



ORIGINAL RESEARCH

Medical Imaging: The Missing Element of National Health Plans

Devanshi R. Shah¹, Abimbola Leslie², Kristen Destigter², Eline van de Broek-Altenburg², Susan Horton³, Bernice Dahn⁴

1. Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada

2. Larner College of Medicine, University of Vermont, Vermont, USA

3. University of Waterloo, Waterloo, Ontario, Canada

4. College of Health Sciences, University of Liberia, Monrovia, Liberia

* **Corresponding author.** Current address: Devanshi Shah, Dalla Lana School of Public Health, University of Toronto, 155 College St Room 500 Toronto, ON, CAN M5T 3M7, devanshir.shah@mail.utoronto.ca

OPEN ACCESS

© 2021 Shah, Leslie, Destigter, van de Broek-Altenburg, Horton & Dahn. This open access article is distributed under a Creative Commons Attribution 4.0 License (<https://creativecommons.org/licenses/by/4.0/>)

DOI: 10.7191/jgr.2021.1158

Published: 9/16/2021

Citation: Shah DR, Leslie A, Destigter K, van de Broek-Altenburg E, Horton S, Dahn B. Medical imaging: the missing element of national health plans. *J Glob Radiol.* 2021;7(2):1158.

Keywords: imaging, radiology, laboratory medicine, universal health care, diagnostics, low-income countries, lower middle-income countries

Word count: 2,342

Abstract

Purpose: Access to diagnostics is vital for clinical decision-making but is rarely prioritized in national health services strategic plans (NHSSPs)[1].

Materials and Methods: An analysis was conducted of the inclusion of medical imaging as well as laboratory medicine in current NHSSPs for both low-income countries (LICs) and lower- middle-income countries (LMICs). NHSSPs of 79 countries were examined for the inclusion of key terms relevant to imaging and laboratory medicine.

Results: Current and electronically available NHSSPs were found for 33 countries, 14 from LICs and 19 from LMICs. Terminology related to imaging was referenced in very few of the plans, and terminology related to laboratory medicine only slightly more. Imaging or laboratory workforce was discussed in 7% and 8% of the NHSSPs respectively. Imaging equipment, technology, or infrastructure was mentioned in 11% of NHSSPs compared to 19% that referenced "laboratory." Information on key performance indicators and budgeting relating to imaging and laboratory were included in 12% and 21% of NHSSPs respectively. No countries referred to national radiology plans, and only three (Sierra Leone, Haiti, and Zambia) mentioned national laboratory plans. Diagnostics services are not well covered in NHSSPs and imaging is particularly disadvantaged.

Conclusion: The absence of medical imaging in NHSSPs makes it less likely that these services will be incorporated into policy and then funded, hence limiting the success of Universal Health Coverage by 2030. The inclusion of imaging in the World Health Organization Essential Diagnostics List is a critical step to addressing inadequate services.

Introduction

Lack of availability and access to diagnostic imaging in low- and lower middle-income countries (LLMICs), and particularly in low-income countries (LICs), contributes to an increase in global disease burden and mortality [1]. Lower middle-income countries (LMICs), faced with the double burden of infectious diseases and the growing threat of non-communicable diseases, are struggling to achieve Universal Health Coverage by 2030 (UHC2030) [2-4]. In LLMICs, the unavailability of imaging tests has been linked to complications of pregnancy and disproportionate impact of trauma, as well as the underdiagnosis of highly prevalent diseases such as tuberculosis and cancer [2,5-8]. The lack of prioritization of medical imaging at a national level, even relative to other diagnostic services such as laboratory medicine, has contributed to the scarcity of a skilled workforce, proper infrastructure, and financial resources [8,9]. Health care services priorities are described and set out in National Health Policies, Strategies, and Plans (referred to in this paper as National Health Services Strategic Plans (NHSSPs)) [10]. NHSSPs are country-specific frameworks to describe how health priorities and issues will be managed, including those related to political benchmarks [10]. They serve as the gateway to establish and strengthen Universal Health Coverage (UHC) at a country level [10]. Items included in these plans are more likely to be operationalized [11].

The call to ensure that medical imaging is included as a vital part of country-level health care systems has been acknowledged in numerous global health documents [6,12,13]. According to the World Health Organization (WHO), a medical treatment regime should not be instituted without a clear diagnosis [5]. Imaging diagnostics, including x-ray, ultrasound, computerized tomography (CT), and magnetic resonance imaging (MRI), play a key role in up to 30% of all medical conditions [14,15]. As countries design and deliver on their essential health benefits packages towards achieving UHC2030, access to medical imaging will be critical to having a reliable health care system. The importance of imaging in UHC2030 plans, however, has not been sufficiently emphasized [1].

This study aims to examine the extent to which NHSSPs recognize medical imaging and laboratory medicine in the areas of workforce, technology/equipment/infrastructure, financing, and key performance indicators in their considerations of the UHC2030 initiative [4].

Materials and Methods

We evaluated the NHSSPs for 79 countries to determine inclusion of key terms. The World Bank classification for Country and Lending Groups was used to identify LLMICs for this analysis [16]. NHSSPs were located through the WHO Country Planning Cycle Database on the WHO extranet,

government websites, NGO websites, and other WHO databases [17,18].

Available documents with a policy end date listed as 2021 or later were included. A flow chart on the availability of NHSSPs for LICs and LMICs is presented in Figure 1. The planning documents were examined for the presence of the key terms (indicators) along with the inclusion of key performance indicators (KPIs), presented in Table 1. Key terms were categorized into workforce, equipment/technology/infrastructure, and budget. KPIs were defined as baseline and target performance metrics related to laboratory medicine and medical imaging. For NHSSPs that were not written in English (instead French, Portuguese, or Spanish), Google Translate was used to interpret each term. Each of these were then examined by a native English speaker [19]. Of the 33 NHSSPs that were current and available online, 13 policies were written in languages other than English. Some terms posed particular issues when translated to different languages. Therefore, redundancy was built into the terms selected for analysis so that inclusion of each category could be assured.

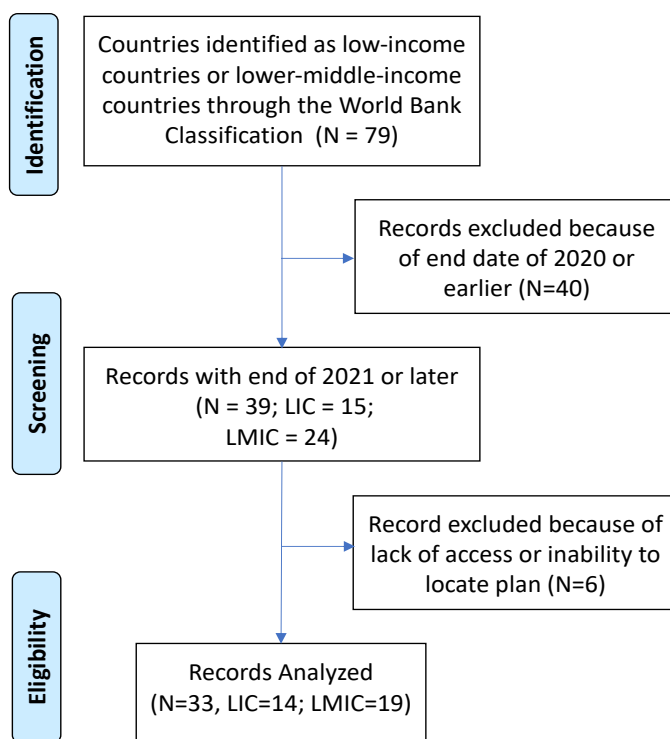


Figure 1. Flow chart of the countries and the associated National Health Service Strategic Plans (NHSSPs) included in this analysis. The status of an NHSSP (whether its status is current based on a policy end date of 2021 or later) was determined through the WHO Country Planning Cycle Database. Five countries were excluded that have a current NHSSP but their documents were not available on the database or through an internet search (Algeria, Sao Tome and Principe, Syrian Arab Republic, Tunisia, and the West Bank and Gaza). Additionally, the NHSSP for Bangladesh must be specially requested through the database due to its size. It was not received following a request and therefore the policy was not included in this analysis.

Table 1. List of terms or definitions used to assess the integration of laboratory medicine and medical imaging in the current National Health Service Strategic Plans. Terms related to (1) imaging workforce, (2) imaging equipment/technology/infrastructure, (3) laboratory workforce (4) laboratory equipment/test/infrastructure, (5) diagnosis, (6) budget were investigated. National Health Service Strategic Plans were examined for metrics related to the outlined definition.

| Category | Terms/ Definitions |
|---|--|
| Imaging workforce | Radiologist, Radiographer, Sonographer, Physicist [specific to radiology], Technologist [specific to radiology], and Technician [specific to radiology] |
| Imaging equipment/technology/infrastructure | Radiology, Imaging, X-ray, Radiograph, Plain film, Ultrasound, Sonogram, Sonography, CT, Computed tomography, Fluoroscopy, MRI, Magnetic resonance imaging, Scan, Radiation, IAEA |
| Laboratory workforce | Pathologist, Technologist [specific to laboratory], and Technician [specific to laboratory], analyst, Chemist, Tester, Scientist |
| Laboratory equipment/test/infrastructure | Microscope, PCR, Urinalysis, Hemoglobin, Hematocrit, Blood, HCG, Blood bank(ing), Transfusion medicine, RDTs, Rapid diagnostic tests, Pathology, Histopathology, Cytopathology, Laboratory, Lab, Laboratory medicine, Medical microbiology, Biochemistry, Hematology, Toxicology, Cellular pathology, Microscopy, Parasitology |
| Diagnosis | Diagnosis [specifically for laboratory and medical imaging] |
| Budget | Budget [specifically for laboratory and medical imaging] |
| Key Performance Indicators (KPIs) | Measurable goals or performance metrics related to laboratory medicine or imaging diagnostics which aid in monitoring (e.g., number of tests per population) |

Results

The NHSSP for each LLMIC country was examined. 42% of all LLMICs have a current and available strategy in an NHSSP. This included 14 of 29 LICs and 19 of 50 LMICs [Figure 2]. The examination of these documents identified large gaps in diagnostics as a component of LLMIC's NHSSPs. Medical imaging was particularly underrepresented, with deficiencies additionally identified in the inclusion of laboratory medicine. Imaging was referenced one percentage point less often than laboratory medicine regarding workforce, eight percentage points less often regarding equipment/technology/infrastructure, and six percentage points less often regarding budget compared to laboratory medicine. The most common imaging terms include imaging (11/33), radiology (10/33), x-ray (9/33), ultrasound (6/33), and MRI (5/33) [Table 2]. The most common laboratory medicine terms appearing in the analysis include laboratory (27/33), blood (26/33), diagnosis (21/33), pathology (14/33), and laboratory technician (10/33).

Workforce

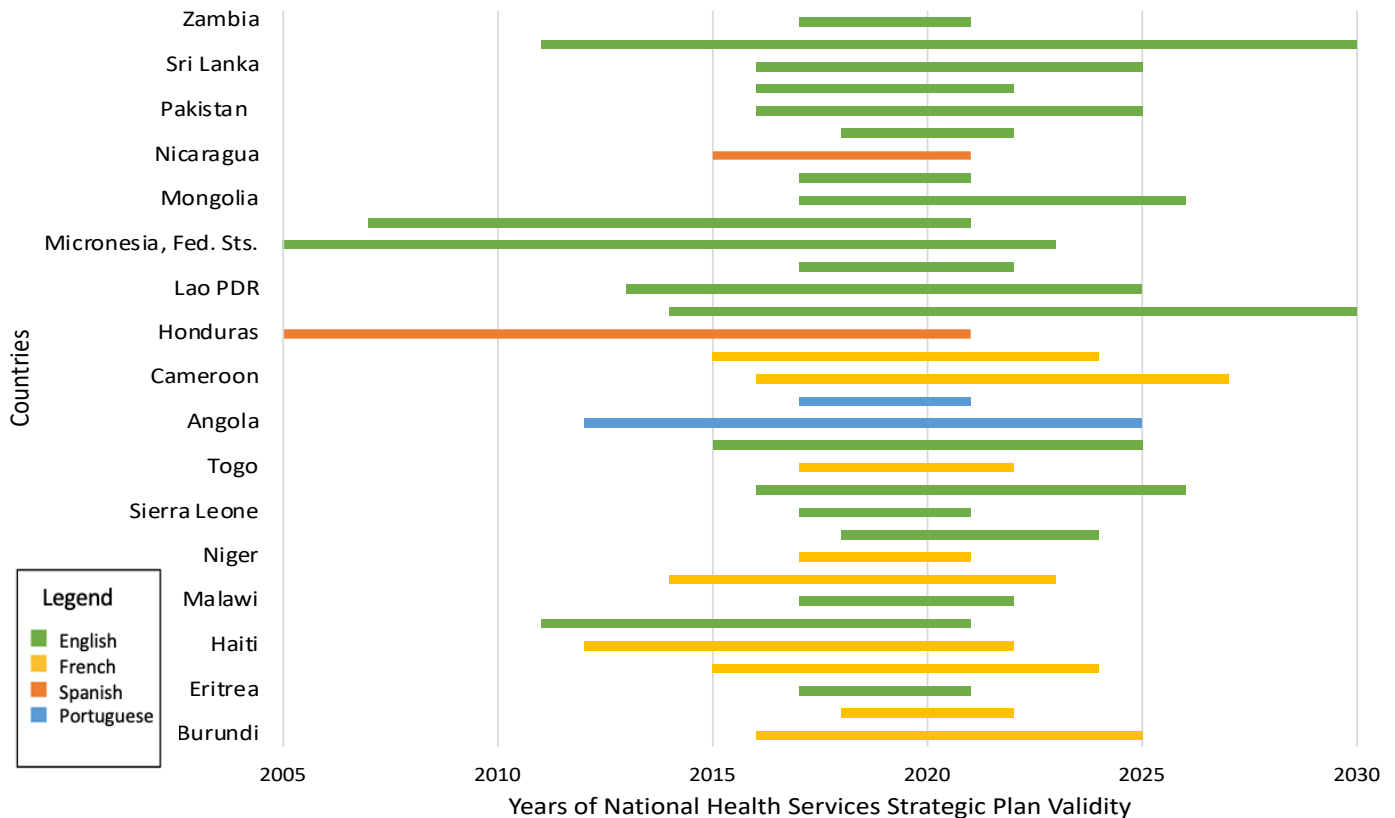
For both medical imaging and laboratory medicine, indicators of the workforce required to provide diagnostic testing were mentioned less often in NHSSPs than the indicators for equipment, technology, and infrastructure. Only 7% and 8% of NHSSPs included discussion of imaging and laboratory workforce respectively. A "radiographer"

(3/33) and a laboratory "technologist" (6/33) were the most referenced occupations for imaging and laboratory medicine respectively. No country included all the terms listed. Radiology technicians were only mentioned in NHSSPs when laboratory technicians were also referenced. This exclusion of health specialist titles underscores the lack of prioritization of quality workforce for laboratory medicine and imaging services. The stark under-representation of radiologists in LICs is underscored by the lack of inclusion of the term "radiologist," which was referenced only by Liberia and Zambia.

Equipment/Technology/Infrastructure

Only 11% of current NHSSPs included discussion of medical imaging equipment, technology, or infrastructure, whereas 18% of NHSSPs included some discussion of laboratory equipment, technology, or infrastructure. Radiology, imaging, and x-ray were the most common terms used for medical imaging. X-ray was mentioned in 9/33 (27%) of NHSSPs. Ultrasound was referenced in 6/33 (18%) of NHSSPs. Magnetic resonance imaging (MRI) was referenced in 6/33 (18%) of NHSSPs. Computed tomography (CT) was referenced in 4/33 (12%) of NHSSPs. Countries acknowledging the advanced modalities of either CT or MRI also mentioned x-ray and ultrasound, with the sole exception of Angola. All countries except for South Sudan, Mongolia, Moldova, and the Philippines referenced the term "laboratory" or its abbreviation, "lab."

Figure 2. Eligibility of low and lower middle-income (LLMIC) countries' National Health Services Strategic Plans for analysis in this study. This Gantt chart provides date-validity data for each of the countries included in the analysis. Countries classified as LICs are Burundi, Chad, Eritrea, Guinea, Haiti, Liberia, Malawi, Mali, Niger, Rwanda, Sierra Leone, South Sudan, Togo, and the Republic of Yemen. Countries classified as LMICs are Angola, Cabo Verde, Cameroon, Comoros, Honduras, Kenya, People's Democratic Republic of Lao, Lesotho, Federated States of Micronesia, Moldova, Mongolia, Myanmar, Nicaragua, Nigeria, Pakistan, Philippines, Sri Lanka, Timor-Leste, Zambia. The language of each country document is noted as yellow for French, green for English, blue for Portuguese, and orange for Spanish.



Key Performance Indicators (KPIs)

KPIs were defined as any measurable metric that was referenced in the document to aid in the monitoring of performance. KPIs can be used to benchmark access to diagnostic testing and are often representative of the financial allocations of resources necessary to meet the targets. Rather than using specific terms to locate KPIs specifically in NHSSPs, documents were scanned for numerical indicators related to diagnostics. Examples of KPIs include numerical values related to the number of laboratories with molecular testing, the number of CTs, or the number of laboratory technicians per population. Only 4/33 (12%) of NHSSPs included KPIs for imaging, and 6/33 (18%) of NHSSPs included KPIs for laboratory medicine [Figure 3]. All four of the NHSSPs which addressed medical imaging also addressed laboratory medicine. An additional 13 NHSSPs included KPIs for diagnostics related to the use of medical imaging or laboratory medicine for the diagnosis and/or treatment of specific diseases. The percentage of newly infected HIV/AIDS cases and tuberculosis incidence rates (diagnosed through medical imaging and laboratory medicine) compared to 2015 are examples of such disease-specific indicators. Even when general indicators of human

resources, infrastructure, and budget were addressed in the policies examined, the metrics for medical imaging and laboratory medicine were often missing from the text.

Budget

Commitment to funding health care services is a vital component of NHSSPs because it identifies priority areas that might then become operationalized. A specific budget for medical imaging was documented in 1/33 (3%) of NHSSPs. A specific budget for laboratory medicine was noted in 3/33 (9%) of NHSSPs. We did not include findings of budgets for specific vertical interventions, such as for diagnostics related to a specific disease like, for example, tuberculosis. Out of the 33 plans, two did not include any budget discussion: Kenya did not include discussion of the overall health budget and Moldova did not include numerical financial data. Budgeting related to medical imaging was noted only for one country (Zambia) and budgeting for laboratory medicine was noted in four NHSSPs (Haiti, Federated States of Micronesia, Timor-Leste, and Zambia).

Alignment with other policies

No reference was made to a national radiology plan, even

Table 2. Number (percent) of NHSSPs that include the most common terms for diagnostics. Data presented in columns as (1) low-income countries, (2) lower middle-income countries, and (3) low- and lower middle-income countries comes from the inclusion of terms in the 33 current and available NHSSPs. All 79 LLMICs (including those without current NHSSPs) as defined by the World Bank are included in column (4).

| Most Common Terms | Low-Income Countries (LICs) N=14 | Lower Middle- Income Countries (LMICs) N=19 | Low- and-Lower Middle-Income Countries (LLMICs) with National Health Service Strategic Plans N=33 | All Low- and Lower Middle-Income Countries N=79 |
|----------------------------------|-------------------------------------|--|--|--|
| Imaging Terms | | | | |
| Imaging | 7 (50) | 4 (21.1) | 11 (33.3) | 11 (13.9) |
| Radiology | 4 (28.5) | 6 (32.6) | 10 (30.3) | 10 (12.7) |
| X-ray | 5 (35.7) | 4 (21.1) | 9 (27.3) | 9 (11.4) |
| Ultrasound | 3 (21.4) | 3 (15.8) | 6 (18.2) | 6 (0.08) |
| MRI | 2 (14.3) | 3 (15.8) | 5 (15.2) | 5 (0.06) |
| Laboratory Medicine Terms | | | | |
| Laboratory | 12 (85.7) | 15 (78.9) | 27 (81.8) | 27 (34.2) |
| Blood | 13 (92.8) | 13 (68.4) | 26 (78.7) | 26 (32.9) |
| Diagnosis | 9 (64.3) | 12 (63.2) | 21 (63.6) | 21 (26.6) |
| Pathology | 9 (64.3) | 5 (26.3) | 14 (42.2) | 14 (17.7) |
| Laboratory Technician | 5 (35.7) | 5 (26.3) | 10 (30.3) | 10 (17.7) |

when available, while national laboratory plans were referenced in only 3/33 (9%) of NHSSPs. The disregard for national plans for diagnostics highlights a critical gap in NHSSPs. Sierra Leone, Haiti, and Zambia referred to their national laboratory plan, though Sierra Leone's plan has since expired.

Overview

Of the NHSSPs examined 31/33 (94%) mentioned medical imaging, and 19/33 (58%) mentioned laboratory medicine to any capacity. None of the NHSSPs examined included all related key terminologies. Only 5/33 and 4/33 of NHSSPs included indicators for medical imaging and the laboratory workforce, respectively. Across all input categories examined, medical imaging was particularly neglected. While 31/33 (94%) of available and current NHSSPs referred to laboratory equipment/technology/infrastructure, only

19/33 (58%) referred to the same categories for medical imaging. Only one country specifically mentioned medical imaging budget, and only four NHSSPs noted budgeting related to laboratory medicine.

Discussion

At the country level, the process of NHSSP development includes convening key stakeholders to identify priority areas [10]. These priority areas then serve as the skeleton of the NHSSP. Resource limitations ensure that not all priority areas identified are included, and accordingly tend to be neglected when plans are implemented [10]. Technical and financial partners, such as Ministries of Health and Finance, are often authors of NHSSPs with support provided by the WHO [11,17]. External stakeholders are brought in to assess the current status of an already finalized NHSSP and to propose areas of improvement. End users are rarely

Figure 3. Inclusion of key performance indicators in NHSSPs. a. Percentage of current National Health Service Strategic Plans that provide information on a particular diagnostic indicator category for all low-income countries and all low-income countries with a current NHSSP. b. Information on all lower middle-income countries and all lower middle-income countries with a current NHSSP. c. Includes diagnostic indicator categories for all low- and lower middle-income countries and all low- and lower middle-income countries with a current NHSSP. Percentage calculations were created relative to the number of terms used to determine inclusion for each diagnostic category as well as the number of countries.

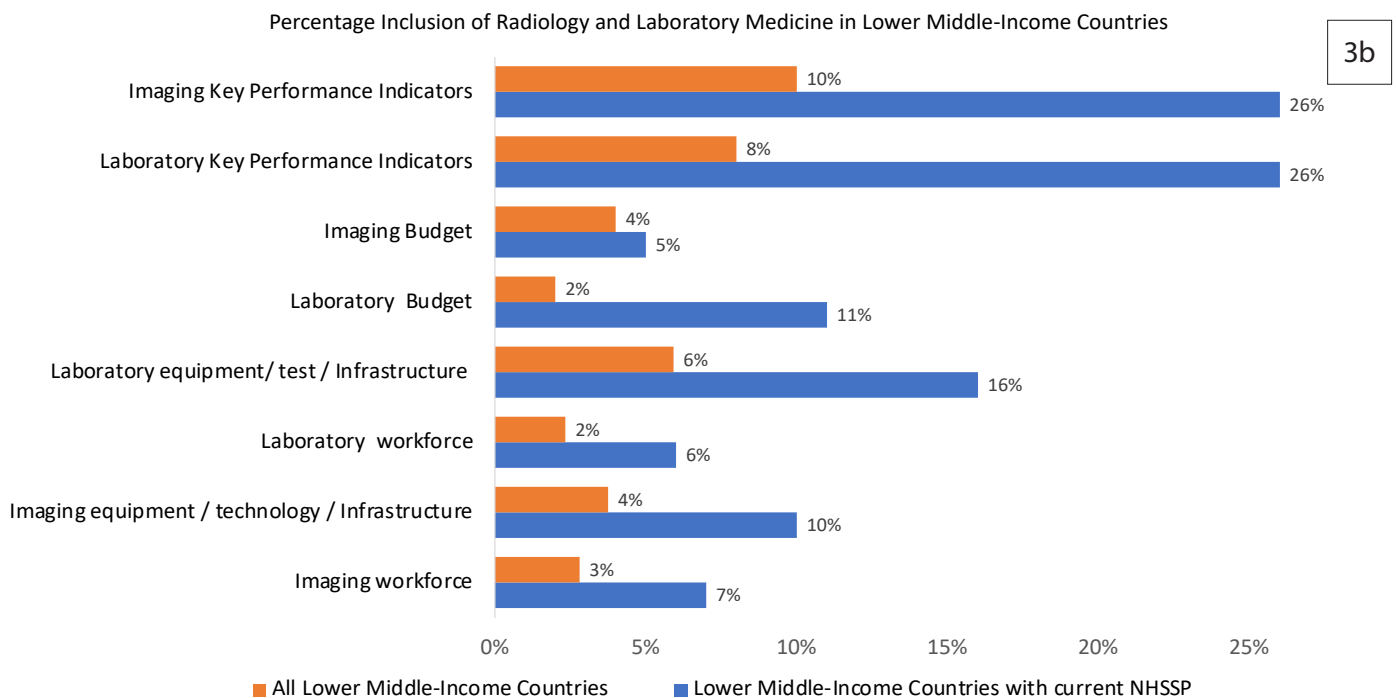
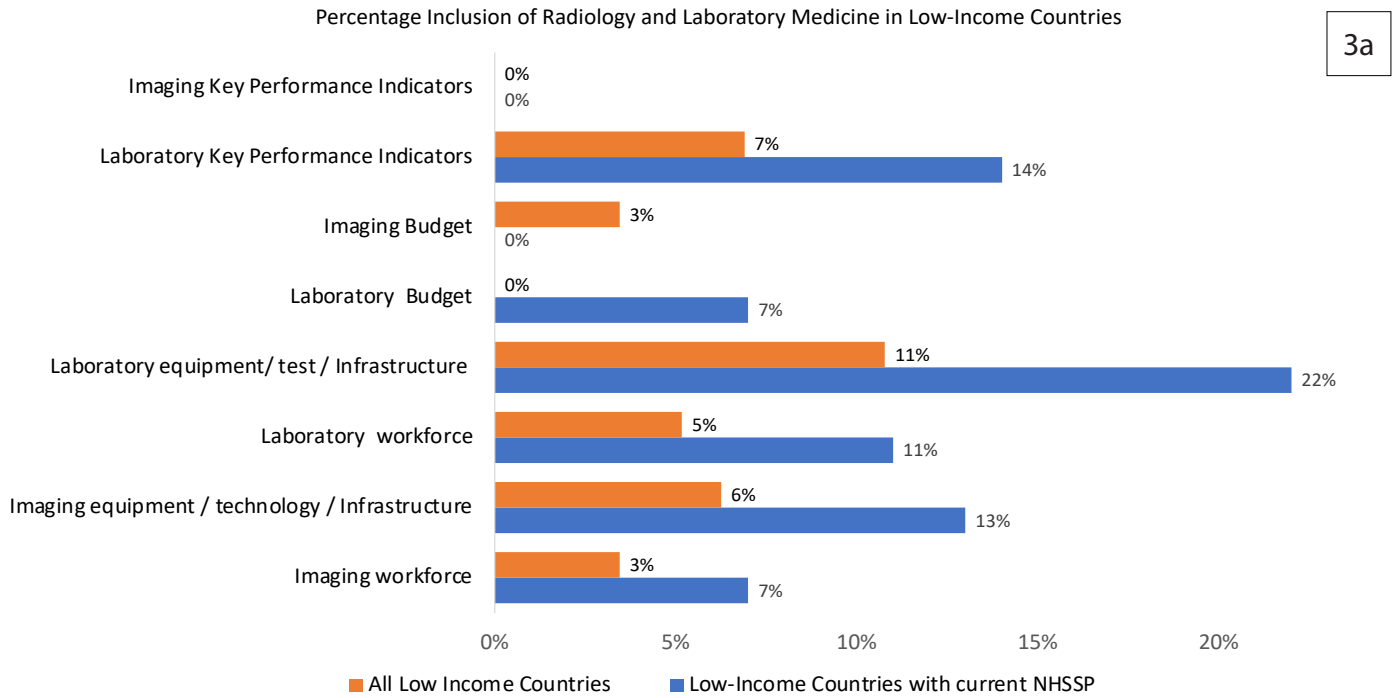
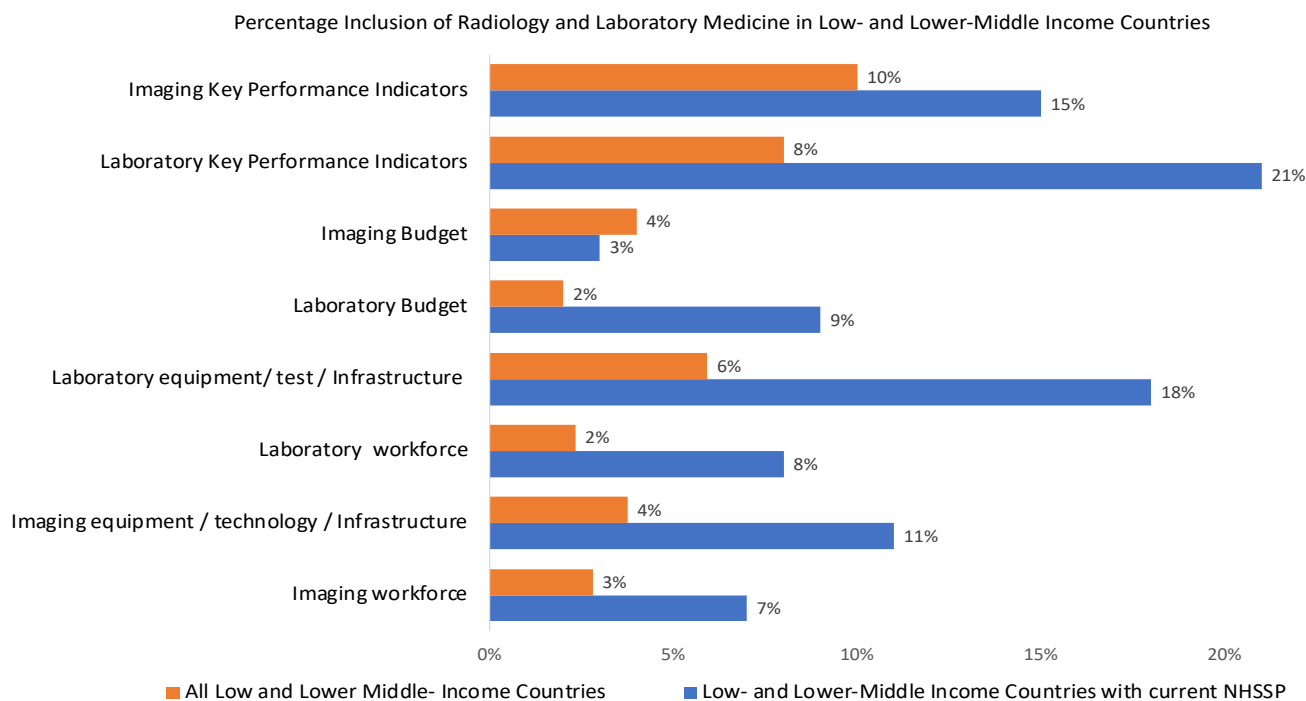


Figure 3 continued.



3c

consulted and are often notably absent from the list of authors.

This study finds limited representation in NHSSPs of medical imaging and laboratory diagnostics from standpoints like workforce, equipment/technology/infrastructure, and finance. This adds barriers to the operationalization of diagnostic services. Of the 79 LICs and LMICs originally included in this analysis, 49 countries do not have an available NHSSP, adversely impacting the operationalization of health care services. The lack of acknowledgment of medical imaging was not particularly surprising, as access to equipment across all modalities in LICs is often significantly lower than the WHO recommends [20].

Findings on work force align with published radiologist workforce numbers in LICs compared to high-income countries. For example, sub-Saharan Africa has 0.9 per 1,000,000 radiologists relative to 104.4 per 1,000,000 in the United States [21]. Sub-Saharan African countries additionally have fewer than 10% of the number of pathologists per capita compared to those in the United States [22]. The estimated number of pathologists in sub-Saharan Africa is 15 per 1,000,000 people compared to 39.4 per 1,000,000 in the United States [9,22]. Lack of space, water, power supply, consumables, supplies, network, and equipment are barriers to medical imaging availability. Large health care infrastructure requirements are also needed for imaging [8].

Limitations in the workforce and relative infrastructure are challenges that must be overcome by countries working to secure access to imaging and diagnostic services in general [9,23-25]. Therefore, investment in medical imaging and laboratory medicine infrastructure needs to address

the overarching factors that impact the availability of these services. For budgetary processes, governments and policymakers in LLMICs aim to make their budgetary plans based on the prioritization of interventions and programs recommended to support the attainment of UHC [20,26]. Addressing these challenges in NHSSPs can help to strengthen health care systems in low resource settings. Additionally, a key issue identified in NHSSPs is the lack of inclusion of financial targets. Investment in medical imaging has been shown to save costs and to be cost-effective [6,27].

While there is an acknowledgment of the indispensable need for medical imaging, access to these services remains limited in LLMICs [6,20]. Almost 20 years ago, the WHO published a document describing when and how diagnostic imaging should be used where resources are limited [12]. However, diagnostics continue to be unavailable or under-resourced in these countries, threatening global health security and advancement of UHC [28]. Documentation addressing medical imaging additionally remains separate from documentation addressing pathology and laboratory medicine, although both are fundamental components of diagnostics [29]. Imaging and laboratory diagnostics are in different silos within the WHO and greater synergy could be helpful. For example, imaging is missing from the Essential Diagnostics List (EDL) [30].

A framework for an NHSSP was released by the WHO in 2010 [11]. The guiding principle of this document for all member countries focuses on generating political dialogue, providing consistent terminology of words used in addressing situations in the plan, the alignment of the plan with other policies in a systematic manner, and finally, reinforcing the plan through prioritization, monitoring, and evaluation

and resource planning [11]. These elements contributed to the category indicators used in this study. WHO guidelines are available for the development of national laboratory strategic plans to address the critical issue. Similar guidelines for national radiology plans are not available, although there are alternatives such as guidelines from the Royal College of Physicians of Ireland [31, 34]. Documentation regarding the development of medical device policies is also available through the WHO [32]. However, the lack of connection between policies adds another barrier to implementation [26]. Therefore, a greater emphasis should be placed on the inclusion of diagnostic imaging in the future versions of NHSSPs [8]. Improved visibility of medical imaging within NHSSPs is vital to increasing access at a country level [9,23,24]. Integrated implementation of combined imaging and laboratory medicine diagnostics would minimize inefficient and ineffective siloed, disease-based approaches and improve access to reliable, timely diagnosis [33].

Recommendations

| National Action |
|---|
| <ul style="list-style-type: none"> All available supporting health care policies should be referenced in the NHSSP, which will then serve as a blueprint. Individual country NHSSPs may vary due to contextual differences, but all should prioritize diagnostics and particularly medical imaging. Health workers should have a prominent role in the process of creating NHSSPs in order to represent the larger healthcare landscape and make it less likely that critical components are ignored. Consulted stakeholder groups should include end-users for better awareness of healthcare issues on the ground [15]. Increased involvement of end-users in the development of NHSSPs is vital. |
| International Action |
| <ul style="list-style-type: none"> The immediate need to include medical imaging and laboratory medicine in NHSSPs, would be bolstered by inclusion of medical imaging in the WHO EDL. Access to diagnostic services is vital to achieving UHC2030 and ensuring the health of the global population [4]. As the WHO provides guidelines and reference for in vitro diagnostics through EDL recommendations, the inclusion of imaging in a similar published list will be critical to addressing inadequate services necessary to promote health, serve vulnerable communities, and improve patient safety. An updated WHO EDL that contains recommendations for tier-based medical imaging services could inform countries' NHSSPs in the provision of improved health care for the population [34]. |

Conclusion

Diagnostic services are essential components of health care. Testing is required for all aspects of a care-cycle, including screening, diagnosis, treatment, and surveillance. The lack of current and available NHSSPs and the omission of diagnostic services in LLMIC NHSSPs when available does not align with the resources required to achieve good population health.

Understanding the current status of under representation of medical imaging in NHSSPs is critical as countries move toward UHC2030 [22]. There is an urgent need to prioritize medical imaging in country strategic planning so that required testing may be budgeted and operationalized. The unique analyses and recommendations provided in this paper highlight the issues of inequitable access to diagnostic services, particularly medical imaging. A newfound commitment to ensuring access to diagnostics for all is vital to "ensure healthy lives and promote well-being for all at all ages" [34].

Conflicts of interest

The authors report no conflicts of interest.

References

- Lozano R, Fullman N, Mumford JE, et al. Measuring universal health coverage based on an index of effective coverage of health services in 204 countries and territories, 1990– 2019: a systematic analysis for the Global Burden of Disease Study 2019 [Internet]. *Lancet* [Internet] 2020 [cited 2021 Feb 25];396(10258):1250-84. Available from [https://doi.org/10.1016/S0140-6736\(20\)30750-9](https://doi.org/10.1016/S0140-6736(20)30750-9)
- World Health Organization [Internet]. Global tuberculosis report 2020: executive summary 2020 [cited 2021 Feb 25];[about 1 screen]. Available from <https://www.who.int/publications/i/item/9789240013131>
- Levi J, Raymond A, Pozniak A, et al. Can the UNAIDS 90-90-90 target be achieved? A systematic analysis of national HIV treatment cascades [Internet]. *BMJ glob health* 2016 [cited 2021 Feb 25];1. Available from <https://gh.bmj.com/content/1/2/e000010>
- United Nations. Political declaration of high-level meeting on Universal Health Coverage "Universal health coverage: moving together to build a healthier world" [Analysis in brief on the Internet]. 2019 [cited 2020 Nov 13]. 11p. Available from <https://www.un.org/pga/73/wp-content/uploads/sites/53/2019/07/FINAL-draft-UHC-Political-Declaration.pdf>
- Lutz H, Buscarini E, World Health Organization, World Federation for Ultrasound in Medicine and Biology. Manual of diagnostic ultrasound: Volume 2 [Analysis in brief on the Internet]. 2011 [cited 2021 Feb 25]. 430 p. Available from https://apps.who.int/iris/bitstream/handle/10665/43881/9789241547451_eng.pdf?sequence=1&isAllowed=y

6. Hricak H, Abdel-Wahab M, Atun R, et al. Medical imaging and nuclear medicine: a Lancet Oncology Commission. *Lancet Oncol* [Internet]. 2021 [cited 2021 Apr 16]. 22(4):E136-E172. Available from DOI:[https://doi.org/10.1016/S1470-2045\(20\)30751-8](https://doi.org/10.1016/S1470-2045(20)30751-8)
7. World Health Organization [Internet]. WHO recommendations on antenatal care for a positive pregnancy experience. World Health Organization; 2016 [cited 2021 Feb 25];[about 1 screen]. Available from <https://www.who.int/publications/i/item/9789241549912>
8. Maru DS, Schwarz R, Andrews J, et al. Turning a blind eye: the mobilization of radiology services in resource-poor regions. *Glob Health* [Internet]. 2010 [cited 2021 Feb 25];6:1-8. Available from <https://globalizationandhealth.biomedcentral.com/articles/10.1186/1744-8603-6-18>
9. Wilson ML, Fleming KA, Kuti MA, et al. Access to pathology and laboratory medicine services: a crucial gap. *Lancet* [Internet]. 2018 [cited 2020 Nov 13];391:1927-38. Available from [https://doi.org/10.1016/S0140-6736\(18\)30458-6](https://doi.org/10.1016/S0140-6736(18)30458-6)
10. World Health Organization [Internet]. Supporting national health policies, strategies, plans; 2021 [cited 2021 July 19];[about 2 screens]. Available from <https://www.who.int/activities/supporting-national-health-policies-strategies-plans>
11. World Health Organization. A Framework for National Health Policies, Strategies and Plans [Analysis in brief on the Internet]. 2010 [cited 2021 Feb 25]. 9 p. Available from https://www.who.int/nationalpolicies/FrameworkNHPSF_final_en.pdf
12. Ostensen H, World Health Organization. Diagnostic imaging: What is it? When and how to use it where resources are limited? [Analysis in brief on the Internet] 2001 [cited 2021 Apr 16]. 32 p. Available from https://apps.who.int/iris/bitstream/handle/10665/66703/WHO_DIL_01.1.pdf?sequence=1&isAllowed=y
13. World Health Organization. First WHO Global Forum on Medical Devices: context, outcomes, and future actions [Analysis in brief on the Internet]. 2011 [cited 2021 Feb 25]. 76 p. Available from https://apps.who.int/iris/bitstream/handle/10665/70668/WHO_HSS_EHT_DIM_11.11_eng.pdf?sequence=1&isAllowed=y
14. Welling RD, Azene EM, Kalia V, et al. White paper report of the 2010 RAD-AID Conference on International Radiology for Developing Countries: identifying sustainable strategies for imaging services in the developing world. *J Am Coll Radiol* [Internet]. 2011 [cited 2020 Nov 13];8:556-62. Available from <https://doi.org/10.1016/j.jacr.2011.01.011>
15. DeStigter K, Horton S, Atalabi OM, et al. Equipment in the global radiology environment: Why we fail, how we could succeed. *J Glob Radiol* [Internet] 2019 [cited 2020 Nov 13];5:3. doi: 10.7191/jgr.2019.1079
16. The World Bank. World Bank Country and Lending Group 2021. <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups> (accessed 16 Aug 2020).
17. World Health Organization [Internet]. Country Planning Cycle Database; 2021 [cited 2020 Aug 16]. Available from <https://extranet.who.int/countryplanningcycles/>
18. Republic of Liberia Ministry of Health and Social Welfare. National Health and Social Welfare Policy and Plan 2011-2021 [Analysis in brief on the Internet]. 2011 [cited 2020 Aug 16]. 114 p. Available from https://www.healthresearchweb.org/files/NHPP_July132011.pdf
19. Google [Internet]. Google Translate; 2021 [cited 2020 Aug 16];[about 1 screen]. Available from <https://translate.google.ca/>
20. 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* [Internet] 2016 [cited 2021 Apr 16];25. Available from 10.11604/pamj.2016.25.99.9736
21. Rosman DA, Bamporiki J, Stein-Wexler R, et al. Developing diagnostic radiology training in low resource countries. *Current Radiology Reports* [Internet] 2019 [cited 2021 Apr 16];7:1-7. Available from <https://doi.org/10.1007/s40134-019-0336-6>
22. Wilson ML. Pathology and laboratory medicine in universal health coverage. *J Lab Precis Med* [Internet] 2019 [cited 2020 Dec 18];34. Available from <https://jlp.amegroups.com/article/view/5142/html>
23. Horton S, Sullivan R, Flanigan J, et al. Delivering modern, high-quality, affordable pathology and laboratory medicine to low-income and middle-income countries: a call to action. *Lancet* [Internet] 2018 [cited 2020 Nov 13];391:1953-64. Available from 10.21037/jlp.2019.09.06
24. Nkengasong JN, Yao K, Onyebujoh P. Laboratory medicine in low-income and middle-income countries: progress and challenges. *Lancet* [Internet] 2018 [cited 2020 Nov 13];391:1873-5. Available from [https://doi.org/10.1016/S0140-6736\(18\)30308-8](https://doi.org/10.1016/S0140-6736(18)30308-8)
25. Stevenson M. A situation analysis of the state of supply of in vitro diagnostics in Low-Income Countries. *Glob Public Health* [Internet] 2020 [cited 2020 Nov 13];15:1836-46. Available from <https://doi.org/10.1080/17441692.2020.1801791>
26. Ondoa P, van der Broek A, Jansen C, et al. National laboratory policies and plans in sub-Saharan African countries: gaps and opportunities. *Afr J Lab Med* [Internet] 2017 [cited 2020 Nov 13];6:1-20. Available from <https://doi.org/10.4102/ajlm.v6i1.578>
27. Sayed S, Cherniak W, Lawler M, et al. Improving pathology and laboratory medicine in low-income and

- middle-income countries: roadmap to solutions. *Lancet* [Internet] 2018 [cited 2020 Nov 13];391:1939-52. Available from [https://doi.org/10.1016/S0140-6736\(18\)30459-8](https://doi.org/10.1016/S0140-6736(18)30459-8)
28. Nichols K, Girdwood SJ, Inglis A, et al. Bringing Data Analytics to the Design of Optimized Diagnostic Networks in Low-and Middle-Income Countries: Process, Terms and Definitions. *Diagnostics* [Internet]. 2021 [cited 2021 Apr 16];11:22. Available from <https://doi.org/10.3390/diagnostics11010022>
 29. Fleming KA, Horton S, Wilson ML, et al. The Lancet Commission on Diagnostics: Transforming access to diagnostics [unpublished]. 2021.
 30. World Health Organization. First WHO model list of essential in vitro diagnostics [Analysis in brief on the Internet]. 2019 [cited 2020 Nov 13]. Available from <https://apps.who.int/iris/bitstream/handle/10665/311567/9789241210263-eng.pdf>
 31. World Health Organization, United States Centers for Disease Control and Prevention. Guidance for Development of National Laboratory Strategic Plans. [Analysis in brief on the Internet]. 2010 [cited 2020 Nov 13]. 47 p. Available from https://www.who.int/hiv/amds/amds_guide_dev_nat_lab_strat.pdf
 32. World Health Organization [Internet]. Development of medical device policies; 2011 [cited 2021 Apr 16];[about 1 screen]. Available from <https://apps.who.int/iris/handle/10665/44600>
 33. Diaconu K, Chen Y, Cummins C, et al. Methods for medical device and equipment procurement and prioritization within low-and middle-income countries: findings of a systematic literature review. *Globalization and health* [Internet]. 2017 [cited 2021 Apr 16];13:1-16. Available from <https://doi.org/10.1186/s12992-017-0280-2>
 34. United Nations. Transforming our world: The 2030 agenda for sustainable development 2016 [Analysis in brief on the Internet]. 2016 [cited 2021 Apr 16]. 41 p. Available from <https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf>