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LITERATURE REVIEW

Overuse of Medical Imaging in Low-Middle Income Countries: A Scoping Review

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Abstract

Purpose: The overuse of medical imaging is a key component of medical resource overutilization. Primary reasons for this include high costs, overdiagnosis, incidental findings and direct harms. Although the overuse of medical imaging is well-researched in high income countries, it is still unclear what evidence there is for the overuse of medical imaging in low-middle income countries (LMICs). Understanding the extent of medical imaging overuse in LMICs could encourage doctors and policymakers to address the problem of overuse, which may facilitate better use of limited resources.

Methods and Materials: A scoping review was performed according to the PRISMA Extension for Scoping Reviews Checklist. Electronic academic databases Medline via Ovid, Embase and CINAHL were searched for relevant studies.

Results: Forty studies were identified, with a total of 42,413 patient participants across 15 LMICs. Computed tomography (CT) scan was the most frequent imaging modality of study (20/40), followed by magnetic resonance imaging (MRI) (13/40), and ultrasound (US) (6/40). Guidelines were used as a tool to define imaging overuse in 58% (23/40) of the included studies. However, only 5% (2/40) of studies used local guidelines. The overall results of the review showed that 35% of MRI, 55% of CT, 40% of radiography, 62% of ultrasound and 12% of single-photon emission computed tomography (SPECT) investigations were recorded as an overuse.

Conclusion: The results of this study show that there is evidence for the widespread overuse of medical imaging in LMICs, including the overuse of CT, MRI, radiography, ultrasound and SPECT. The majority of studies demonstrated a lack of local imaging guidelines. Future research may focus on developing guidelines designed for the local disease epidemiology and the financial context of the locality, to better identify overuse and promote more contextually appropriate imaging practices.

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Introduction

Access to quality healthcare remains a major barrier to development. For this reason, health has been given a central place in the 2030 Sustainable Development Agenda, with universal health coverage (UHC) seen as a "unifying platform" for the achievement of Health Sustainable Development Goal 3 (1). Strategies to tackle the underuse of healthcare services are core in the pursuit of UHC. However, tackling the overuse of healthcare services is often under-recognized as an opportunity for development and for the achievement of more equitable healthcare.

Overuse is defined as "when a health care service is provided under circumstances in which its potential for harm exceeds the possible benefit" (2). Since the 1980s, overuse of healthcare has become an increasingly important area of research in high-income countries. Previous research has highlighted the direct harm that the overuse of healthcare services can cause patients through physical, psychological and financial burdens (3).

The most widely recognized direct harm caused by medical imaging is radiation, leading to an increased risk of developing cancer (4). Whilst the increased risk is very small, studies have shown that the risks associated with imaging are underestimated by the doctors ordering the imaging (5). Despite the substantial disparity between the radiological resources of high-income countries (HICs) and low-middle income countries (LMICs), exposure to medical radiation is nevertheless an important consideration in LMICs, which often lack regulatory authorities governing the use of medical imaging equipment, diagnostic reference levels for safety and adequately trained staff, and have older imaging equipment (6-7).

A further harm of medical imaging overuse is overdiagnosis. The more a diagnostic test is used or overused, the risk of overdiagnosis increases (8-9). The harms of overdiagnosis are widely accepted in medical literature, including high costs and wasted resources, harm caused by unnecessary treatments and further testing, psychological harm due to unnecessary disease labelling, and the diversion of attention and resources away from the most severely ill (10-11).

In LMICs, the financial harms of overdiagnosis may be exaggerated due to high out-of-pocket payments (OOP), which make up a larger proportion of health system financing in developing countries where health insurance coverage is generally low (12). OOPs for healthcare can be financially crippling, pushing families below the poverty line (13). Therefore, it may be critical to reduce unnecessary diagnostic imaging and, in turn, reduce the cascade of spending that can be caused by overdiagnosis and overtreatment in LMICs.

Furthermore, radiology is very labor-intensive and expensive, raising concerns regarding the possible financial effect of overuse on LMICs. As technology advances in HICs, the technology is transferred to LMICs. In a setting where health budgets are limited, caution should be applied when resources are drained from other services, including less technological (and potentially higher value) methods of improving population health (14).

Although the overuse of medical imaging is well-researched in HICs, it is still unclear whether there is evidence of overuse of medical imaging in LMICs. Understanding the extent of medical imaging overuse in LMICs could put pressure on doctors and policymakers to develop interventions to address the problem of low-value imaging and create a safer and fairer allocation of resources.

The existing knowledge about the overuse of medical imaging in the context of LMICs has not been systematically searched, summarized, and synthesized. A scoping review is essential to determine the size and scope of the literature in this area. The purpose of this review is to assess whether evidence exists for the overuse of medical imaging in LMICs.

Research design

This study employs a scoping review research design. A scoping review is defined as a "preliminary assessment of potential size and scope of available research literature." (15). The overuse of medical imaging is an area which has been under-researched in the context of LMICs. Therefore, a scoping review was used to indicate the volume of literature, as well as the focus of the content (16). Ethical approval was not required, as only information in the public domain was used.

Search strategy

This scoping review was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (17).

The databases Medline via Ovid, Embase and CINAHL were searched on May 22, 2023. A search strategy was developed in Medline-Ovid and adapted for other databases. Language filters were not used, and no limits were placed on the year of publication. The Cochrane EPOC LMIC search filter (18) was utilized in the search strategy. Full search strategies are available in Appendix A.

The final search results were exported to Zotero, where duplicates were removed by the author. The title and abstracts were screened for eligibility, followed by full-text screening by the author.

The search was expanded through a snowballing technique

Figure 1. Medline search strategy.

1. Medical Overuse/
2. overuse.ti,ab.
3. overmedicalization.ti,ab.
4. overdiagnosis.ti,ab.
5. inappropriate.ti,ab.
6. overutilization.ti,ab.
7. low-value.ti,ab.
8. overinvestigation.ti,ab.
9. wasteful.ti,ab.
10. appropriateness.ti,ab.
11. (The Cochrane EPOC LMIC search filter - see appendix A)
12. CT.ti,ab.
13. MRI.ti,ab.
14. X-ray.ti,ab.
15. computed tomography.ti,ab.
16. magnetic resonance imaging.ti,ab.
17. ultrasound.ti,ab.
18. Diagnostic Imaging/
19. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
20. 12 or 13 or 14 or 15 or 16 or 17 or 18
21. 11 and 19 and 20

of hand-searching the reference lists of included studies for relevant studies and hand-searching key journals.

Eligibility criteria

To be included in the review, studies needed to measure the overuse of at least one medical imaging modality. Peer-reviewed journal papers were included if they were written in English, in a low, middle or upper-middle country as defined by The World Bank 2023 (19) , and described a measure for the overuse of an imaging modality; for example, the use of the modality made no change to clinical decision-making, or an imaging request was inappropriate according to guidelines or expert opinion. No limitations were placed on the publication date.

Data charting and synthesis

A data-charting form was developed to determine which variables to extract from the studies. Variables were chosen that provide information about the medical imaging process, which could have been related to the overuse of imaging. The data charting form included: author(s); year of publication; country of study setting; population age (e.g. adult or pediatric); location (e.g. tertiary hospital); image modality (e.g. computed tomography (CT), magnetic resonance imaging (MRI)); indication for imaging request; sample size; percentage of overuse and indicator of overuse (e.g. guidelines, expert opinion). However, the process of data charting was iterative, and revisions were made to the variables. The indication for imaging request was revised to body region (e.g. head and neck), due to a lack of clinical information. If information was missing or results were indeterminate for a selected variable, the data point was charted as indeterminate/not applicable. The data-charting form is available in Appendix B.

The development and completion of the data-charting table allowed for the summarization and synthesis of the data in narrative and graphical form. The data were grouped by modality and body region for further analysis.

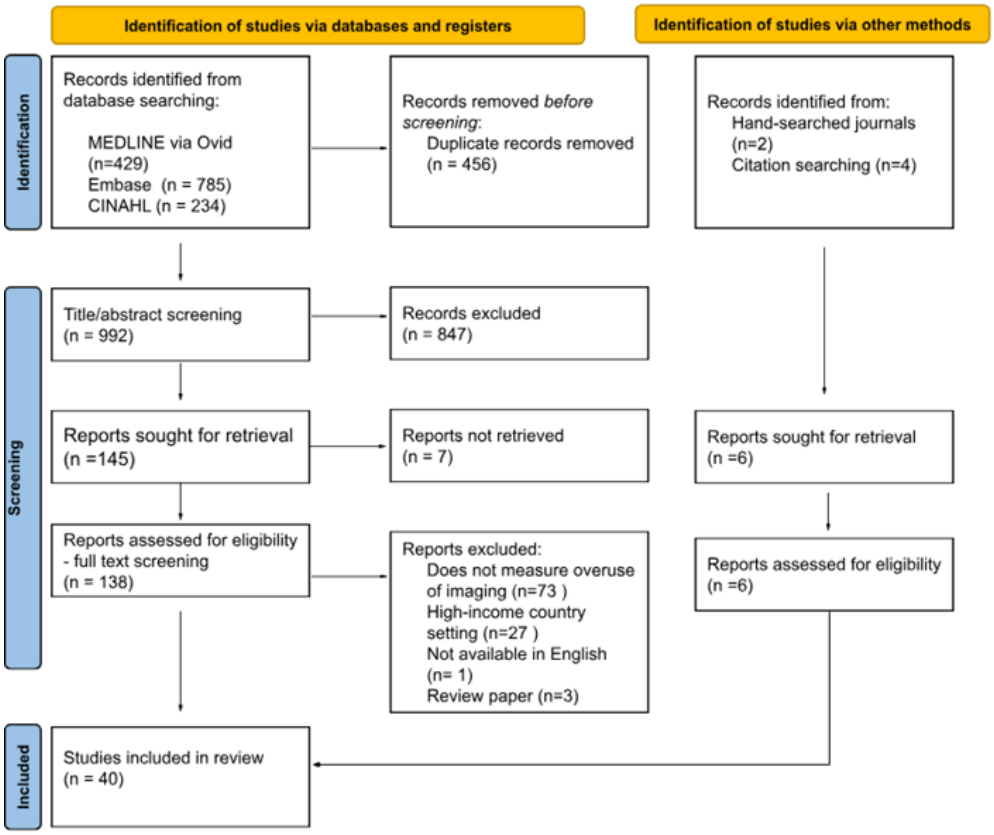
Results

Study selection

Electronic database searches yielded 1,448 citations. After deduplication and title/abstract screening, 138 papers were assessed for eligibility through full-text screening, of which 34 papers met the inclusion criteria for the scoping review. Reasons for exclusion were recorded. Six additional papers were identified through reference searching and hand-searching of relevant journals. In total, 40 papers were included in the scoping review.

The PRISMA flow diagram (20) in Figure 2 presents the number of identified citations and reasons for exclusion. The full list of included studies is available in Appendix C.

Figure 2. PRISMA flow diagram of study selection.



Legend: Number of studies identified by search strategy, number of studies excluded and included during title/abstract and full text screening, and final number of studies included in the review.

Study characteristics

The 40 included studies contained a total of 42,413 patients or image requisitions (median: 361; interquartile range, IQR: 203-761). The earliest publication identified is by Saadat et al. in 2008 (21) and the most recent is by Baiguissova et al. in 2023 (22). The majority of studies (55%, 22/40) were published in the past five years. An increasing trend in publications was noted. The table of study characteristics can be found in Appendix C.

Location

Fifteen low-middle-income countries were included in the scoping review. The studies spanned 6 regions: 15 in the Middle East; 13 in Sub-Saharan Africa; 5 in Latin America; 3 in Europe and Central Asia; 3 in South Asia; and 1 in East Asia and the Pacific. Thirteen studies were conducted in Iran; 4 studies were conducted in Brazil and Ghana; 3 in India and Uganda; 2 each in Cameroon, Lebanon and South Africa; and 1 study was conducted each in Argentina, Bosnia and Herzegovina, China, Ethiopia, Kazakhstan, Kenya and Serbia. The majority of studies (25/40, 62.5%) were conducted in countries classified by The World Bank (2023) as lower-middle-income countries. Upper-middle-income countries accounted for 27.5% (11/40) of the studies and 4% (4/40) of the studies were conducted in low-income countries.

Modality

Studies were classified into modality and body regions. The vast majority of studies (90%, 36/40) measured the overuse of one imaging modality. Whereas 5% of studies (2/40) measured the overuse of 2 modalities and 5% (2/40) of studies measured the overuse of 3 modalities. CT was the most frequent imaging modality of study, as 50% (20/40) of the studies measured its overuse. Thirteen studies (32.5%) measured the overuse of MRI; 6 studies (15%) measured the overuse of ultrasound; 4 studies (10%) measured the overuse of single-photon emission computed tomography (SPECT). The least studied modality in the context of overuse was radiography, which was included in 7.5% of studies (3/40).

Body region

Body regions were classified into head and neck, chest, heart and vessels, abdomen and pelvis, musculoskeletal system, reproductive system, spine, and limbs. Ten

Figure 3. Studies investigating overuse by radiological modality (n=40) .

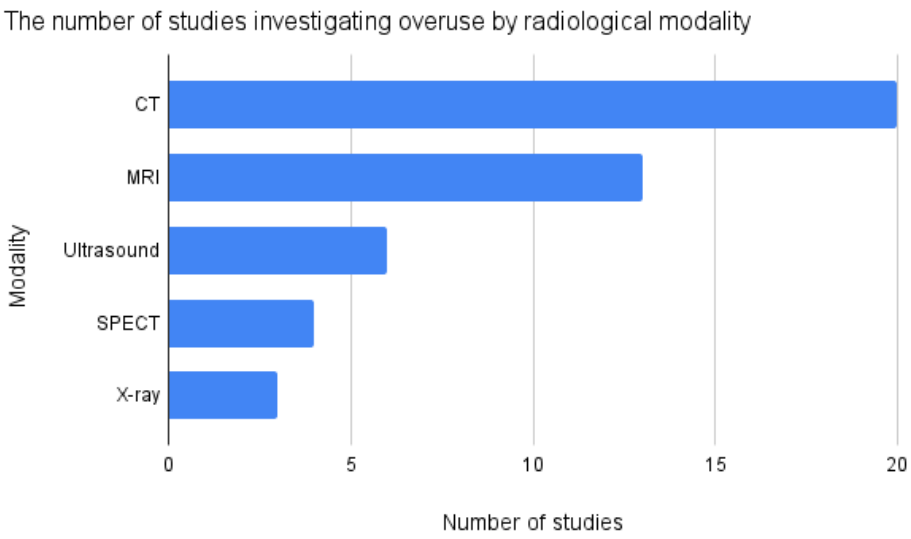
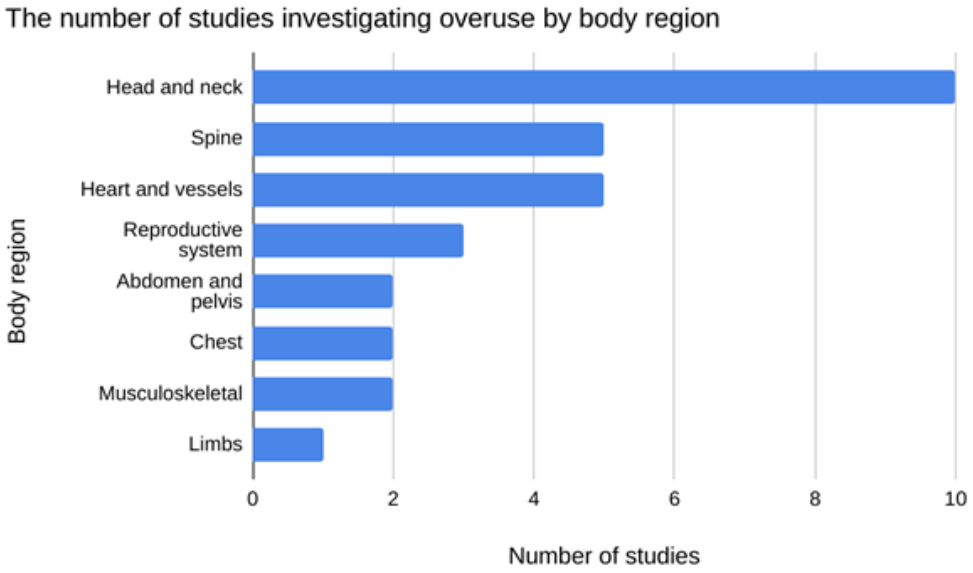


Figure 4. The number of studies investigating overuse by body region (n=40) .



studies were excluded from the bar chart as they did not investigate the overuse of a modality related to a specific body region. Of the remaining 30 studies, the region most frequently investigated for imaging overuse was the head and neck (33.3%, 10/30). Five studies (16.7%) investigated imaging overuse of the heart and vessels; five studies (16.7%) investigated imaging overuse of the spine; three studies (10.0%) investigated imaging overuse of the reproductive system; the abdomen and pelvis, the musculoskeletal system and the chest were investigated for imaging overuse in two studies each (6.7% each); and one study (3.3%) investigated imaging overuse in the limb region.

Indicator of overuse

Most of the studies referred to using guidelines in the methodology for determining overuse of imaging. The most common set of guidelines used was the American College of Radiology (ACR) Appropriateness criteria (25%, 10/40). This is followed by the use of international society guidelines, which were utilized by eight studies (20%). Four studies used expert opinion (10%), and three studies (7.5%) used a combination of ACR guidelines and expert opinion. Local guidelines, negative results and no change in management were used as indicators of overuse in two studies each (5% each). Guidelines for imaging appropriateness were sourced from previous research

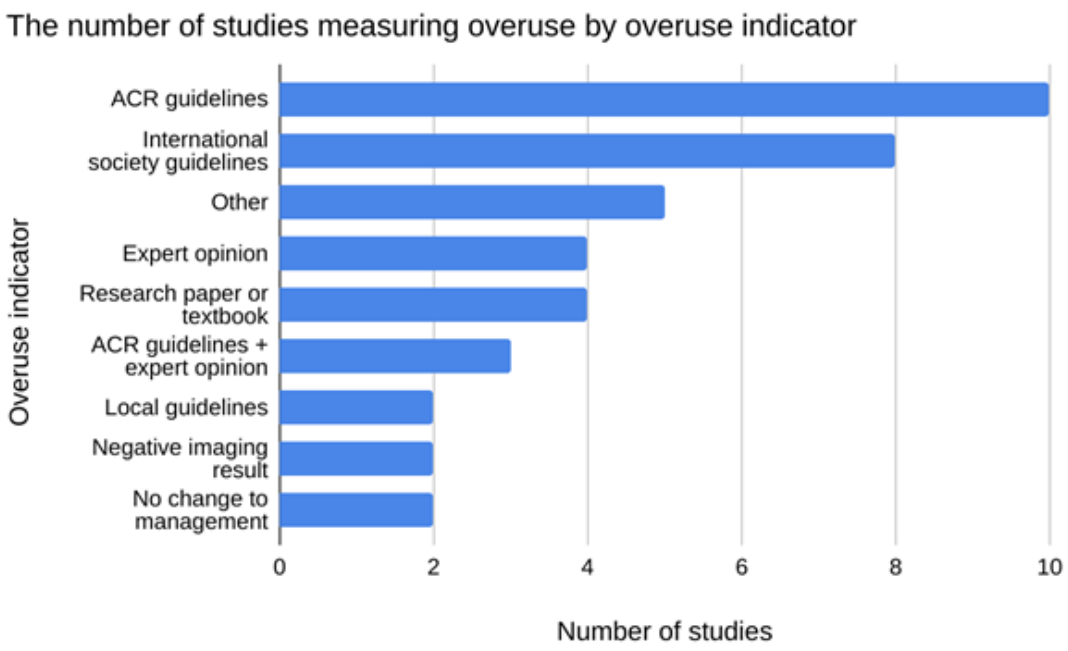


Figure 5. The number of studies measuring overuse by overuse indicator (n=40).

papers or textbooks in four studies (10%). Other methods of determining overuse of imaging included: as low as reasonably achievable (ALARA) principles, proportions of normal findings to positive results, and risk calculations.

Computed-tomography

Twenty studies measured the overuse of CT. Study sample sizes ranged from 22 (23) to 11,806 (24) scans. The percentage of CT overuse ranged from 4.6% (64/1392) (25), to 91.7% (765/834) (26). However, these studies may be considered as outliers. The lowest value of CT overuse came from a pediatric study. Two studies reviewed pediatric CT. The percentage overuse of pediatric CT ranged from the lowest value of all CT studies, 4.6% (64/1392) (25), to 32% (7/22) (23).

The largest overuse of CT was seen where CT did not change the diagnosis of appendicitis, which can usually be a clinical diagnosis (26).

The most common body region imaged by CT that was measured for overuse was the head and neck (seven studies). The overall average overuse of CT head and neck imaging from the included studies is 63% (9200/14583). Two studies measured the overuse of abdominal and pelvis CT. The average overuse of abdominal and pelvis CT from the included studies is 71% (607/856). The total average overuse of CT from the included studies is 55% (10331/18740).

Magnetic resonance imaging

Thirteen studies measured the overuse of MRI. Sample sizes ranged from 115 (27) to 3170 (28) scans. The percentage of reported MRI overuse ranged from 0% ('no evidence of overuse; 0/1650) (21) to 58.3% (1848/3170) (28). Two studies measured the overuse of head and neck MRI. The average overuse of head and neck MRI from the included studies is 21% (114/545). Three studies measured the overuse of spine MRI. The average overuse of spine MRI in the included studies is 55% (2089/3786). Two studies measured the overuse of knee MRI. Both studies were conducted in Iran. Refahi et al. (27) reported an overuse of 45.2% (52/115), whereas Salari et al. (29) reported 24.8% overuse of knee MRI (68/274). The total average overuse of MRI from the included studies is 35% (2555/7352).

Single-photon emission computed tomography

Four studies measured the overuse of SPECT. Sample sizes ranged from 119 (30) to 1015 (31). The percentage of overuse ranged from 5% (6/119) (30) to 16.8% (49/291) (32). All studies were conducted in a tertiary-level facility. The average overuse of SPECT in the included studies is 12% (200/1615).

Ultrasound

Six studies measured the overuse of ultrasound. Three of the four studies were in the context of obstetric and gynecology ultrasound. Sample sizes ranged from 168 (32) to 1997 (34). The percentage of overuse ranged from 8.3% (14/168) (33) to 75.7% (1512/1997) (34). One of the studies (34) was conducted in a private hospital, with the high overuse due to patient requests during health checks with no indication in the medical history to support repeated use of ultrasound. The total average overuse of obstetric and gynecology ultrasound from the included studies is

66% (1666/2543). The total average overuse of ultrasound from the included studies is 62% (1680/2711).

Radiography

Two studies reported the percentage overuse of radiography. Sample sizes ranged from 717 (35) to 737 (36). Ahmed et al. (2022) reported an overuse of 23.7% (175/737) of radiographs in an emergency department in Kenya. Whereas, in an intensive care unit, Velickovic et al. (2013) reported that 55.9% (401/737) of radiographs were an overuse. The total average overuse of radiography from the included studies is 40% (576/1454).

Reasons for imaging

Half of the studies (20/40) investigated the overuse of an imaging modality in relation to a specific disease, condition or symptom. The most frequently studied indication was back pain. The overuse of imaging related to back pain was measured by five studies. Other indications which were the focus of the overuse studies include headache, myocardial perfusion imaging, obstetric sonography, knee pain, abdominal pain, minor head trauma, deep vein thrombosis and acute pancreatitis.

Of the studies with a specific imaging indication, the highest reported overuse was 71% (49/69) overuse of CT for the indication of back pain in Bosnia and Herzegovina (37). The lowest reported overuse was 5% (6/119) overuse according to the license indication for imaging dopamine transporters in Parkinson's disease, using SPECT in Brazil (30).

Discussion

This scoping review identified 40 primary studies that measured the overuse of an imaging modality in a low or middle-income country setting, published between the years 2008 and 2023.

Measuring overuse

Guidelines

Guidelines were used as a tool to define imaging overuse in 58% (23/40) of the included studies. However, only 5% (2/40) of studies used local guidelines. This means that of the studies which utilized guidelines, 91% (21/23) were guidelines of international and high-income country origin, such as the ACR Appropriateness criteria. This is likely because high-quality local guidelines often do not exist in LMICs (38).

Relying on guidelines designed in high-income countries, however, could lead to problems. For example, there is a difference between diseases prevalent in guideline-setting nations like the USA and UK, and those prevalent in countries in the Global South. Kawooya et al. (39) utilized the ACR criteria and Royal College of Radiologists (UK) guidelines to measure imaging overuse in Uganda, but encountered "local conditions like tropical diseases, malaria, malnutrition, and bilharzias, which are not addressed by these criteria." (39). In addition, 13.6% of the clinical scenarios in an imaging overuse study in Kenya were not found in the ACR Appropriateness criteria (36). The same problem was reported by Demeke et al. (40), where 21.3% of clinical indications were not able to be coded under the ACR criteria. As well as clinical scenarios which do not appear in ACR criteria, many studies reported a relatively high level of clinical scenarios coded under 'maybe appropriate' or 'uncertain' (40-42). As a result, it is probable that there is more overuse occurring than is reported.

Furthermore, the high levels of scenarios coded as 'maybe appropriate' or 'uncertain' may further corroborate the point that there is a mismatch between the clinical scenarios the clinicians in LMICs are managing and the guidelines which are developed in HICs. Without the inclusion of local conditions in guidelines, clinicians may not have an evidence-based foundation to base their decisions around medical imaging. This may lead to variation in the use of imaging, as well as potential overuse due to external drivers.

Moreover, relying on imaging guidelines developed in high-income countries could also be problematic due to the difference in budget and equipment availability. For instance, in the USA there are 43 CT scanners per one million people (43), whereas in South Africa there are an estimated 1.7 CT scanners per one million people (44). Therefore, what is considered an appropriate use of imaging resources in the USA could be seen as a waste of limited resources in an LMIC. Consequently, it is critical for future research to focus on the development of region-specific imaging guidelines. Guidelines must be designed for the local disease epidemiology and the financial context of the region, to better identify overuse and promote more contextually appropriate imaging practices.

Ratio of positive to negative imaging results as an indicator of overuse

Assessment of imaging results was used as a method to identify overuse of imaging in 7.5% (3/40) of studies. In a study measuring the overuse of MRI in private imaging centers in Iran (21), researchers recorded the number of images which had positive findings. Only 17.5% of the images were reported as normal, which the researchers used to infer that the investigation was not being overused. However, it could be argued that the positive findings may have also included incidental findings (findings not related to the indication of the scan), causing a level of overuse which was not captured by the study. Incidental findings have the potential to cause harm to patients and

health systems through overdiagnosis, and are one of the products of imaging overuse. Furthermore, even if the positive findings were not found incidentally, a proportion of the findings recorded as positive, are likely to be benign. For instance, identifying something on a scan does not necessarily mean it is clinically useful. As a result, the percentage of images recorded as positive may be inflated, which could indicate there is overuse which is not being captured.

Recording benign findings as positive was also seen in a study of CT scans of the head in India (45). For example, the researchers noted that "even those who had abnormal findings on CT scan, most of them were deviated nasal septum and sinusitis and not any significant intracranial lesions" (45). Therefore, it could be argued that this method of categorizing image results may not detect some level of overuse. On the other hand, it should be taken into account that negative and 'positive benign' results can provide benefits to patients, which contributes to the difficulty of defining and measuring overuse, due to its subjective nature.

Furthermore, it must be appreciated that the balance between the benefits of negative scans and the costs is likely to be weighed differently depending on the financial context of the country. In a high-income country such as the UK, for instance, the pay-off of a CT for a mild head injury is regarded as reasonable. Whereas in LMICs, it could be argued that for minimal benefit, the money could be better spent elsewhere. Ultimately, this suggests that defining what is an overuse of medical imaging varies between contexts and countries.

Overuse across the modalities

The overall results of the review showed that 35% of MRI, 55% of CT, 40% of radiography, 62% of ultrasound and 12% of SPECT investigations were recorded as an overuse. The results of this study show that there is evidence for the overuse of medical imaging in LMICs. The overuse of medical imaging shown in this study is comparable to results from HICs. For example, one appropriateness study found that "21% of the MRIs, 40% of the CTs, 44% of the radiographs, and 56% of the ultrasound examinations were not appropriate" (46). This shows that overuse is a problem affecting LMICs by a comparable, if not greater, degree to high-income countries.

The results are in agreement with Albarquoni et al.'s (47) findings which showed high overuse of CT and MRI in a previous scoping review investigating overdiagnosis and overuse of diagnostic tests in LMICs. However, a finding from this review that stands out from the results reported earlier, is that there is also evidence of overuse of other modalities — radiography, ultrasound and SPECT.

SPECT had the lowest average percentage of overuse across the modalities, at 12% (200/1615). There may be several possible explanations for this result. Firstly, SPECT is carried out and interpreted by nuclear medicine specialists, who have expertise in deciding whether SPECT is indicated or not. This is opposed to other modalities such as CT which can be interpreted by all radiologists. As a result, CT scans may be easier to get accepted as they require less expertise. Secondly, SPECT is not a particularly well-known investigation. Because of this, nuclear medicine physicians may be more likely to ensure the scan is indicated and will provide benefit to the patient before carrying out the imaging. In addition, SPECT is only ordered by specialist doctors such as cardiologists for myocardial perfusion imaging. Therefore, the requests may be more considered, as opposed to other modalities such as CT which can be requested by any doctor, including juniors. Nevertheless, as the equipment and specialist knowledge become more available over time, it may become important to ensure that levels of overuse do not increase with this form of highly specialized imaging.

Impacts of overuse

Five studies calculated the financial impact of the associated imaging overuse. Based on the information that 6% of all imaging was inappropriate, Kawooya et al. (39) calculated the financial impact of 22,772 inappropriate examinations to be 20,385,415.00 Ugandan shillings ($11,325 USD). The entire budget for the five hospitals analyzed was 340,000,000; therefore, this imaging overuse accounted for 0.7% of the total budget of these hospitals. Although the percentage of inappropriate imaging is small compared to other studies, this shows that even tackling small amounts of overuse can lead to substantial financial savings. This finding is further supported by Dos Santos et al. (48), who calculated that $64,252.04 USD could be saved in one year through the use of appropriateness criteria for myocardial perfusion scintigraphy, which had an overuse rate of 12%. This value represents the amount saved in a single nuclear medicine department on a single exam in one year, so broader changes in imaging utilization would likely show substantially higher savings.

In a study investigating the overuse of MRI in Iran, the costs of inappropriate MRI investigations were calculated to be $10,310 USD for 244 inappropriate scans. The costs were paid by "insurance organizations (38.8%), direct patient costs (39%), and indirect patient costs (22.1%)" (49). Similar results were found in hospitals in Shiraz, Iran, with the financial burden of MRI overuse calculated as $99,988 USD in 2017, which is 17 times Iran's Gross Domestic Product (GDP) per capita (50). This shows that patients are being burdened by the cost of inappropriate imaging investigations. In addition, it can therefore be assumed that insurance organizations are likely paying out considerable amounts of money on a population level for imaging which

is not appropriate. Further research into the costs could push policymakers to address the issue of medical imaging overuse.

Taken together, the evidence from this review suggests that even seemingly modest levels of overuse can place large financial burdens on patients and insurance organizations. This may be particularly harmful in LMICs where health systems often have fewer resources and there are high levels of co-existing underuse of medical services. However, more research is needed to understand the impacts of imaging overuse in LMICs.

Future research

Research using large sample sizes and measuring the overuse of multiple modalities and indications may be useful to demonstrate the scale of imaging overuse in the institution and its associated financial burden. This may attract the attention of stakeholders, such as health insurance companies, hospital trusts and governments, who may have an interest in reducing costs. Moreover, imaging overuse is likely to vary between modality, body region or indication, so this type of data could be used to identify specific pockets of high imaging overuse for further study. However, large-scale research of this sort is likely to be cost- and resource-intensive, and may not be feasible in some LMIC settings. Therefore, research could instead be focused on areas which have been identified as having high rates of overuse in previous research, and in this scoping review, such as back pain or headache.

Although the percentages of overuse found in previous studies are not generalizable to other hospitals, the characteristics of the modality/body region/indication with high overuse could be generalizable. Selecting these modalities/departments/services to research for overuse could lead to more actionable solutions, such as the creation of local guidelines for the specific indication causing high overuse of imaging.

Controlling the use of all modalities for all signs and symptoms is perhaps too ambitious at this stage, especially where there may not be existing local guidelines, and in private healthcare systems where 'doctor shopping' is common. Therefore, it is important to understand the common signs, symptoms and indications which result in the highest percentages of unnecessary imaging. As a result of this, local clinical guidelines can be developed to target the areas of high overuse, reducing the burden of unnecessary imaging on the patients, doctors and healthcare system.

More broadly, research is also needed to better understand the factors driving medical imaging overuse in LMICs. Research into the drivers of imaging overuse may aid doctors, patients and policymakers to minimize the overuse of imaging and foster responsible and evidence-based use of imaging technology.

Strengths and limitations

This scoping review is limited by its design as well as the designs of the secondary studies included in the review.

This scoping review includes evidence from a range of low-income countries. These countries may differ in culture, health system, socio-economic factors and demographics, among other factors. The participants involved in the studies may differ from the patients one would expect to see in another low-middle-income country. Therefore, the extent of medical imaging overuse cannot be generalized to other low-middle-income countries.

The review contains a variable scope of studies, which include a range of methodologies for interpreting appropriate and inappropriate uses of imaging. This may be a limitation in the direct comparison of overuse between studies. However, as mentioned in the Discussion section, defining and measuring overuse is likely to vary between settings and countries due to differing resource levels.

A limitation of this approach is that it does not provide the depth of analysis that might be achieved if the focus was on one country. However, as there is limited research on this topic, a review paper focusing on one country may have been less feasible at this stage. Instead, this study achieved its goal of obtaining a broader idea of the issue and themes surrounding medical imaging overuse in this under-researched context.

Including only published papers written in English is a further limitation of the study, as excluding non-English studies may have led to a biased assessment of the topic. Unfortunately, due to cost and time restraints, including non-English studies was not feasible.

Conclusion

Through the summarization and synthesis of findings from various studies, this scoping review finds high levels of overuse in LMICs across multiple modalities, including CT, MRI, SPECT, ultrasound, and radiography. The implications of these findings are significant, as the overuse of medical imaging has been shown to cause physical, psychological, and financial harm to individuals, as well as threatening the equitable provision of healthcare services. This study calls for more research measuring imaging overuse in different areas, research focused on local imaging guidelines, and research to understand the harms and drivers of imaging overuse in LMICs. Further work in this field would help to improve the quality and equity of radiology services in these resource-restrained settings.

Conflicts of interest

The authors report no conflicts of interest.

References

1. World Health Organization Regional Office for South-East Asia. SDGs and progress towards universal health coverage. Geneva: World Health Organization; 2017 Sep. Available from: https://iris.who.int/handle/10665/258544

2. Chassin MR, Galvin RW, National Roundtable on Health Care Quality. The urgent need to improve health care quality: Institute of Medicine National Roundtable on Health Care Quality. JAMA. 1998;280(11):1000-1005. Available from: https://doi.org/10.1001/jama.280.11.1000

3. Brownlee S, Chalkidou K, Doust J, Elshaug AG, Glasziou P, Heath I, et al. Evidence for overuse of medical services around the world. Lancet. 2017;390:156-68. Available from: https://doi.org/10.1016/S0140-6736(16)32585-5

4. Karavas E, Ece B, Aydın S, Kocak M, Cosgun Z, Bostanci IE, et al. Are we aware of radiation: A study about necessity of diagnostic X-ray exposure. World J Methodol. 2022;12(4):264-73. Available from: https://doi.org/10.5662/wjm.v12.i4.264.

5. Shiralkar S, Rennie A, Snow M, Galland RBH. Doctors' knowledge of radiation exposure: questionnaire study. BMJ. 2003;327:371-2. Available from: https://doi.org/10.1136/bmj.327.7411.371

6. Meyer S, Groenewald WA, Pitcher RD. Diagnostic reference levels in low- and middle-income countries: early "ALARAm" bells?. Acta Radiol. 2016;58:442-8. Available from: https://doi.org/10.1177/0284185116658681

7. Mariani G, Kasznia-Brown J, Paez D, Mikhail MN, H. Salama D, Bhatla N, et al. Improving women's health in low-income and middle-income countries. Part II: the needs of diagnostic imaging. Nucl Med Commun. 2017;38:1024-8. Available from: https://doi.org/10.1097/mnm.0000000000000752

8. Brodersen J, Schwartz LM, Heneghan C, O'Sullivan JW, Aronson JK, Woloshin S. Overdiagnosis: what it is and what it isn't. BMJ Evid Based Med. 2018;23:1-3. Available from: https://doi.org/10.1136/ebmed-2017-110886

9. Aronson JK. When I use a word . . . . Too much healthcare—overdetection. BMJ 2022: 378:o1963. Available from: https://doi.org/10.1136/bmj.o1963

10. Bulliard J-L, Chiolero A. Screening and overdiagnosis: public health implications. Public Health Rev. 2015;36. Available from: https://doi.org/10.1186/s40985-015-0012-1

11. Treadwell J, McCartney M. Overdiagnosis and overtreatment: generalists — it's time for a grassroots revolution. Br J Gen Pract. 2016;66:116-7. Available from: https://doi.org/10.3399/bjgp16x683881

12. Hooley B, Afriyie DO, Fink G, Tediosi F. Health insurance coverage in low-income and middle-income countries: progress made to date and related changes in private and public health expenditure. BMJ Glob Health. 2022;7:e008722. Available from: https://doi.org/10.1136/bmjgh-2022-008722

13. Xu K, Evans DB, Kawabata K, Zeramdini R, Klavus J, Murray CJL. Household catastrophic health expenditure: a multicountry analysis. Lancet. 2003;362(9378):111-7. Available from: https://doi.org/10.1016/s0140-6736(03)13861-5

14. Schmidt H, Gostin LO, Emanuel EJ. Public health, universal health coverage, and Sustainable Development Goals: can they coexist? Lancet. 2015;386(9996):928-930. Available from: https://doi.org/10.1016/S0140-6736(15)60244-6

15. Grant MJ, Booth A. A typology of reviews: an analysis of 14 review types and associated methodologies. Health Info Libr J. 2009;26(2):91-108. Available from: https://doi.org/10.1111/j.1471-1842.2009.00848.x

16. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol.. 2018;18:143. Available from: https://doi.org/10.1186/s12874-018-0611-x

17. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467-73. Available from: https://doi.org/10.7326/m18-0850

18. Cochrane Effective Practice and Organisation of Care (EPOC). LMIC filters. London: The Cochrane Collaboration; 2022 [accessed 2023 May 22]. Available from: https://epoc.cochrane.org/lmic-filters

19. Hamadeh N, Van Rompaey C, Metreau E, Eapen SG. New World Bank country classifications by income level: 2022-2023 [Internet]. Washington, DC: World Bank; 2022 [cited 2023 Aug 16]. Available from: https://blogs.worldbank.org/en/opendata/new-world-bank-country-classifications-income-level-2022-2023

20. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. Available from: https://doi.org/10.1136/bmj.n71

21. Saadat S, Ghodsi SM, Firouznia K, Etminan M, Goudarzi K, Naieni KH. Overuse or underuse of MRI scanners in private radiology centers in Tehran. Int J Technol Assess Health Care. 2008;24(3):277-81. Available from: https://doi.org/ 10.1017/S0266462308080379

22. Baiguissova D, Laghi A, Rakhimbekova A, Fakhradiyev I, Mukhamejanova A, Battalova G, et al. An economic impact of incorrect referrals for MRI and CT scans: a retrospective analysis. Health Sci Rep. 2023;6(3):e1102. Available from: https://doi.org/10.1002/hsr2.1102

23. Khiabani MS, Mohammadi MS, Ghoreyshi SA, Rohani P, Alimadadi H, Sohouli MH. Acute pancreatitis in 60 Iranian children: do pediatricians follow the new guidelines in diagnosis and management of acute pancreatitis? BMC Pediatr. 2022;22(457). Available from: https://doi.org/10.1186/s12887-022-03509-6

24. Gorleku PN, Dzefi-Tettey K, Edzie EKM, Setorglo J, Piersson AD, Ofori IN, et al. The degree and appropriateness of computed tomography utilization for diagnosis of headaches in Ghana. Heliyon. 2021;7(4):e06722. Available from: https://doi.org/10.1016/j.heliyon.2021.e06722

25. Sodhi KS, Krishna S, Saxena AK, Sinha A, Khandelwal N, Lee EY. Clinical application of "Justification" and "Optimization" principle of ALARA in pediatric CT imaging: "How many children can be protected from unnecessary radiation?" Eur J Radiol. 2015;84(9):1752-7. Available from: https://doi.org/10.1016/j.ejrad.2015.05.030

26. Silva HS, Oliveira FKF, Prado LOM, Almeida-Santos M, Reis FP. Abdominal computed tomography in the emergency room: overuse of medical technologies and the depreciation of clinical diagnosis. Rev Bras Educ Med. 2019;43(Suppl 1). Available from: https://doi.org/10.1590/1981-5271v43suplemento1-20190022.ing

27. Refahi S, Kachooei AR, Farsadpour M, Shahrayeni R, Goudarzian M, Molavi Taleghani YM, et al. Is prescription of knee MRI according to standard clinical guideline? Acta Med Mediterr. 2016;4:1207-11. Available from: https://www.actamedicamediterranea.com/archive/2016/special-issue-4/is-prescription-of-knee-mri-according-to-standard-clinical-guideline

28. Yu L, Wang X, Lin X, Wang Y. The use of lumbar spine magnetic resonance imaging in Eastern China: appropriateness and related factors. PLoS One. 2016;11:e0146369. Available from: https://doi.org/10.1371/journal.pone.0146369

29. Salari H, Omranikhoo H, Amini A, Amiri M, Bayyenat S, Azmal M, et al. Examining the amount of unnecessary knee MRI prescription in the MRI Center of Bushehr University of Medical Sciences in 2018. Evid Based Health Policy, Manag Econ. 2020;4(2):82-88. Available from: https://doi.org/10.18502/jebhpme.v4i2.3433

30. Arjona M, Toldo JMP, Queiroz NCM, Pedroso JL, de Carvalho Campos Neto G, Barsottini OGP, et al. A real-world study of cerebral 99mtc-trodat-1 single-photon emission computed tomography (SPECT) imaging of the dopamine transporter in patients with Parkinson disease from a tertiary hospital in Brazil. Med Sci Monit. 2020;26:e925130. Available from: https://doi.org/10.12659/msm.925130

31. Srivastava MK, Pagala RM, Kendarla V, Nallapareddy K. Appropriate use criteria in myocardial perfusion imaging in a tertiary care hospital in South India: an audit. World J Nucl Med. 2021;20(03):281-5. Available from: https://doi.org/10.4103/wjnm.wjnm_77_20

32. Gholamrezanezhad A, Shirafkan A, Mirpour S, Rayatnavaz M, Alborzi A, Mogharrabi M, et al. Appropriateness of referrals for single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI) in a developing community: a comparison between 2005 and 2009 versions of ACCF/ASNC appropriateness criteria. J Nucl Cardiol. 2011;18(6):1044-52. Available from: https://doi.org/10.1007/s12350-011-9419-3

33. Tramujas L, Judice MM, Becker AB. Evaluation of the diagnostic management of deep vein thrombosis in the emergency department of a tertiary hospital in Santa Catarina, Brazil: a cross-sectional study. J Vasc Bras. 2022;21. Available from: https://doi.org/10.1590/1677-5449.202002171

34. Iñurrategui MC, Tablado MR, Esteban S, Kopitowski K, Marchitelli C, Terrasa S. Transvaginal ultrasound overuse in a private university hospital in Argentina: a cross-sectional study. BMJ Evid Based Med. 2022;27:A7-A8. Available from: https://doi.org/10.1136/bmjebm-2022-podabstracts.14

35. eličković J, Hajdarević S, Palibrk IG, Janić NR, Đukanović M, Miljkovic B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chir Iugosl. 2013;60(3):39-44. Available from: https://doi.org/10.2298/aci1303039v

36. Ahmed SS, Onyambu CK, Omamo E, Odhiambo A. Appropriateness of imaging modality choice by doctors at the Kenyatta National Hospital's Accident and Emergency Department. S Afr J Radiol. 2022;26(1):a2367. Available from: https://doi.org/10.4102/sajr.v26i1.2367

37. Denjagić A. Justification of radiological procedures algorithm adjustment in diagnosis of lower back pain cause at University Clinical Center Tuzla. Acta Medica

Saliniana. 2019;49(1):33-40. Available from: https://doi.org/10.5457/ams.v49i1.489

38. Olayemi E, Asare EV, Benneh-Akwasi Kuma AA. Guidelines in lower-middle income countries. Br J Haematol. 2017;177(6):846-54. Available from: https://doi.org/10.1111/bjh.14583

39. Kawooya MG, Pariyo G, Malwadde EK, Byanyima R, Kisembo H. Assessing the performance of imaging health systems in five selected hospitals in Uganda. J Clin Imag Sci. 2012;2:12. Available from: https://doi.org/10.4103/2156-7514.94225

40. Demeke E, Mekonnen A. Appropriateness of head CT scans at Tikur Anbessa Specialized Hospital, Ethiopia. Ethiop J Health Sci. 2022;32(2):359-68. Available from: https://doi.org/10.4314/ejhs.v32i2.17

41. Becker J, Jenkins LS, De Swardt M, Sayed R, Viljoen M. Appropriateness of computed tomography and magnetic resonance imaging scans in the Eden and Central Karoo districts of the Western Cape Province, South Africa. S Afr Med J. 2014;104(11):762. Available from: https://doi.org/10.7196/samj.8158

42. Piersson AD, Nunoo G, Gorleku PN. An audit of clinical practice, referral patterns, and appropriateness of clinical indications for brain MRI examinations: a single-centre study in Ghana. Radiography. 2018;24(2):e25-e30. Available from: https://doi.org/10.1016/j.radi.2017.10.004

43. OECD. Computed tomography (CT) scanners. Paris: Organisation for Economic Co-operation and Development; 2021. Available from: https://data.oecd.org/healtheqt/computed-tomography-ct-scanners.htm

44. Ngoya PS, Muhogora WE, Pitcher RD. Defining the diagnostic divide: an analysis of registered radiological equipment resources in a low-income African country. Pan Afr Med J. 2016;25(99). Available from: https://doi.org/10.11604/pamj.2016.25.99.9736

45. Maitra D, Chatterjee S, Debnath S, Mukhopadhyay DK, Chattopadhyay S. Assessment of appropriateness of doing CT scan for investigating headache in a tertiary care hospital in eastern India. Indian J Public Health Res Dev. 2022;13(4):65-9. Available from: https://doi.org/10.37506/ijphrd.v14i4.18531

46. Walther F, Eberlein-Gonska M, Hoffmann R-T, Schmitt J, Blum SFU. Measuring appropriateness of diagnostic imaging: a scoping review. Insights Imaging. 2023;14(62). Available from: https://doi.org/10.1186/s13244-023-01409-6

47. Albarqouni L, Arab-Zozani M, Abukmail E, Greenwood H, Pathirana T, Clark J, et al. Overdiagnosis and overuse of diagnostic and screening tests in low-income and middle-income countries: a scoping review. BMJ Glob Health. 2022;7:e008696. Available from: https://doi.org/10.1136/bmjgh-2022-008696

48. Dos Santos MA, Santos MS, Tura BR, Félix R, Brito ASX, De Lorenzo A. Budget impact of applying appropriateness criteria for myocardial perfusion scintigraphy: the perspective of a developing country. J Nuc Cardiol. 2016;23(5):1160-5. Available from: https://doi.org/10.1007/s12350-016-0505-4

49. Jahanmehr N, Bigdeli AS, Salari H, Mokarami H, KhodaKarim S, Damiri S. Analyzing inappropriate magnetic resonance imaging (MRI) prescriptions and resulting economic burden on patients suffering from back pain. Int J Health Plann Manage. 2019;34(4):e1437-e1447. Available from: https://doi.org/10.1002/hpm.2806

50. Kavosi Z, Sadeghi A, Lotfi F, Salari H, Bayati M. The inappropriateness of brain MRI prescriptions: a study from Iran. Cost Eff Resour Alloc. 2021;19(14). Available from: https://doi.org/10.1186/s12962-021-00268-6

Appendix A: Search strategies

Medline search strategy

1 Medical Overuse/

2 overuse.ti,ab.

3 overmedicalization.ti,ab.

4 overdiagnosis.ti,ab.

5 inappropriate.ti,ab.

6 overutilization.ti,ab.

7 low-value.ti,ab.

8 overinvestigation.ti,ab.

9 wasteful.ti,ab.

10 appropriateness.ti,ab.

11 (afghan* or africa* or albania* or algeria* or angola* or antigua* or barbuda* or argentin* or armenia* or aruba* or azerbaijan* or bahrain* or bangladesh* or bengal* or bangal* or barbados* or barbadian* or bajan or bajans or belarus* or belorus* or byelarus* or byelorus* or belize* or benin* or dahomey or bhutan* or bolivia* or bosnia* or herzegovin* or botswan* or batswan* or bechuanaland* or brazil* or brasil* or bulgaria* or burkina* or burkinese* or upper volta* or burundi* or urundi* or cabo verde* or cape verde* or cambodia* or kampuchea* or khmer* or cameroon* or cameroun* or ubangi shari* or chad* or chile* or china* or chinese or colombia* or comoro* or comore* or comorian* or mayotte* or congo* or zaire* or costa rica* or "cote d'ivoir*" or "cote d' ivoir*" or cote divoir* or cote d ivoir* or ivory coast* or ivorian* or croatia* or cuba or cuban or cubans or "cuba's" or cyprus* or cypriot* or czech* or djibouti* or french somaliland* or dominica* or ecuador* or egypt* or united arab republic* or el salvador* or salvadoran* or guinea* or equatoguinea* or eritrea* or estonia* or eswatini* or swaziland* or swazi* or swati* or ethiopia* or fiji* or gabon* or gabonese* or gabonaise* or gambia* or ((georgia or georgian or georgians) not (atlanta or california or florida)) or ghana* or gibraltar* or greece* or greek* or grecian* or grenada* or grenadian* or guam* or guatemala* or guyana* or guiana* or guyanese* or haiti* or hispaniola* or hondura* or hungary* or hungarian* or india* or indonesia* or iran* or iraq* or isle of man* or jamaica* or jordan* or kazakh* or kenya* or karabati* or korea* or kosovo* or kosova* or kyrgyz* or kirgiz* or kirghiz* or laos or lao or laotian* or latvia* or lebanon* or lebanese* or lesotho* or lesothan* or lesothonian* or basutoland* or mosotho* or basotho* or liberia* or libya* or jamahiriya* or lithuania* or macedonia* or madagasca* or malagasy* or malawi* or nyasaland* or malaysia* or malay* federation or maldives* or maldivian* or indian ocean or mali or malian* or "mali's" or malta or maltese* or "malta's" or micronesia* or marshallese* or kiribati* or marshall island* or nauru or nauran or nauruans or "naurian's" or mariana or marianas or palau or paluan* or tuvalu* or mauritania* or mauritan* or mauritius* or mexico* or mexican* or moldova* or moldovia* or mongol* or montenegr* or morocco* or moroccan* or ifni or mozambique* or mozambican* or myanmar* or burma* or burmese or namibia* or nepal* or new caledonia* or netherlands antill* or nicaragua* or niger* or oman or omani or omanis or "oman's" or 3 pakistan* or palestin* or gaza* or west bank* or panama* or paraguay* or peru or peruvian* or "peru's" or philippine* or philipine* or phillipine* or phillippine* or filipino* or filipina* or poland* or polish or pole or poles or portugal* or portuguese or puerto ric* or romania* or russia* or ussr* or soviet* or rwanda* or rwandese or ruanda* or ruandese or samoa* or navigator island* or pacific island* or polynesia* or "sao tome and principe*" or sao tomean* or santomean* or saudi arabia* or saudi or saudis or senegal* or serbia* or seychell* or sierra leone* or slovak* or sloven* or melanesia* or solomon island* or norfolk island* or somali* or sri lanka* or ceylon* or "saint kitts and nevis*" or "st kitts and nevis*" or kittian* or nevisian* or saint lucia* or st lucia* or saint vincent* or st vincent* or vincentian* or grenadine* or sudan* or surinam* or syria* or tajik* or tadjik* or tadzhik* or tanzania* or tanganyika* or thai* or timor leste* or east timor* or timorese* or togo or togoles* or "togo's" or tonga* or trinidad* or tobago* or tunisia* or turkiy* or turkey* or turk or turks or turkish or turkmen* or uganda* or ukrain* or uruguay* or uzbek* or

Medline search strategy (continued)

vanuatu* or new hebrides* or venezuela* or vietnam* or viet nam* or yemen* or yugoslav* or zambia* or zimbabwe* or rhodesia* or arab* countr* or middle east* or global south or sahara* or subsahara* or magreb* or maghrib* or west indies* or caribbean* or central america* or latin america* or south america* or central asia* or north asia* or northern asia* or southeastern asia* or south eastern asia* or southeast asia* or south east asia* or west asia* or western asia* or east europe* or eastern europe* or developing countr* or developing nation* or developing population* or developing world or less developed countr* or less developed nation* or less developed world or lesser developed countr* or lesser developed nation* or lesser developed world or under developed countr* or under developed nation* or under developed world or underdeveloped countr* or underdeveloped nation* or underdeveloped world or middle income countr* or middle income nation* or middle income population* or low income countr* or low income nation* or low income population* or lower income countr* or lower income nation* or lower income population* or underserved countr* or underserved nation* or underserved population* or under served population* or under served nation* or under served population* or deprived countr* or deprived population* or high burden countr* or high burden nation* or countdown countr* or countdown nation* or poor countr* or poor nation* or poor population* or poor world or poorer countr* or poorer nation* or poorer population* or poorer world or developing econom* or less developed econom* or underdeveloped econom* or under developed econom* or middle income econom* or low income econom* or lower income econom* or low gdp or low gnp or low gross domestic or low gross national or lower gdp or lower gnp or lower gross domestic or lower gross national or lmic or lmics or third world or lami countr* or transitional countr* or emerging econom* or emerging nation*).ti,ab,hw,kf.

12 CT.ti,ab.

13 MRI.ti,ab.

14 X-ray.ti,ab.

15 computed tomography.ti,ab.

16 magnetic resonance imaging.ti,ab.

17 ultrasound.ti,ab.

18 Diagnostic Imaging/

19 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10

20 12 or 13 or 14 or 15 or 16 or 17 or 18

21 11 and 19 and 20

Embase search strategy

1 Medical Overuse/

2 overuse.ti,ab.

3 overmedicalization.ti,ab.

4 overdiagnosis.ti,ab.

5 inappropriate.ti,ab.

6 overutilization.ti,ab.

7 low-value.ti,ab.

8 overinvestigation.ti,ab.

9 wasteful.ti,ab.

10 appropriateness.ti,ab.

11 (afghan* or africa* or albania* or algeria* or angola* or antigua* or barbuda* or argentin* or armenia* or aruba* or azerbaijan* or bahrain* or bangladesh* or bengal* or bangal* or barbados* or barbadian* or bajan or bajans or belarus* or belorus* or byelarus* or byelorus* or belize* or benin* or dahomey or bhutan* or bolivia* or bosnia* or herzegovin* or botswan* or batswan* or bechuanaland* or brazil* or brasil* or bulgaria* or burkina* or burkinese* or upper volta* or burundi* or urundi* or cabo verde* or cape verde* or cambodia* or kampuchea* or khmer* or cameroon* or cameroun* or ubangi shari* or chad* or chile* or china* or chinese or colombia* or comoro* or comore* or comorian* or mayotte* or congo* or zaire* or costa rica* or "cote d'ivoir*" or "cote d' ivoir*" or cote divoir* or cote d ivoir* or ivory coast* or ivorian* or croatia* or cuba or cuban or cubans or "cuba's" or cyprus* or cypriot* or czech* or djibouti* or french somaliland* or dominica* or ecuador* or egypt* or united arab republic* or el salvador* or salvadoran* or guinea* or equatoguinea* or eritrea* or estonia* or eswatini* or swaziland* or swazi* or swati* or ethiopia* or fiji* or gabon* or gabonese* or gabonaise* or gambia* or ((georgia or georgian or georgians) not (atlanta or california or florida)) or ghana* or gibraltar* or greece* or greek* or grecian* or grenada* or grenadian* or guam* or guatemala* or guyana* or guiana* or guyanese* or haiti* or hispaniola* or hondura* or hungary* or hungarian* or india* or indonesia* or iran* or iraq* or isle of man* or jamaica* or jordan* or kazakh* or kenya* or karabati* or korea* or kosovo* or kosova* or kyrgyz* or kirgiz* or kirghiz* or laos or lao or laotian* or latvia* or lebanon* or lebanese* or lesotho* or lesothan* or lesothonian* or basutoland* or mosotho* or basotho* or liberia* or libya* or jamahiriya* or lithuania* or macedonia* or madagasca* or malagasy* or malawi* or nyasaland* or malaysia* or malay* federation or maldives* or maldivian* or indian ocean or mali or malian* or "mali's" or malta or maltese* or "malta's" or micronesia* or marshallese* or kiribati* or marshall island* or nauru or nauran or nauruans or "naurian's" or mariana or marianas or palau or paluan* or tuvalu* or mauritania* or mauritan* or mauritius* or mexico* or mexican* or moldova* or moldovia* or mongol* or montenegr* or morocco* or moroccan* or ifni or mozambique* or mozambican* or myanmar* or burma* or burmese or namibia* or nepal* or new caledonia* or netherlands antill* or nicaragua* or niger* or oman or omani or omanis or "oman's" or 3 pakistan* or palestin* or gaza* or west bank* or panama* or paraguay* or peru or peruvian* or "peru's" or philippine* or philipine* or phillipine* or phillippine* or filipino* or filipina* or poland* or polish or pole or poles or portugal* or portuguese or puerto ric* or romania* or russia* or ussr* or soviet* or rwanda* or rwandese or ruanda* or ruandese or samoa* or navigator island* or pacific island* or polynesia* or "sao tome and principe*" or sao tomean* or santomean* or saudi arabia* or saudi or saudis or senegal* or serbia* or seychell* or sierra leone* or slovak* or sloven* or melanesia* or solomon island* or norfolk island* or somali* or sri lanka* or ceylon* or "saint kitts and nevis*" or "st kitts and nevis*" or kittian* or nevisian* or saint lucia* or st lucia* or saint vincent* or st vincent* or vincentian* or grenadine* or sudan* or surinam* or syria* or tajik* or tadjik* or tadzhik* or tanzania* or tanganyika* or thai* or timor leste* or east timor* or timorese* or togo or togoles* or "togo's" or tonga* or trinidad* or tobago* or tunisia* or turkiy* or turkey* or turk or turks or turkish or turkmen* or uganda* or ukrain* or uruguay* or uzbek* or vanuatu* or new hebrides* or venezuela* or vietnam* or viet nam* or yemen* or yugoslav* or zambia* or zimbabwe*

Embase search strategy, continued

or rhodesia* or arab* countr* or middle east* or global south or sahara* or subsahara* or magreb* or maghrib* or west indies* or caribbean* or central america* or latin america* or south america* or central asia* or north asia* or northern asia* or southeastern asia* or south eastern asia* or southeast asia* or south east asia* or west asia* or western asia* or east europe* or eastern europe* or developing countr* or developing nation* or developing population* or developing world or less developed countr* or less developed nation* or less developed world or lesser developed countr* or lesser developed nation* or lesser developed world or under developed countr* or under developed nation* or under developed world or underdeveloped countr* or underdeveloped nation* or underdeveloped world or middle income countr* or middle income nation* or middle income population* or low income countr* or low income nation* or low income population* or lower income countr* or lower income nation* or lower income population* or underserved countr* or underserved nation* or underserved population* or under served population* or under served nation* or under served population* or deprived countr* or deprived population* or high burden countr* or high burden nation* or countdown countr* or countdown nation* or poor countr* or poor nation* or poor population* or poor world or poorer countr* or poorer nation* or poorer population* or poorer world or developing econom* or less developed econom* or underdeveloped econom* or under developed econom* or middle income econom* or low income econom* or lower income econom* or low gdp or low gnp or low gross domestic or low gross national or lower gdp or lower gnp or lower gross domestic or lower gross national or lmic or lmics or third world or lami countr* or transitional countr* or emerging econom* or emerging nation*).ti,ab,hw,kf.

12 CT.ti,ab.

13 MRI.ti,ab.

14 X-ray.ti,ab.

15 computed tomography.ti,ab.

16 magnetic resonance imaging.ti,ab.

17 ultrasound.ti,ab.

18 Diagnostic Imaging/

19 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10

20 12 or 13 or 14 or 15 or 16 or 17 or 18

21 11 and 19 and 20

CINAHL search strategy

(afghan* or africa* or albania* or algeria* or angola* or antigua* or barbuda* or argentin* or armenia* or aruba* or azerbaijan* or bahrain* or bangladesh* or bengal* or bangal* or barbados* or barbadian* or bajan or bajans or belarus* or belorus* or byelarus* or byelorus* or belize* or benin* or dahomey or bhutan* or bolivia* or bosnia* or herzegovin* or botswan* or batswan* or bechuanaland* or brazil* or brasil* or bulgaria* or burkina* or burkinese* or upper volta* or burundi* or urundi* or cabo verde* or cape verde* or cambodia* or kampuchea* or khmer* or cameroon* or cameroun* or ubangi shari* or chad* or chile* or china* or chinese or colombia* or comoro* or comore* or comorian* or mayotte* or congo* or zaire* or costa rica* or "cote d'ivoir*" or "cote d' ivoir*" or cote divoir* or cote d ivoir* or ivory coast* or ivorian* or croatia* or cuba or cuban or cubans or "cuba's" or cyprus* or cypriot* or czech* or djibouti* or french somaliland* or dominica* or ecuador* or egypt* or 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Dependent searches

S3 AB ("overutilization" OR "overuse" OR “overmedicalization” OR "overdiagnosis" OR "inappropriate" OR "low value" OR waste*" OR "overinvestigation" OR "appropriate*") OR TI ("overutilization" OR "overuse" OR “overmedicalization” OR "overdiagnosis" OR "inappropriate" OR "low value" OR waste*" OR "overinvestigation" OR "appropriate*")

S4 AB ("radiology" OR "imaging" OR "MRI" OR "magnetic resonance imaging" OR "CT" OR "computed tomography" OR "X-ray" OR "ultrasound" OR "diagnostic imag*") OR TI ("radiology" OR "imaging" OR "MRI" OR "magnetic resonance imaging" OR "CT" OR "computed tomography" OR "X-ray" OR "ultrasound" OR "diagnostic imag*")

Appendix B: Results of individual sources of evidence (p. 1 of 6)

Reference number	Year	Country	Population age	Location	Image modality	Body region	Sample size	% Overuse	Indictor of overuse	Indicator of overuse categories	Impacts
1	2022	Kenya	Indeterminate	A&E	CT, X-ray, ultrasound	Other	737 (225, 98, 414)	49.3, 23.7, 37.2	ACR	ACR Appropriateness criteria	None noted
2	2015	Lebanon	Indeterminate	Tertiary referral center	MRI	Heart and vessels	142	8.4	Asian society of cardiac imaging guidelines 2010	International society guideline	None noted
3	2021	Iran	Adult	Hospital	CT	Head and neck	160	16.9 - 31.2	Merritt's textbook of neurology	Research paper or textbook	None noted
4	2020	Brazil	Adult	Tertiary hospital	SPECT	Head and neck	119	5	No change in management	No change in management	None noted
5	2023	Kazakhstan	Adult and child	Two major hospitals	CT and MRI	Other	9,725	13	ACR and RCR guidelines	ACR Appropriateness criteria	None noted
6	2014	South Africa	Adult and child	Hospital	CT and MRI	Other	219	6.4	ACR and RCR	ACR Appropriateness criteria	None noted
7	2022	Ethiopia	Adult and child	Specialized hospital	CT	Head and neck	443	11.7	ACR	ACR Appropriateness criteria	None noted
8	2019	Bosnia and Herzegovina	Adult	University hospital	CT	Spine	69	71	International Classification of Diseases	International society guideline	None noted
9	2016	Brazil	Adult	Tertiary hospital	SPECT	Heart and vessels	190	12	Appropriate Use Criteria for Cardiac Radionuclide Imaging published in 2009.	International society guideline	Budget impact analysis showed that the use of appropriateness criteria, applied to the population referred to myocardial perfusion scintigraphy within 1 year, could generate savings of $ 64,252.04 dollars. savings of 18.6%

Appendix B: Results of individual sources of evidence (p. 2 of 6)

Reference number	Year	Country	Population age	Location	Image modality	Body region	Sample size	% Overuse	Indictor of overuse	Indicator of overuse categories	Impacts
10	2021	Ghana	Adult	Tertiary hospital	Ultrasound	Reproductive system	314	9.6	American College of Radiology (ACR) - American Institute of Ultrasound in Medicine (AIUM) - American College of Obstetricians and Gynecologists (ACOG) practice guidelines + experts	ACR Appropriateness criteria and expert opinion	None noted
11	2021	South Africa	Adult and child	Hospital	CT	Other	515	11.2	ACR	ACR Appropriateness criteria	None noted
12	2011	Iran	Adult	Public hospital and private centers	SPECT	Heart and vessels	291	16.8	American College of Cardiology Foundation (ACCF) and the American Society of Nuclear Cardiology (ASNC) + expert panel	International society guideline	None noted
13	2010	Uganda	Adult	Peri-urban health center	Ultrasound	Reproductive system	232	53.4	A previous research paper: Thompson E, Freake D, Worrall G. Are rural general practitioner--obstetricians performing too many prenatal ultrasound examinations? Evidence from western Labrador. CMAJ. 1998 Feb 10;158(3):307-13.	Research paper or textbook	None noted
14	2021	Ghana	Adult and child	4 tertiary government hospitals and one private hospital	CT	Head and neck	11,806	69	ACR	ACR Appropriateness criteria	None noted
15	2022	Argentina	Adult	Private hospital	Ultrasound	Reproductive system	1,997	75.7	requested upon a health check or without a problem documented in the medical history to support its performance - inappropriate	Other	None noted

Appendix B: Results of individual sources of evidence (p. 3 of 6)

Reference number	Year	Country	Population age	Location	Image modality	Body region	Sample size	% Overuse	Indictor of overuse	Indicator of overuse categories	Impacts
16	2019	Iran	Adult	Public and private imaging centers	MRI	Spine	614	39.7	Clinical guideline scenarios	Other	Total cost of inappropriate prescriptions was $10 310, including the costs paid by insurance organizations (38.8%), direct patient costs (39%), and indirect patient costs (22.1%)
17	2014	Iran	Indeterminate	3 imaging centers	CT	Head and neck	400	37	Expert panel	Expert opinion	None noted
18	2014	Iran	Indeterminate	Four radiographic centers in two public hospitals, a private imaging center and a hospital affiliated with National Iranian Oil Company in Tehran	MRI	Spine	400	53.3	ACR and CAR Standard for Magnetic Resonance Imaging. Ottawa, Canada: Canadian Association of Radiologists (CAR) and expert panel	ACR Appropriateness criteria and expert opinion	None noted
19	2022	Iran	Indeterminate	Teaching hospitals	CT	Chest	216	38-49.5	Expert pulmonologists, ACR guidelines	ACR Appropriateness criteria and expert opinion	None noted

Appendix B: Results of individual sources of evidence (p. 4 of 6)

Reference number	Year	Country	Population age	Location	Image modality	Body region	Sample size	% Overuse	Indictor of overuse	Indicator of overuse categories	Impacts
20	2021	Iran	Adult	3 public teaching hospitals	MRI	Head and neck	385	21.6	Salari H, Ravanbod M R, Akbari Sari A, Farzanegan G, Esfandiari A. Developing Appropriate Indications for Prescriptions of Brain MRI using RAND Appropriateness Method. Evid Based Health Policy, Manag Econ. 2017;1(4):205-210.	Research paper or textbook	If taking 21.6 percent of all MRIs in the 3 hospitals. The financial burden of inappropriate brain MRIs on the patients and insurers for "without injection", "with and without injection" and all MRIs were $50,848, $49,140 and $99,988 USD, respectively
21	2022	Uganda	Indeterminate	Faith-based, private non-profit	CT	Head and neck	262	47-53	iGUIDE, a CIG application software for the European Society of Radiology	International society guideline	None noted
22	2012	Uganda	Indeterminate	Multiple hospitals	CT, X-ray, ultrasound	Other	207	6	Expert panel	Expert opinion	Given the total imaging load (22,772 inappropriate examinations), 20,385,415.00 shillings were wasted in inappropriate imaging
23	2022	Iran	Child	Children's hospital	CT	Abdomen and pelvis	22	32	North American Society for Pediatric Gastroenterology Hepatology and Nutrition Pancreas Committee guideline for management of acute pancreatitis in the pediatric population	International society guideline	None noted
24	2022	India	Adult and child	Tertiary hospital	CT	Head and neck	1,142	57	Normal findings	Negative result	None noted

Appendix B: Results of individual sources of evidence (p. 5 of 6)

Reference number	Year	Country	Population age	Location	Image modality	Body region	Sample size	% Overuse	Indictor of overuse	Indicator of overuse categories	Impacts
25	2017	Iran	Adult and child	Tertiary hospital	CT	Head and neck	370	9.1	ACR	ACR Appropriateness criteria	None noted
26	2020	Ghana	Adult	Tertiary hospital	MRI	Other	840	20-32.4	Ministry of Health Policies	Local guidelines	None noted
27	2016	Iran	Indeterminate	Private centers, public imaging hospital	MRI	Spine	279 (144, 135)	19.4, 29.6	Guidelines which an expert panel developed for the study	Expert opinion	None noted
28	2018	Ghana	Adult	N/A	MRI	Head and neck	161	19	ACR Appropriateness criteria	ACR Appropriateness criteria	None noted
29	2016	Iran	Adult	Referral institution in 110 patients (73.3%) was a private office and in 40 patients (26.7%) was a state hospital	MRI	Musculoskeletal	115	45.2	Local clinical guideline	Local guidelines	Financial burden of 39,204,000 IRR, 70% of which burdened insurance companies
30	2008	Iran	Indeterminate	Private imaging center	MRI	Other	1,650	No evidence of overuse	Proportion of normal findings. Only 17.2% of scans were normal suggesting there is no overuse	Other	None noted
31	2018	Iran	Indeterminate	MRI imaging center	MRI	Musculoskeletal	274	24.8	Vojdani et al.'s study	Research paper or textbook	None noted
32	2011	Lebanon	Adult	MSCT laboratory medical center	CT	Heart and vessels	100	45-49	2006, 2010 ACCF	International society guideline	None noted
33	2019	Brazil	Adult	Private hospital	CT	Abdomen and pelvis	834	52.6 - 91.7	When the CT did not change the diagnosis	No change in management	None noted
34	2015	India	Child	Tertiary hospital	CT	Other	1,392	4.6	'Justification' and 'Optimization' principles of ALARA	Other	None noted

Appendix B: Results of individual sources of evidence (p. 6 of 6)

Reference number	Year	Country	Population age	Location	Image modality	Body region	Sample size	% Overuse	Indictor of overuse	Indicator of overuse categories	Impacts
35	2021	India	Indeterminate	Tertiary care	SPECT	Heart and vessels	1,015	12	Appropriate use criteria (AUC) in cardiac radionuclide imaging" was formulated by the American College of Cardiology Foundation and the American Society of Nuclear Cardiology, 2009	International society guideline	None noted
36	2021	Cameroon	Adult	Peripheral referral hospital	CT	Other	352	8.2	ACR	ACR Appropriateness criteria	None noted
37	2020	Cameroon	Adult and child	Urban imaging center	CT	Other	432	16.4	ACR	ACR Appropriateness criteria	None noted
38	2022	Brazil	Adult		Ultrasound	Limbs	168	8.3	CDUS was requested in patients with low probability according to the WellsScore and a negative DD result	Other	None noted
39	2013	Serbia		ICU of university teaching hospital	X-ray	Chest	717	55.9	Clinician opinion	Expert opinion	None noted
40	2016	China		3 general hospitals	MRI	Spine	3,107	58.3	Was determined to be inappropriate if it did not find anything of clinical relevance. expert panel	Negative result	None noted

Appendix C: List of included studies

1. Ahmed SS, Onyambu CK, Omamo E, Odhiambo A. Appropriateness of imaging modality choice by doctors at the Kenyatta National Hospital's Accident and Emergency Department. S Afr J Radiol. 2022;26(1):a2367. Available from: https://doi.org/10.4102/sajr.v26i1.2367

2. AlJaroudi W, Isma'eel H, El Merhi F, Assad T, Hourani M. (2015). Appropriateness and diagnostic yield of cardiac magnetic resonance imaging from a tertiary referral center in the Middle East. Cardiovasc Diagn Ther. 2015;5(2):88-97. Available from: https://doi.org/10.3978/j.issn.2223-3652.2014.11.01

3. Alimohammadi H, Zareh Shahamati S, Karkhaneh Yousefi A, Safarpour Lima B. (2021). Potentially inappropriate brain CT-scan requesting in the emergency department: A retrospective study in patients with neurologic complaints. Acta Bio Medica : Atenei Parmensis, [online] 92(5), p.e2021302. Available from: https://doi.org/10.23750/abm.v92i5.10209

4. Arjona M, Toldo JMP, Queiroz NCM, Pedroso JL, de Carvalho Campos Neto G, Barsottini OGP, et al. A real-world study of cerebral 99mtc-trodat-1 single-photon emission computed tomography (SPECT) imaging of the dopamine transporter in patients with Parkinson disease from a tertiary hospital in Brazil. Med Sci Monit. 2020;26:e925130. Available from: https://doi.org/10.12659/msm.925130

5. Baiguissova D, Laghi A, Rakhimbekova A, Fakhradiyev I, Mukhamejanova A, Battalova G, et al. An economic impact of incorrect referrals for MRI and CT scans: a retrospective analysis. Health Sci Rep. 2023;6(3):e1102. Available from: https://doi.org/10.1002/hsr2.1102

6. Becker J, Jenkins LS, De Swardt M, Sayed R, Viljoen M. Appropriateness of computed tomography and magnetic resonance imaging scans in the Eden and Central Karoo districts of the Western Cape Province, South Africa. S Afr Med J. 2014;104(11):762. Available from: https://doi.org/10.7196/samj.8158

7. Demeke E, Mekonnen A. Appropriateness of head CT scans at Tikur Anbessa Specialized Hospital, Ethiopia. Ethiop J Health Sci. 2022;32(2):359-68. Available from: https://doi.org/10.4314/ejhs.v32i2.17

8. Denjagić A. Justification of radiological procedures algorithm adjustment in diagnosis of lower back pain cause at University Clinical Center Tuzla. Acta Medica Saliniana. 2019;49(1):33-40. Available from: https://doi.org/10.5457/ams.v49i1.489

9. Dos Santos MA, Santos MS, Tura BR, Félix R, Brito ASX, De Lorenzo A. Budget impact of applying appropriateness criteria for myocardial perfusion scintigraphy: the perspective of a developing country. J Nuc Cardiol. 2016;23(5):1160-5. Available from: https://doi.org/10.1007/s12350-016-0505-4

10. Edzie EKM, Dzefi-Tettey K, Gorleku PN, Brakohiapa EK, Botwe BO, Amankwa AT, Idun EA, Kusodzi H, Asemah AR. Audit of the appropriateness of the indication for obstetric sonography in a tertiary facility in Ghana. Pan Afr Med J. 2021;40(35). Available from: https://doi.org/10.11604/pamj.2021.40.35.26349

11. Fouche PE, Jenkins L, Vermeulen A. Appropriateness of computed tomography and magnetic resonance imaging scans in a rural regional hospital in South Africa: a 6-year follow-up study. S Afr Med J. 2020;111(1):46. Available from: https://doi.org/10.7196/samj.2020.v111i1.14860

12. Gholamrezanezhad A, Shirafkan A, Mirpour S, Rayatnavaz M, Alborzi A, Mogharrabi M, et al. Appropriateness of referrals for single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI) in a developing community: a comparison between 2005 and 2009 versions of ACCF/ASNC appropriateness criteria. J Nucl Cardiol. 2011;18(6):1044-52. Available from: https://doi.org/10.1007/s12350-011-9419-3

13. Gonzaga MA, Kiguli-Malwadde E, Businge F, Byanyima RK. Utilisation of obstetric sonography at a peri-urban health centre in Uganda. Pan Afr Med J. 2010;7(24):24. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3172624/

14. Gorleku PN, Dzefi-Tettey K, Edzie EKM, Setorglo J, Piersson AD, Ofori IN, et al. The degree and appropriateness of computed tomography utilization for diagnosis of headaches in Ghana. Heliyon. 2021;7(4):e06722. Available from: https://doi.org/10.1016/j.heliyon.2021.e06722

15. Iñurrategui MC, Tablado MR, Esteban S, Kopitowski K, Marchitelli C, Terrasa S. Transvaginal ultrasound overuse in a private university hospital in Argentina: a cross-sectional study. BMJ Evid Based Med. 2022;27:A7-A8. Available from: https://doi.org/10.1136/bmjebm-2022-podabstracts.14

16. Jahanmehr N, Bigdeli AS, Salari H, Mokarami H, KhodaKarim S, Damiri S. Analyzing inappropriate magnetic resonance imaging (MRI) prescriptions and resulting economic burden on patients suffering from back pain. Int J Health Plann Manage. 2019;34(4):

e1437-e1447. Available from: https://doi.org/10.1002/hpm.2806

17. Jame SZB, Majdzadeh R, Akbari Sari A, Rashidian A, Arab M, Rahmani H. Indications and overuse of computed tomography in minor head trauma. Iran Red Crescent Med J. 2014;16(5);e13067. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4082513/

18. Jame SZB, Sari AA, Majdzadeh R, Rashidian A, Arab M, Rahmani H. The extent of inappropriate use of magnetic resonance imaging in low back pain and its contributory factors. Int J Prev Med. 2014;5(8):1029-36. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4258662/

19. Kamrani R, Fallahi MJ, Masoompour SM, Ghayumi SMA, Jalli R, Khederzadeh S, et al. Evaluation of the appropriate use of chest CT-Scans in the diagnosis of hospitalized patients in shiraz teaching hospitals, Southern Iran. Cost Eff Resour Alloc. 2022;20(44). Available from: https://doi.org/10.1186/s12962-022-00381-0

20. Kavosi Z, Sadeghi A, Lotfi F, Salari H, Bayati M. The inappropriateness of brain MRI prescriptions: a study from Iran. Cost Eff Resour Alloc. 2021;19(14). Available from: https://doi.org/10.1186/s12962-021-00268-6

21. Kawooya M, Kisembo H, Malumba R, Nsereko EK. Effectiveness of clinical imaging guidelines to reduce inappropriate head computed tomography imaging: a case of Uganda. Egypt J Radiol Nucl Med. 53(164). Available from: https://doi.org/10.1186/s43055-022-00833-w

22. Kawooya MG, Pariyo G, Malwadde EK, Byanyima R, Kisembo H. Assessing the performance of imaging health systems in five selected hospitals in Uganda. J Clin Imag Sci. 2012;2:12. Available from: https://doi.org/10.4103/2156-7514.94225

23. Khiabani MS, Mohammadi MS, Ghoreyshi SA, Rohani P, Alimadadi H, Sohouli MH. Acute pancreatitis in 60 Iranian children: do pediatricians follow the new guidelines in diagnosis and management of acute pancreatitis? BMC Pediatr. 2022;22(457). Available from: https://doi.org/10.1186/s12887-022-03509-

24. Maitra D, Chatterjee S, Debnath S, Mukhopadhyay DK, Chattopadhyay S. Assessment of appropriateness of doing CT scan for investigating headache in a tertiary care hospital in eastern India. Indian J Public Health Res Dev. 2022;13(4):65-9. Available from: https://doi.org/10.37506/ijphrd.v14i4.18531

25. Meidani Z, Hamidian Y, Farzandipour M, Aliasgharzade A. CT utilization: a case study in Iran based on ACR appropriateness criteria. Radiol Manage. 2017;39(1):33-38. Available from: https://pubmed.ncbi.nlm.nih.gov/30725547/

26. Mensah YB, Mensah K, Gbadamosi H, Mensah NA. Magnetic resonance imaging (MRI) utilization in a Ghanaian teaching hospital: trend and policy implications. Ghana Med J. 2020;54(1): 3-9. Available from: https://doi.org/10.4314/gmj.v54i1.2

27. Mohammadi N, Farahmand F, Hadizadeh Kharazi H, Mojdehipanah H, Karampour H, Nojomi M. Appropriateness of physicians' lumbosacral MRI requests in private and public centers in Tehran, Iran.Med J Islam Repub Iran. 2016;30:415. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5307604/#:~:text=In%20the%20private%20center%2C%2080.6,studies%20mostly%20from%20developed%20countries.

28. Piersson AD, Nunoo G, Gorleku PN. An audit of clinical practice, referral patterns, and appropriateness of clinical indications for brain MRI examinations: a single-centre study in Ghana. Radiography. 2018;24(2):e25-e30. Available from: https://doi.org/10.1016/j.radi.2017.10.004

29. Refahi S, Kachooei AR, Farsadpour M, Shahrayeni R, Goudarzian M, Molavi Taleghani YM, et al. Is prescription of knee MRI according to standard clinical guideline? Acta Med Mediterr. 2016;4:1207-11. Available from: https://www.actamedicamediterranea.com/archive/2016/special-issue-4/is-prescription-of-knee-mri-according-to-standard-clinical-guideline

30. Saadat S, Ghodsi SM, Firouznia K, Etminan M, Goudarzi K, Naieni KH. Overuse or underuse of MRI scanners in private radiology centers in Tehran. Int J Technol Assess Health Care. 2008;24(3):277-81. Available from: https://doi.org/ 10.1017/S0266462308080379

31. Salari H, Omranikhoo H, Amini A, Amiri M, Bayyenat S, Azmal M, et al. Examining the amount of unnecessary knee MRI prescription in the MRI Center of Bushehr University of Medical Sciences in 2018. Evid Based Health Policy, Manag Econ. 2020;4(2):82-88. Available from: https://doi.org/10.18502/jebhpme.v4i2.3433

32. El Sibai K, Itani S, Rabah A, Hourani M, Dakik HA. Evaluation of the appropriateness criteria for coronary computed tomography angiography in an academic medical center in a developing country: comparison of the 2006 and 2010 criteria. J Nucl Cardiol.. 2011;18(6):1053-1058. Available from: https://doi.org/10.1007/s12350-011-9437-1

33. Silva HS, Oliveira FKF, Prado LOM, Almeida-Santos M, Reis FP. Abdominal computed tomography in the emergency room: overuse of medical technologies

and the depreciation of clinical diagnosis. Rev Bras Educ Med. 2019;43(Suppl 1). Available from: https://doi.org/10.1590/1981-5271v43suplemento1-20190022.ing

34. Sodhi KS, Krishna S, Saxena AK, Sinha A, Khandelwal N, Lee EY. Clinical application of "Justification" and "Optimization" principle of ALARA in pediatric CT imaging: "How many children can be protected from unnecessary radiation?" Eur J Radiol. 2015;84(9):1752-7. Available from: https://doi.org/10.1016/j.ejrad.2015.05.030

35. Srivastava MK, Pagala RM, Kendarla V, Nallapareddy K. Appropriate use criteria in myocardial perfusion imaging in a tertiary care hospital in South India: an audit. World J Nucl Med. 2021;20(03):281-5. Available from: https://doi.org/10.4103/wjnm.wjnm_77_20

36. Tambe J, Mbuagbaw L, Nguefack-Tsague G, Foyet J, Ongolo-Zogo P.. Multidetector computed tomography utilization in an urban sub-Saharan Africa setting: user characteristics, indications and appropriateness. Pan Afr Med J. 2020;37(42). Available from: https://doi.org/10.11604/pamj.2020.37.42.21176

37. Tambe J, Onana Y, Dongmo S, Nguefack-Tsague G, Ongolo-Zogo P. Health insurance ownership and quality of computed tomography requests: experience from a peripheral referral hospital in Cameroon. Radiol Res Pract. 2021:e9959114. Available from: https://doi.org/10.1155/2021/9959114

38. Tramujas L, Judice MM, Becker AB. Evaluation of the diagnostic management of deep vein thrombosis in the emergency department of a tertiary hospital in Santa Catarina, Brazil: a cross-sectional study. J Vasc Bras. 2022;21. Available from: https://doi.org/10.1590/1677-5449.202002171

39. Veličković J, Hajdarević S, Palibrk IG, Janić NR, Đukanović M, Miljkovic B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chir Iugosl. 2013;60(3):39-44. Available from: https://doi.org/10.2298/aci1303039v

40. Yu L, Wang X, Lin X, Wang Y. The use of lumbar spine magnetic resonance imaging in Eastern China: appropriateness and related factors. PLoS One. 2016;11:e0146369. Available from: https://doi.org/10.1371/journal.pone.0146369