnaires to obtain data concerning routine brain MRI practice. We then retrospectively analyzed (i) demographic characteristics, (ii) clinical history, and (iii) appropriateness of brain MRI requests against published criteria.
Results: All patients were administered the screening questionnaire; however, no reviews were undertaken directly with patients, and no signature of the radiographer was recorded. Apart from routine brain protocol, there were dedicated protocols for epilepsy and stroke. Brain MRI images from 161 patients (85 Males; 76 Females) were analyzed. The age group with most brain MRI requests were from 26 to 45 year olds. The commonest four clinical indications for imaging were brain tumour, headache, seizure, and stroke. Using the ACR Appropriateness Criteria, almost 43% of the brain MRI scans analyzed were found to be "usually appropriate", 38% were "maybe appropriate" and 19% were categorized as "usually not appropriate".
Conclusion: There was knowledge gap with regards to MRI safety in local practice, thus there is the utmost need for MRI safety training. Data on the commonest indications for performing brain MRI in this study should be used to inform local neuroradiological practice. Dedicated stroke and epilepsy MRI protocols require additional sequences i.e. MRA and 3D T1 volume acquisition, respectively. The ACR Appropriateness Criteria is recommended for use by the referring practitioners to improve appropriateness of brain MRI requests.

Introduction

Magnetic resonance imaging (MRI) of the brain is the most sensitive technique available for the vast majority of intracranial disease because of its high sensitivity, and higher resolution in exploiting inherent contrast differences of tissues and water content.[1–4] These unique inherent properties, thus allow for the detection of subtle anatomical and vascular changes.[3,4] MRI can provide important pre-surgical information in the investigation of brain tumors.[2] MRI also allows the assessment of invasion of venous sinuses by meningioma, the assessment of optimal sites for biopsy in malignant tumors, and monitoring of the response to treatment.[1] Other indications for MRI include suspected pituitary disease, sensory neural hearing loss, disease of the cerebral white matter, multiple sclerosis, temporal lobe epilepsy and many others.[1,2] The use of contrast media may also be warranted in probing some of these conditions to improve enhancement, characterization and lesion grading.

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In-depth knowledge and understanding on the clinical application of MRI is important in order to produce high quality images. This includes the ability to critically evaluate, justify, and modify protocols (i.e. weightings, pulse sequence parameters) where appropriate in common MRI examinations. As such, the MR protocols employed should be standardized to ensure continuity over time and adapted to the equipment available and requirements of the patient.[5] As a general rule, MRI studies of the brain should include at least two imaging planes and two "weightings," and preferably more.[5] Commonly used weightings in MRI of the brain include T1-weighted (T1W), T2-weighted (T2W), proton-density weighted (PDW), and T2*-weighted (T2*W). T1W images best demonstrate anatomy but after contrast enhancement, it can demonstrate pathology. T2W images are best suited for demonstrating pathology as most lesions have an increased water content and are therefore hyperintense on T2W images. PDW images are also capable of demonstrating anatomy and some pathology. T2*W images best demonstrate haemorrhage. Gadolinium chelates may be administered intravenously when there is suspicion of breakdown of the blood–brain barrier,[1] after which post-contrast T1W images can be obtained in the axial and/or coronal and/or sagittal planes with short TR and TE sequences.

Essentially, to operate the MRI equipment, it is also very important to demonstrate an understanding of the safe use of MRI, particularly in areas such as policy and procedures. In addition, knowledge of the use of contrast agents including safety issues, indications and contraindications are required. Another consideration is that it is expected that a facility with MRI will provide a suitable environment for patients to access their care without any difficulty. This includes putting in place policies regarding the cost of the examination, method of reimbursement, establishment and implementation of picture archiving communication systems (PACS), how images are issued, when the MRI report is ready for collection, and radiologist specialists.

Evidence shows that the availability of imaging and its use has in no doubt contributed to improved health outcomes; however, it is also a strong contributor to increasing healthcare cost, and suspicions of inappropriate or unnecessary use.[6,7] It has been shown that the growth rate of advanced imaging procedures exceeds that of medical cost increases overall.[8,9] The appropriateness of MRI is gaining a wide attention in the medical community, just like other diagnostic imaging modalities. Criticisms around MRI imaging studies being overutilized and inappropriate which generates unnecessary costs and delays.[10] It is estimated that inappropriate imaging are reported to amount to up to 30%, or even up to 77% inappropriate use for certain applications.[11] In British Columbia (Canada), in an analysis of computer tomography (CT) and MRI requests across indications, using a five-point rating scale for appropriateness based on Canadian Association of Radiologists (CAR) guidelines and a meta-analysis of other guidelines, the rates of inappropriate imaging accounted to 2%.[12] Also, in a Finnish University Hospital using the European Commission (EC) referral guidelines, 7% inappropriate examinations were reported.[6] In an analysis of outpatient referrals for CT and MRI using an evidence-based appropriateness criteria from a radiology benefit management company, it was reported that 35%, 37%, and 13% of referrals for MRI of the spine, shoulder, brain and orbits were considered inappropriate respectively.[13] American College of Radiology (ACR) Appropriateness Criteria guidelines[14] have been provided with the intention of enhancing quality and efficacy of health care delivery.[15] The guidelines are evidence based and emphasize appropriate use of testing for accurate staging and tailoring of therapeutic interventions with an aim of reducing unnecessary treatments.[15] Little is known about the level of adherence to these published guidelines within routine clinical practice.[15] However, provision of the level of adherence of these guidelines in routine clinical practice may provide important information for policymakers as they struggle with physicians and patients, who are unhappy with restrictive utilization management programs, and payers and the public, who are looking for ways to decrease health care costs and increase the quality and safety of examinations.

Therefore, the aim of this study was to investigate current brain MRI practice, patterns of brain MRI requests, and their appropriateness. We also retrospectively analyzed (i) demographic characteristics, (ii) clinical history, and (iii) appropriateness of brain MRI requests using the ACR appropriateness criteria.[14]

Materials and methods

This study was in two parts which took place at a public MRI suite in Ghana. We used two methods for collecting data: observation and questionnaire. To generate qualitative data, we used an overt, non-participatory, natural, and systematic observation approach[16] with the goal of gaining a respondent's knowledge of brain MRI practice i.e. patient preparation and screening. The observation was performed over a period of 5 days (30 h in total). With observational methods, there is an epistemological position which suggests that knowledge or evidence of the social world can be generated by observing, or participating in, or experiencing 'natural' or 'real-life' settings, interactive situations and so on.[17] However, it is acknowledged that by trying to obtain consent, the situation of observation may be destroyed.[16] In our case, consent was sought from the respondent. In addition, a structured questionnaire (closed-ended and open-ended) (Table 1) was used with the intention to collect quantitative data.[18]

In the second part, we obtained information from the MRI register which included age, sex, and clinical history of adult patients (aged ≥ 18 years) who presented to the suite for brain MRI during the period of 1st January 2017 to 30th May 2017. We then retrospectively analyzed (i) demographic characteristics, (ii) clinical history, and (iii) appropriateness according to the American College of Radiology.[14]

Results

Patient preparation

A patient (safety) screening form was provided to the patients for completion. If all contraindications were ruled out, then the patient was instructed to remove all ferromagnetic items on their body and change into an MRI dedicated gown.

Table 1
Response to MRI practice.

Question	Response
1. What is the MRI scanner field strength?	1.5 T
2. What type of MRI contrast is in use?	Gadovist
3. Do you screen for renal function prior to administering contrast?	No
4. What is the average time of scan?	
- Without contrast?	25 min
- With contrast?	45 min
5. What is the price of brain MRI	
- Without contrast?	GH¢625.00[a]
- With contrast?	GH¢900.00[a]
6. How is the price of MRI reimbursed?	Out-of-pocket; Private health insurance
7. Do you have PACS connected to the MRI system?	Yes
8. When is MRI report issued?	3 days after imaging
9. How are MRI images issued?	Films and Compact Disc

[a] GH₵1 = US$4.2.

Imaging planes

The MRI scanner is able to permit the positioning of the slices position slices simultaneously on three localizer images. On a midsagittal image, the corpus callosum, sylvian aqueduct, and 4th ventricle are usually used as anatomical landmarks.

Apart from the routine brain MRI protocol, there are dedicated protocols for stroke and epilepsy. All the sequences in Table 2 are similar to that used in the stroke protocol in the exception of the post-contrast sequences. Similarly, the same sequences are employed in the epilepsy protocol, but in addition to Axial T2W 3 mm temporal and Coronal FLAIR 3 mm. Contrast is not administered routinely used except in the presence or a suspected lesion.

Discussion

MRI scanners are technologically sophisticated and require a high level of knowledges and skills for effective clinical application. Therefore, it is important that radiographers handling MRI equipment have in-depth knowledge about its operation, and associated safety issues. In Ghana, to the best of our knowledge, currently, there are only two radiographers with postgraduate MRI qualification, one of which is the author. As such, apart from the undergraduate radiography education provided at only two universities (University of Ghana and University of Cape Coast), there is no formal training in the area of MRI and so majority of the radiographers using MRI equipment acquired their skills on-the-job, both from colleagues or from application specialists who provided training after installation. In very few occasions, some have had to undergo short training courses in order to complement their knowledge. Similar factors have been reported in previous studies.[19,20] In our observation of practice during brain MRI, we noted that all patients were administered the screening questionnaire. However, the radiographer did not review it with the patients to ensure that they understood every detail of it, and no signature of the radiographer was recorded to indicate approval for the scan. It is recommended that the screening form should be complemented with verbal interaction and review, and should be signed by the MRI staff.[21] Even though the facility had a metal detector, it was observed that none of the patients were subjected to screening for metallic materials. The use of metal detector is no more encouraged because it is incapable of differentiating between metallic and non-metallic materials.[21] Currently, the use of ferromagnetic detection systems is recommended as they are capable of detecting even very small ferromagnetic objects external to the patient, and differentiating between ferromagnetic and non-ferromagnetic materials.[21] Clearly, this study showed that there were knowledge gaps with regards to MRI safety in local practice and this is supported by Opoku et al.[19] The limitations witnessed might have come about as a result of workload or stress being routinely borne by the radiographer who is tasked with cannulation, patient instruction, checking body mass index, entering demographic data on the scanner, patient positioning, scanning, as well as other clerical duties and interference from other staff, patients, and their accompanying relatives.

The routinely used contrast medium in this facility was Gadovist, a non-ionic macrocyclic agent; even though it was acknowledged that Magnevist and ProHance had been used in the past. Macrocyclic agents are currently recommended for patients with renal dysfunction, and those that may require repetitive dosing as they are more stable than linear agents. Renal screening information is provided on the screening questionnaire, however it clear that the facility does not undertake estimated glomerular filtration rate (eGFR) for patients prior to the administration of MRI contrast. This practice falls in line with the recommendation of the European Society of Urogenital Radiology[22] which only mandates the measurement of eGFR prior to the administration of contrasts in patients receiving the high-risk agents i.e. Omniscan, OptiMark, and Magnevist which have been associated with subsequent development of NSF. Notably, in the information leaflet attached to the Gadovist package, it stated that “prior to the administration of Gadovist all patients should be screened for renal dysfunction by obtaining a history and/or laboratory tests”.[23] Thus, as a precaution, it may be valuable to adhere to this recommendation, and taking into consideration, according to the ACR manual[24] that pre-administration of eGFR calculation should be undertaken in individuals scheduled to receive any gadolinium based contrast agent with the following risk factors – more than 60 years of age, history of renal disease (i.e. dialysis, kidney transplant, single kidney, kidney surgery, and history of known cancer involving the kidney[s]), history of hypertension requiring medical therapy, and history of diabetes mellitus. The average MRI acquisition time for brain imaging is between 25 and 45 min. This is consistent with a previous survey.[25] In a recent survey of 12 MRI facilities to determine availability, accessibility, and affordability of magnetic resonance imaging services in Ghana, the authors[26] reported a mean price of GH₵ 590.00 for brain MRI, and mean cost per MRI examination, was lower in public health facilities compared to the private facilities. It is widely known that MRI is much expensive as compared with other imaging modalities. It is also acknowledged that whilst MRI examinations are affordable for >70% of the total populations in the Organization for Economic Cooperation and Development countries, in Africa and in Southeast Asia, such examinations can only be affordable by <50% of the total population at <10% of annual household disposable income.[27] This is confirmed in a previous Ghanaian study.[26] The mode for reimbursement of MRI in Ghana is either by out-of-pocket payment or some private health insurance.[26] Indeed the National Health Insurance Scheme is to cover for MRI services, but evidence shows that the tariffs apportioned by the National Health Insurance Levy for MRI examinations are very low, as compared with the private health insurance and recovery takes a long time for many facilities.

The integration of PACS within the workflow of imaging departments enables, efficient image acquisition, viewing, interpretation, storage, and speedy electronic transfer of data for teleradiology which can lead to improved patient care.[28,29] Compared to film-based systems, there is no risk of film loss, and it significantly reduces the cost and time of storing and retrieving prior imaging studies.[28] It is noteworthy that this facility had PACS for processing its images. It is a remarkable achievement as evidence shows that the implementation of PACS in developing countries is relatively slow, due to budget constraints to accommodate for information and technology developments. Nevertheless, PACS is a necessity. However, PACS is associated with high initial capital expenses for equipment, infrastructure, and training, as well as ongoing costs for maintenance and for additional IT staff.[28]

Table 2
Protocol for routine MRI of the brain, epilepsy, and stroke.

Pre-contrast sequences
Axial T2W
Axial FLAIR
Axial T1W
Axial FE T2*
Axial DWI
Sag T1W
Post-contrast sequences
Axial T1W
Coronal T1W
Sagittal T2W

It is vital that patients have rapid access to test results so they are diagnosed early, and are treated as quickly. Lengthy delays in diagnosis can result in extra worry and concern for people at a time when they are most vulnerable thus heightening anxiety for patients, waste of time and other resources, not just in radiology but throughout the healthcare system. In some other countries in Europe, scans are reported in as little as 24 h.[30] However, the availability of MRI reports within 3 working days may seem reasonable in this facility as compared to previous practice where it takes a week to get results. Ghana has only 40 trained radiologists per a total population of 24,658,823. While Germany has 92, Spain has 112 and France has 130 radiologists per million population (Campbell, 2014).[30]

The use of CDs as a means of transmitting data from imaging studies has some potential benefits but incurs degradation over time, including significant cost for the treating physician, the need for additional equipment (computers) and their maintenance.[31,32] In a review of lumbar MRI on CD versus film, Fras and Castilleja[31] noted the time needed to review an MRI of the lumbar spine on CD was on average more than double that needed to review a lumbar MRI on film, a situation which has cost implication and diminished productivity. Thus the authors[31] noted that the move to placing imaging studies on CD may in fact represent “cost shifting” rather than “cost saving”. It is important that patients have CD or printed copies of their imaging results for review. This is to avoid wasted time and unnecessary repetition of tests.[33]

MRI of the brain at 1.5 T provides a high signal-to-noise ratio and allows improved spatial resolution sufficient to yield diagnostic MR images. In recent times, phased-array head coils have become the standard of brain MRI due to their high resolution. They contain multiple small coil elements, arranged in an integrated design which surrounds the head (e.g., 8-, 12- or even 32-channel head coils).[5] The major advantage of phased-array head coil is that it allows the application of parallel acquisition techniques which can be used to reduce acquisition time; however, the trade-off is a decrease in SNR. The most commonly accepted basic imaging protocols for MRI of the brain currently include a T1-weighted sequence in the sagittal plane and T2-weighted fluid-attenuated inversion recovery (FLAIR) in the axial plane (ACR). Typically, an MRI protocol can include 5 or more pulse sequences[25] as evidenced in Table 2.

In any type of neurological MRI, it is crucial to gather as much information as possible to increase diagnostic confidence.[34] Whether it is an exam for brain tumor, stroke, or epilepsy, scanning must not only be fast and efficient, but the images produced must provide high-detailed information.[34] Stroke can be evaluated with both conventional MRI and MR angiography (MRA) sequence.[35] The use of MRI in stroke helps in direct visualization of ischemia in the acute phase, but can also help rule out differentials such as multiple sclerosis and haematoma.[36] The ideal protocol for stroke includes diffusion weighted imaging (DWI), T2/FLAIR, T2*W, perfusion-weighted imaging, fast susceptibility imaging, and two-dimensional (2D) and/or three-dimensional (3D) time of-flight (TOF) and contrast-enhanced MRA images through the neck and 3D TOF MRA images through the Circle of Willis.[35–38] 3D MRA provides information on cervical and brain vessels.[36–38] Compared with 2D TOF, the 3D TOF technique has better spatial resolution, a better signal-to-noise ratio and less intravoxel dephasing, but it is more limited by the vascular saturation artifact and therefore can cover only a small volume.[35] 2D TOF, is also vulnerable to artifactual signal loss from flow turbulence.[35] MRA is not included in the stroke protocol (Table 2) of this facility despite its usefulness in the interrogation of brain vessels.[36–38] Microbleeds (small hemosiderin deposits) not apparent on CT, can be detected by T2*-weighted images.[39] Fat-saturated axial T1 (T1-FS)-weighted through the neck should be considered if cervical artery dissection is suspected.[35,40]

MRI is the imaging modality of choice in the investigation of patients with epilepsy.[41,42] The sensitivity of MRI in detecting abnormalities in patients with epilepsy is not only dependent on the type of pathologic substrate of the epilepsy, but also on the MRI protocol used, and on the experience of the interpreting.[43] Standard brain MRI protocols are not adequate for interrogating epileptic brains. This is supported in a study[44] that reported that standard MRI protocols fail to detect up to 50% lesions in patients with refractory epilepsy. A dedicated epilepsy protocol is required and should have sequences with the minimum slice thickness, covering the whole brain, and providing high contrast resolution, good SNR, good spatial resolution, and short imaging time.[42,45,46] MRI protocol should comprised of 3D T1W volume acquisition, T2W, FLAIR, and inversion recovery pulse sequence acquisitions.[41,45,46] Notably, 3D T1W sequence is not included in the local protocol of epilepsy (Table 2) in this facility. Evidence shows that

Table 3
Demographics.

Total Number of Patients = 161 (85 Males; 76 Females)				
Age (years)	Sex, Male (=85)	Age (years)		
		Mean	Median	Standard deviation
18–25	6	22.0	22.5	2.3
26–35	16	31.0	32.0	3.1
36–45	17	40.7	40.5	2.8
46–55	8	51.2	51.0	3.0
56–65	14	61.0	61.0	3.2
≥66	24	73.4	72.0	5.2

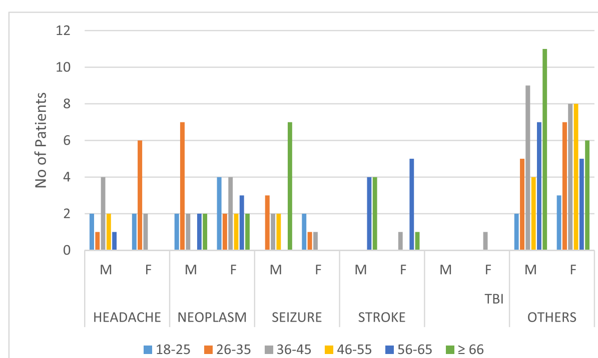

Figure 1. Demographic distribution of brain MRI referral patterns.

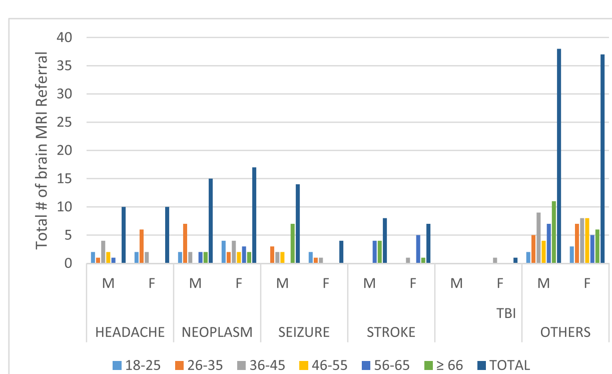

Figure 2. Total of brain MRI referral pattern.

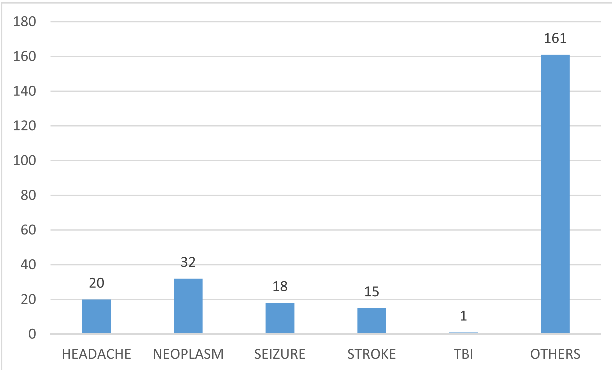

Figure 3. Summary of the frequency of clinical indications for brain MRI request.

Table 4
Number of cases sent for brain MRI and analyzed according to the ACR Appropriateness Criteria.[14]

Appropriateness rating category	Number of Cases
Usually not appropriate	31 (19%)
May be appropriate	61 (38%)
Usually appropriate	69 (43%)

the acquisition of thin-section 3D coronal oblique T1 gradient echo (SPGR [spoiled gradient echo], MPRAGE [magnetization-prepared rapid gradient echo], or BRAVO [brain volume]) and coronal oblique T2 series permits the assessment of more subtle abnormalities, including hippocampal sclerosis or cortical dysplasias,[45] but also provides exquisite anatomic detail which can be reconstructed to obtain high quality volume imaging thus providing the best data for digital image processing.[46] High-resolution 3D sequences and T2 FLAIR (fluid attenuated inversion recovery) images also increase the sensitivity to subtle cortical dysplasia and other abnormalities, including neoplasms.[47] MR imaging of the hippocampus (and amygdala) is best performed using 2- to 3-mm FSE (fast spin-echo) T2, and FSE FLAIR in a slightly oblique coronal plane.[48] Contrast-enhanced T1 may be useful for interrogating brain tumours, and Sturge-Weber syndrome.[41] However, evidence shows that contrast enhanced images did not improve the detection rate for epileptogenic lesions, but did help characterize vascular lesions and grade tumors.[49]

In this study, the patients' demographics (Table 3), and clinical indications (Fig. 2) entered in the MRI register were obtained, and subjected to an evaluation using the ACR Appropriateness Criteria. In a total of 161 (85 males, 76 females) brain MRI requests (Table 3; Fig. 1), the age group with most requests were within 26–45 years (Fig. 1). The four main clinical indications in this study were brain tumour (primary and secondary neoplasm), headache, seizure, and stroke (Fig. 3). This is somewhat in contrast with a review study[50] of clinical indications for CT and MRI studies which reported headache, head trauma, and acute neurological deficit as the most common indications for examinations requested. This contrast might be because we only evaluated the use of MRI in our study whereas in the study as compared to that of Paniagua et al.[50] which included CT which is often used to screen for headaches, which can be linked to tumours, and may be more suitable for trauma than MRI. Using the ACR Appropriateness Criteria,[14] almost 43% of the MRI scans performed in our facility were found to be "usually appropriate", 38% were "maybe appropriate" and 19% were categorized as "usually not appropriate (Table 4). Inappropriate MRI examinations may result from cases with high clinical suspicion of intracranial pathology, mainly due to symptoms of concern or positive neurological signs. It is also likely that due to inadequate or the lack of knowledge and/or training on when, how, and why MRI should be used, unnecessary examinations may be requested. Another reason for inappropriate MRI could also be due to increased supply and demand of MRI services. Patient demand may be related to this cause, and for the reason that health practitioners have increasing concerns for medicolegal risk (fear of litigation), there may be the possibility of promoting defensive medicine and imaging without clinical justification, other than to exclude pathology. Indeed inappropriateness of MRI examinations have also been widely reported in the literature by several authors.[6,10–13,51,52] It is well acknowledged that appropriateness of MRI for individual indications and in general is complex as it may vary with patient characteristics including patients' condition and symptom.[53] A crucial point to note is that inappropriate use of a certain technology may also include its overuse or misuse.[54] 'Overuse/overutilisation' can be defined as the use of a technology more often than is indicated,[55] not improving patient outcome at the same time.[56] On the other hand, 'misuse' can be described as the use of a technology for purposes other than those for which it was originally intended in the absence of evidence that doing so is clinically effective and cost-effective (for example, scope creep).[55] Excessive imaging may also cause additional need for imaging because of false-positive and extra findings.[6] Various forces influence overutilization of imaging in many countries, such as financial incentives, self-referrals and defensive medicine,[13,56] duplicate imaging studies and patient expectations,[6] preference for high technology, and unawareness from the true costs of care due to third-party payment.

There are limitations in the present study. It is a study from one tertiary care hospital, and the study was restricted to the observation of only one radiographer. Only brain MRI requests of patients of ≥18 years of age were analyzed. Also, we did not evaluate for the final radiological diagnosis.

In conclusion, there was knowledge gap with regards to MRI safety in local practice, thus there is the utmost need for MRI safety training. The revelation of the commonest four clinical indications for brain MRI in this study should inform local neuroradiological practice. The dedicated stroke and epilepsy MRI protocols require additional sequences i.e. MRA and 3D T1 volume acquisition respectively. The ACR Appropriateness Criteria is recommended for use by the referring practitioners to improve appropriateness of brain MRI requests.

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