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The integration of artificial intelligence in medical imaging practice: Perspectives of African radiographers

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ABSTRACT

Introduction: The current technological developments in medical imaging are centred largely on the increasing integration of artificial intelligence (AI) into all equipment modalities. This survey assessed the perspectives of African radiographers on the integration of AI in medical imaging in order to offer unique recommendations to support the training of the radiography workforce.
Methods: An exploratory cross-sectional online survey of radiographers working within Africa was conducted from March to August 2020. The survey obtained data about their demographics and perspectives on AI implementation and usage. Data obtained were analysed using both descriptive and inferential statistics.
Results: A total of 1020 valid responses were obtained. Majority of the respondents ($n = 883$,86.6%) were working in general X-ray departments. Of the respondents, 84.9% ($n = 866$) indicated that AI technology would improve radiography practice and quality assurance for efficient diagnosis and improved clinical care. Fear of job losses following the implementation of AI was a key concern of most radiographers ($n = 625$,61.3%).
Conclusion: Generally, radiographers were delighted about the integration of AI into medical imaging, however; there were concerns about job security and lack of knowledge. There is an urgent need for stakeholders in medical imaging infrastructure development and practices in Africa to start empowering radiographers through training programmes, funding, motivational support, and create clear roadmaps to guide the adoption and integration of AI in medical imaging in Africa.
Implication for practice: The current study offers unique suggestions and recommendations to support the training of the African radiography workforce and others in similar resource-limited settings to provide quality care using AI-integrated imaging modalities.

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Introduction

Artificial intelligence (AI) broadly refers to the theory and development of computer systems capable of performing tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and language translation.[1,2] These advanced computer-controlled systems have the capacity to accomplish tasks commonly associated with human intelligence.[2] Machine and deep learning algorithms are subsets of AI and their applications in medical imaging practice is gradually becoming more common.[3–7] AI is recognised to offer unique advantages in medical imaging practice such as reduced rates of diagnostic errors, workplace-related stress and provide clinical decision support to radiologists and radiographers.[6–8] The joint statement from the International Society of Radiographers and Radiological Technologists (ISRRT) and the European Federation of Radiographer Societies (EFRS),[9] argued that AI systems could optimise imaging workflows and potentially aid dose reduction, increase research efficiency and consistently deliver high quality planning processes. It is therefore generally accepted that AI has come to stay as an integral tool for practice and medical imaging professionals have been vanguards of this movement.[10–12]

Although radiographers have acknowledged these technologies within the profession,[3] there are concerns about AI. Some radiographers have indicated that the emergence of AI and its application could have a negative impact on their core skills.[3] Issues of ethics and potential medico-legal concerns in relation to image manipulation and cyber security were also highlighted.[13] In the African context, the lack of adequate workforce training and the technical expertise, data-right frameworks, public policies, cost of AI equipment installation/management, fear of consequent job losses and internet connectivity challenges have been previously reported.[14] Nevertheless, there is an increasing advocacy for the integration of AI in the core aspects of imaging especially in low-resource settings.[4,12,15]

For efficient use of AI, radiographers would need to adapt their practices to ensure that the new technology is utilised in line with accredited standards for maximum patient benefit.[9] With the emergence of baseline guidance statements[9,10] for future radiography practice and the inescapable market progression resulting from the continuous application of cutting-edge medical imaging technologies,[16–18] there is a demand for radiographers with requisite expertise and knowledge of AI.[19] This warrants the understanding of the current perspectives of radiographers in Africa on the integration of AI into medical imaging practice. This study aimed to comprehensively assess the perspectives of radiographers in Africa about AI in order to provide unique recommendations to support the training of this workforce in readiness to provide quality patient care using this technology.

Methods

An exploratory cross-sectional survey of radiographers working within Africa was conducted. The catchment of radiographers eligible and included were diagnostic radiographers working across the five regions of Africa[20] during the study period. A previously validated research instrument[19] was adapted for the current study. A representative group of the research team reviewed the adopted questionnaire and recommended areas for modification. These recommendations comprise the inclusion of variables such as country of residence and knowledge on previous computer coding/programming experience. Briefly, the adapted instrument broadly includes questions relating to demographics, general attitudes and perspectives on job security, the future of medical Imaging including workforce development and ethics in relation to the integration of AI (Appendix 1). The content validity of the final instrument was assessed and approved by three faculty members in radiography with experience ranging between 5 and 15 years.

The survey was piloted in three African countries (Ghana, Nigeria and Tanzania) to address reliability concerns and to ensure there were no ambiguities. In order to gain an unbiased and representative insight from across Africa, the research instrument was translated into French and Arabic by academic radiographers in the research team with proficiency in both English and either of the two languages. A test-retest analysis was used to approve the reliability of the French and Arabic versions of the research instrument.

The survey was hosted online using Google Forms (Google, Mountain View, CA). The link to the survey was shared amongst the leadership of the professional radiography societies across Africa via email and was advertised on social media platforms (WhatsApp, Twitter, Facebook, LinkedIn etc). Time frame for the survey response was five months (March 25th to August 31st, 2020) with weekly reminders on respective social media to maximise response. The Ethics and Protocols Review Committee of the School of Biomedical and Allied Health Sciences of the University of Ghana approved the study prior to its commencement (SBAHS/AA/RAD/29245/2019–2020) and all the respondents provided electronic informed consent for participation. To ensure confidentiality, participants' responses were kept anonymous and stored on a computer with an encrypted password.

Statistical analysis

Data from the survey were downloaded from Google Forms, analysed using the Statistical Package for the Social Sciences (SPSS) version 23 (IBM Corp, NY, USA). The response to rating questions/items were assigned scores (1–5) on the Likert scale, corresponding to responses (strongly agree = 5, agree = 4, neutral = 3, disagree = 2, strongly disagree = 1). Spearman's rank-order correlation was used to investigate the relationship between some of the demographic variables and respondents' perspectives on the integration of AI in medical imaging. A two-tailed α level of 0.05 was used for testing statistical significance in all analyses. For easy presentation of the results, the "strongly agreed" and "agreed" responses were grouped together as an "agreement response" while the "strongly disagree" and "disagree" responses were also grouped together as a "disagreement response".

Results

A total of 1020 valid responses [English: (n = 950), Arabic: (n = 40) and French (n = 30)] were obtained, comprising of 69.6% male (n = 710) and female (n = 310, 30.4%) respondents. Demographic details of the respondents are presented in Table 1. Responses were received from 51.8% (n = 28/54) of countries across Africa (Fig. 1). Peak responses were received from Nigeria (n = 254, 24.9%), Ghana (n = 157, 15.3%)] and Tanzania (n = 190, 18.6%)] (Fig. 1). Eight hundred and sixty-six (84.9%) of the respondents indicated that AI technology would improve general radiography practice and quality assurance for efficient diagnosis and improved clinical care of patients (Table 2). Details of the respondents' general attitudes about the emerging integration and use of AI in medical imaging in Africa are presented in Table 2.

Of the respondents, 61.3% (n = 625) indicated that AI tools could replace the job of most radiographers and negatively affect the radiography profession in Africa rather than being an assistive tool in easing workload (Table 3). Further details of the respondents' perspectives on job security with the emerging integration and use of AI in medical imaging in Africa are presented in Table 3. The

Table 1
Demographic distribution of respondents.

Demographic	*n* (%)
Gender	
Male	710 (69.6)
Female	310 (30.4)
Age range (years)	
≤20 - 29	386 (37.8)
30–39	388 (38.0)
40–49	167 (16.4)
50–59	60 (5.9)
60 and above	19 (1.9)
Workplace setting	
Private	364 (35.7)
Public	581 (57.0)
Quasi-government	64 (6.3)
Others	11 (1.1)
Years of practice (years)	
≤5	463 (45.4)
6–10	238 (23.3)
11–15	131 (12.8)
16–20	91 (8.9)
21 and above	97 (9.5)
Highest educational level	
Certificate	12 (1.2)
Diploma	301 (29.5)
BSc/BTech	482 (47.3)
Masters	186 (18.2)
PGCert/DP	7 (0.7)
PhD	27 (2.6)
Others	5 (0.5)
Knowledge on coding/programming	
Competent	64 (6.3)
Basic concepts	631 (61.9)
Not at all	325 (31.9)

BSc/BTech: Bachelor of Science/Technology, PGCert/DP: Postgraduate certificate/diploma, PhD: Doctor of Philosophy.

respondents' perspectives on the future of AI in medical imaging in Africa are presented in Table 4.

The score for respondents' general attitudinal perspectives showed significant positive correlations with age (r_s = 0.83, $p = 0.008$) and years of practice ($r_s = 0.108$, $p = 0.001$). However, no significant positive correlation was noted with education levels (r_s = 0.60, p = 0.345). Respondents' score for perspective on job security significantly correlated positively with age (r_s = 0.136, p = 0.001), years of practice ($r_s = 0.154$, p = 0.01) and educational levels ($r_s = 0.209$, p = 0.001).

Discussion

Radiographers are experiencing a massive technological change in their field that will significantly impact the profession.[12,21,22] To facilitate the successful adoption of AI in medical imaging practice, considering the overriding positive implications of AI implementation, this survey sought to broadly evaluate the perspective of African radiographers on the integration of AI in medical imaging. To the best of our knowledge this is the first study that have assessed the perspective of radiographers in Africa about the integration of AI in medical imaging practice.

A total of 1020 responses were obtained with 710 male respondents, highlighting male dominance of the sample. Currently, no data exist on the total number of radiographers to suggest male dominance of the radiography workforce in Africa. However, the general observed trend in some previous studies[23,24] indicates a male dominance radiography workforce in some African countries, contrary to the finding of female dominance reported in the United Kingdom and mainland Europe.[25] Responses were received from all the five geographical regions of Africa,[20] specifically, from 28 out of the 54 countries of the continent. Irrespective of respondent's expertise (Fig. 1B), they held the view that AI would advance general radiography practice, particularly, in the context of image quality improvement for diagnostic precision to enhance patient care (Table 2). This perspective was supported by their indication of awareness of AI trends in medical imaging (78.3) and excitement about the global use of AI in medical imaging (80.2%). The position share by these respondents could be because of their knowledge that AI systems have the capacity to accomplish tasks commonly associated with human intelligence.[2]

The majority of respondents (76.0%) had a positive opinion about AI as an assistive technology in optimising radiation dose levels. It was very re-assuring that the majority (80.2%) felt that AI would ensure the production of quality images with greater benefits than harm to patients as reported previously.[26,27] These perspectives are very encouraging as the concepts mentioned are very important in radiographic practice.[9] Similar evidence suggests that Ghanaian radiographers thought of AI as the future of medical imaging.[19]

Prespane et al.[28] reported several potential clinical applications of AI in diagnostic imaging such as image acquisition, image processing and reporting, data storage among others. The majority (86.1%) of respondents in the current study, believe that, AI tools that support image reporting (through the flagging) of common conditions like tuberculosis would be very important, particularly in Africa. This is because infectious diseases like tuberculosis are common in Africa, as such, AI would augment the relatively small radiology workforce and the expertise required for diagnostic image reporting and interpretation in Africa. Evidence suggest that radiographers approved of the implementation of AI technologies because of several other advantages beyond image acquisition.[3]

AI technology would require some knowledge in coding and programming for effective implementation in practice. It was therefore encouraging that more than half (61.9%) of the respondents, had basic knowledge of coding or programming (see Table 1). Notwithstanding, some respondents' views were found to reflect negatively on job security regardless of their age and educational level. Particularly, 67.3% of respondents thought that AI could replace radiographers and adversely affect their profession. Similarly, a previous study[28] reported some doubts among radiologists about their looming job security moving forward with the emerging trends in AI technologies. Although, there exist general anxiety that AI may substitute human employment,[29] there is no evidence to suggest that this would be the case.[4] This finding may be due to lack of knowledge in line with a recent report.[30] Interdepartmental communication and clear guidelines can facilitate the understanding of the role of AI in medical imaging. Consistently, technological changes and development have unswervingly, impacted on the radiography profession with the practice developing and acclimating in response to the operation of new technologies and cutting-edge imaging prospects presented by their implementation.[3,11] Therefore, the assertion on job insecurity and salary reduction is difficult to accept as AI has not demonstrated how it could for example, replace the human face of patient positioning by radiographers for various imaging investigations and the necessary instructions that they have to provide patients referred to the imaging department.

Radiographers, however, should be assured that AI is a potential support to the practice of their profession.[3] Respondents believed that AI would eventually change radiographers' role leading to extended practices. However, previous studies,[8–11] suggest that it would advance the practice and create other opportunities but will

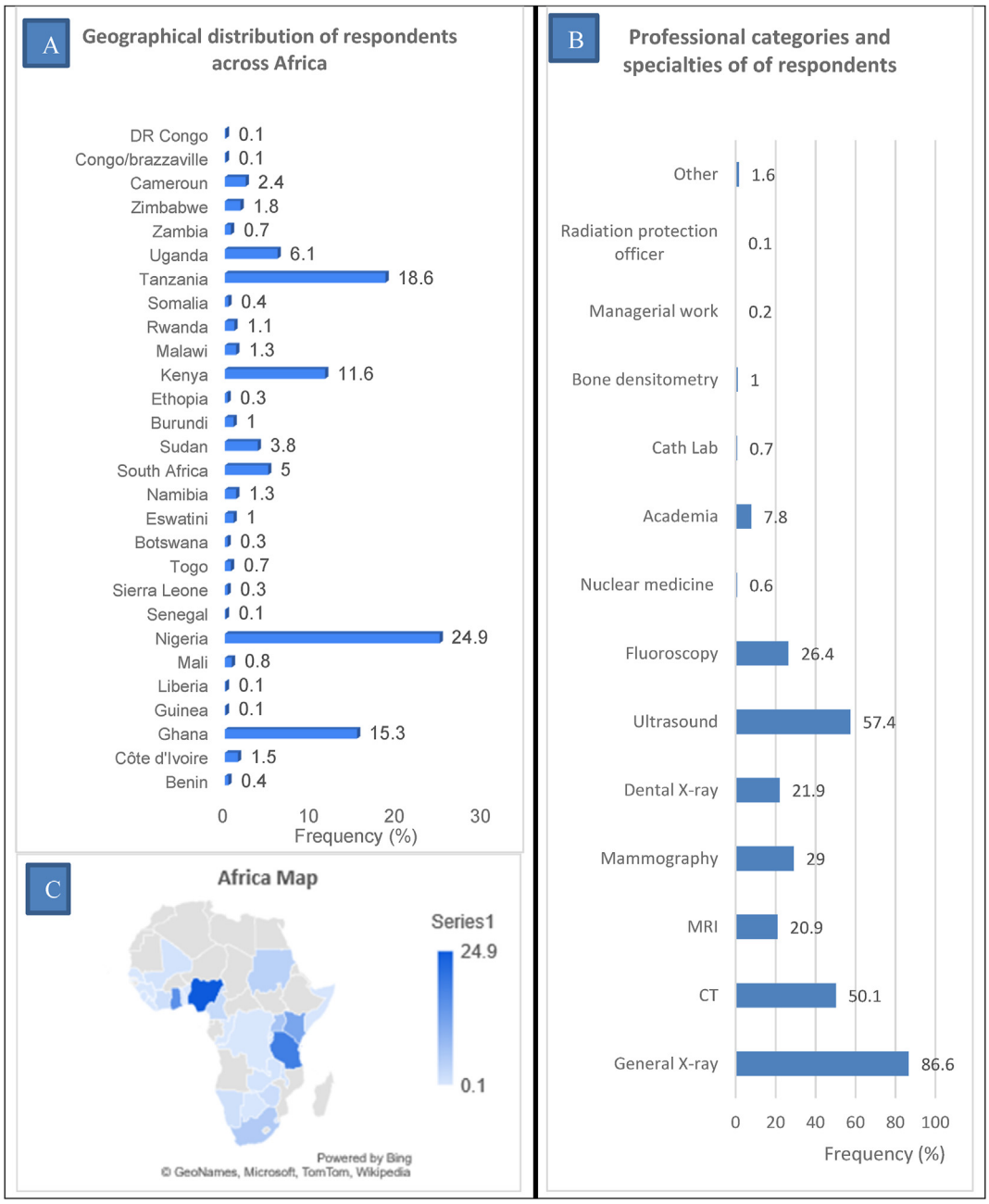

Figure 1. Geographical distribution of respondents across Africa (A) and Professional categories and specialties of respondents (B), Africa map showing distribution of respondents (C). *In B, respondents selected more than one option, so the sum of the percentages are more than 100%.*

not change the core roles of radiographers entirely. There is a global interest in radiography role extension due to increased radiology investigations and career development.[11,31,32] It is therefore recommended that radiographers prepare themselves through education (e.g., CPD activities, post graduate studies, seminars etc.) for the job opportunities that AI would present to medical imaging professionals.

Legal implications as a result of AI integration in medical imaging is anticipated. Currently, no clear laws or policy frameworks are available to guide the use of AI in medical imaging and healthcare in general.[33] It was therefore not surprising that the majority (45.5%) of respondents in the current study felt that the future applications of AI in Africa might encompass errors in clinical radiography practice and unethical utilisation of patient data. This suggests the critical need for governance policies in relation to AI before its full implementation in Africa.

Respondents' general attitudinal perspective scores strongly correlated positively with age and years of practice but not with the level of education. This trend is explained by the lack of core AI components in the current curriculum of radiography education in Africa and most other training institutions globally.[30] Notably, there are efforts for curriculum revisions to address this in the near future.[3,4,9,11]

The findings of this study are potentially reflective of other low-resource settings, considering the similar healthcare resource challenges within these communities. However, the survey did not

Table 2
Attitudinal perspectives on the emerging integration and use of AI in medical imaging in Africa.

Statements	Responses *n* (%)		
	Agreement	Neutral	Disagreement
I am aware of AI as an emerging trend in medical imaging in Africa.	799 (78.3)	202 (19.8)	19 (1.9)
I believe most of my patients would be excited about the use of AI technologies in their standard care.	704 (69.0)	271 (26.5)	45 (4.4)
AI could help reduce radiation dose levels whiles maintaining optimal image quality in medical imaging.	834 (82.8)	159 (15.6)	27 (2.6)
AI technology would improve general radiography practice and quality assurance for its efficient diagnosis and improved clinical care of my patients.	866 (84.9)	124 (12.2)	30 (2.9)
The introduction of AI technologies in medical imaging could provide an avenue for more research to improve practice and patient care.	924 (90.6)	78 (7.6)	18 (1.8)
I am excited about the integration of AI tools into medical imaging practice worldwide.	836 (82.0%)	146 (14.3)	38 (3.7)
I am very concerned about the integration of AI into medical imaging practice worldwide.	689 (67.5)	226 (22.2)	105 (10.3)
The integration of AI into medical imaging practice in Africa would introduce more benefits than harm.	775 (76.0)	205 (20.1)	40 (3.9)

Table 3
Perspectives on job security with the emerging integration and use of AI in medical imaging in Africa.

Statements	Responses *n* (%)		
	Agreement	Neutral	Disagreement
AI tools could replace most radiographers' jobs and negatively affect the radiography profession in Africa rather than being an assistive tool in easing my workload.	625 (61.3)	154 (15.1)	241 (23.6)
AI tools could replace the job of most radiologists/reporting radiographers and negatively affect the radiology profession in Africa especially in the role of image interpretation.	686 (67.3)	149 (14.6)	185 (18.1)
I have a concern that the role of AI as an assistive tool can potentially cause a reduction in my basic salary and eventually displace me from my job in the future.	590 (57.8)	176 (17.3)	254 (24.9)
AI would change the role of radiographers leading on to extended practices.	779 (76.4)	136 (13.3)	105 (10.3)

Table 4
Perspectives on the future of the emerging integration and use of AI in medical imaging in Africa.

Statements	Responses *n* (%)		
	Agreement	Neutral	Disagreement
I require further education and/or training to be able to embrace these emerging AI trends in medical imaging?	943 (92.5)	48 (4.7)	29 (2.8)
It is important for radiography departments in Africa to start planning for AI and machine learning tools?	900 (88.2)	97 (9.5)	23 (2.3)
The use of AI tools could lead to unethical utilisation of patient data for unwarranted commercial purposes.	463 (45.4)	352 (34.5)	205 (20.1)
There is a possibility of errors associated with AI technologies integrated into my clinical radiography practice.	653 (64.0)	263 (25.8)	104 (10.2)

Questions	Options	*Response n (%)*
What do you see as the single greatest barrier to yourself or others in learning about AI?	Lack of dedicated courses and learning materials	219 (21.5)
	Lack of mentorship, guidance and support from “experts"	136 (13.3)
	Lack of evidence-based material and proof of improved clinical outcomes	117 (11.5)
	Lack of time to learn new technologies	33 (3.2)
	Lack of funding/investment for new technologies	360 (35.3)
	Lack of motivation for change and interest to learn	66 (6.5)
	Fear of the unknown	89 (8.7)
What sort of AI tools would you prioritise for medical imaging practice in Africa?	Tools that support image reporting by detecting or flagging common conditions like tuberculosis.	879 (86.1)
	Tools that improve scanning efficiency	126 (2.4)
	Tools that help identify poor patient positioning prior to imaging studies	10 (1)
	Tools that improve the efficiency of workflow for booking scans and radiology appointments	5 (0.5)

fully address this particular subject; therefore, future studies may be needed using in-depth qualitative approaches to explore the impact of work settings on the perceptions of AI amongst radiographers. Moreover, the study is likely limited by the use of an online exploratory approach for data collection, thus, the sampling used for this research is not proportionate, resulting in countries with large populations and large number of radiographers having small responses, and vice versa.

Conclusion

The findings indicate that radiographers working in Africa have positive perspectives about the integration of AI in medical imaging. However, concerns about job security regarding the integration of AI in medical imaging were eminent. Just like other transformative and revolutionary technologies, there are potential challenges that would be integral to the implementation of AI in medical imaging in Africa. Lack of knowledge, funds, regulatory policies and support systems were identified as key barriers to the effective implementation of AI which should be given attention by stakeholders. The current study offers unique suggestions and recommendations in order to support the training of the African radiography workforce and others in similar resource-limited settings to provide quality care using AI-integrated imaging modalities.

Conflict of interest statement

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.radi.2021.01.008.

References

1. Ranschaert ER, Duerinckx AJ, Algra P, Kotter E, Kortman H, Morozov S. Advantages, challenges, and risks of artificial intelligence for radiologists. In: Ranschaert ER, Morozov S, Algra PR, editors. *Artificial intelligence in medical imaging: opportunities, applications and risks*. Cham: Springer; 2019. p. 329–46.
2. Frankenfield J. *How artificial intelligence works*. from, https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp, 2019, November 18. [Accessed 19 January 2020].
3. Hardy M, Harvey H. Artificial intelligence in diagnostic imaging: impact on the radiography profession. *Br J Radiol* 2019;**92**:20190840. https://doi.org/10.1259/bjr.20190840.
4. Murphy A, Liszewski B. Artificial intelligence and the medical radiation profession: how our advocacy must inform future practice. *J Med Imag Radiat Sci* 2019;**50**(4S2):S15e9. https://doi.org/10.1016/j.jmir.2019.09.001.
5. Litjens G, Kooi T, Bejnordi BE, Seto A, Ciompi F, Ghafoorian M, et al. A survey on deep learning in medical image analysis. *Med Image Anal* 2017;**42**:60–88. https://doi.org/10.1016/j.media.2017.07.005.
6. Kitson S. *Artificial Intelligence - medical imaging innovation*. Retrieved from, https://openmedscience.com/artificial-intelligence-medical-imaging/; 2020, March 8.
7. Gore JC. Artificial intelligence in medical imaging. Magn Reson Imag 68(2020), A1-A4
8. Lakhani P, Prater AB, Hutson RK, Andriole KP, Dreyer KJ, Morey J, et al. Machine learning in radiology: applications beyond image interpretation. *J Am Coll Radiol* 2018;**15**:350–9. https://doi.org/10.1016/j.jacr.2017.09.044.
9. International Society of Radiographers and Radiological Technologists. The European federation of radiographer societies. Artificial intelligence and the radiographer/radiological technologist profession: a joint statement of the international society of radiographers and radiological Technologists and the European federation of radiographer societies. *Radiography* 2020;**26**(2):93-95. https://doi.org/10.1016/j.radi.2020.03.007.
10. Chaix B, Bibault JE, Pienkowski A, Delamon G, Guillemassé A, Nectoux P, et al. When Chatbots meet patients: one-year prospective study of conversations between patients with breast cancer and a Chatbot. *JMIR Cancer* 2019;**5**: e12856.
11. Lewis SJ, Gandomkar Z, Brennan PC. Artificial Intelligence in medical imaging practice: looking to the future. *J Med Radiat Sci* 2019;**66**(4):292–5. https://doi.org/10.1002/jmrs.369.
12. American Society of Radiologic Technologists. *The artificial intelligence era: the role of radiologic technologists and radiation therapists*. Albuquerque: ASRT Foundation; 2020.
13. Iannucci JM, Howerton LJ. *Dental radiography: principles and techniques*. 5th ed. St. Louis, MO: Elsevier; 2017.
14. Nyathi T, Chirwa T, van der Merwe D. A survey of digital radiography practice in four South African teaching hospitals: an illuminative study. *Biomed Imaging Interv J* 2010;**6**(1):e5. https://doi.org/10.2349/biij.6.1.e5.
15. Wagner JB. Artificial intelligence in medical imaging. *Radiol Technol* 2019;**90**(5):489-501.
16. Mollura DJ, Culp MP, Pollack E, Battino G, Scheel JR, Mango VL, et al. Artificial intelligence in low- and middle-income countries: innovating global health radiology. Radiology. 2020,201434. doi: 10.1148/radiol.2020201434.
17. IAEA Brief. *Human health: enhancing patient care in Africa through safe medical imaging*. Retrieved from, https://www.iaea.org/sites/default/files/16/11/enhancing-patiient-care-in-africa-through-safe-medical-imaging.pdf; 2016.
18. East Coast Polytechnic Institute. *How medical imaging advances have changed the world*. https://www.ecpi.edu/blog/medical-imaging-advances-have-changed-world, 2020. [Accessed 27 July 2020].
19. Botwe OB, Antwi KW, Arko S. Akudjedu T. Radiographers' perspectives on the emerging integration of artificial intelligence into medical imaging: the Ghana study. J Med Radiat Sci. DOI: 10.1002/jmrs.460.
20. The United Nations Statistics Division. *Standard country or area codes for statistical use (M49)*. Retrieved from: https://unstats.un.org/unsd/methodology/m49/. 20/08/2020.
21. Morozov S, Ranschaert ER, Algra PR. Introduction: game changers in radiology. In: Ranschaert ER, Morozov S, Algra PR, editors. *Artificial intelligence in medical imaging: opportunities, applications and risks*. Cham: Springer; 2019. p3–5.
22. Kulkarni S, Seneviratne N, Baig MS, Khan AHA. Artificial intelligence in medicine: where are we now? *Acad Radiol* Jan. 01, 2020;**27**(1):62–70. https://doi.org/10.1016/j.acra.2019.10.001. Elsevier USA.
23. Anim-Sampong S, Arthur L, Nkansah JA, Botwe BO. Women in radiography practice in Ghana: motivating and demotivating factors. *Radiol Technol* 2018;**89**(4):337–43.
24. Luntsi G, Muhammed R, Nwobi IC, Njiti M, Nkubli FB. Radiography profession regulation, practice and challenges in Northern Nigeria. *J Assoc Rad Niger* 2015;**29**(1):1–8.
25. Akudjedu TN, Lawal O, Sharma M, Elliott J, Stewart S, Gilleece T, et al. Impact of the COVID-19 pandemic on radiography practice: findings from a UK radiography workforce survey. *BJR Open* 2020 Sep 2;**2**(1):20200023. https://doi.org/10.1259/bjro.20200023.
26. Wang Y, Yu B, Wang L, Zu C, Lalush DS, Lin W, et al. 3D conditional generative adversarial networks for high-quality PET imageestimation at low dose. *Neuroimage* 2018;**174**:550–62.
27. Wolterink J, Leiner T, Viergever T, Isgum I. Generativeadversarial networks for noise reduction in low dose CT. *IEEE Trans Med Imag* 2017;**36**:2536–25345.10.
28. Pesapane F, Codari M, Sardanelli F. Artificial intelligence in medical imaging: threat or opportunity? Radiologists again at the forefront of innovation in medicine. *Eur Radiol Exp* 2018 Oct 24;**2**(1):35. https://doi.org/10.1186/s41747-018-0061-6.
29. Felten Edward W, Raj Manav, Seamans Robert. *The occupational impact of artificial intelligence: labor, skills, and polarization*. NYU Stern School of Business; September 8, 2019. https://doi.org/10.2139/ssrn.3368605. Retrieved from.
30. Abuzaid MM, Elshami W, Tekin H, Issa B. Assessment of the willingness of radiologists and radiographers to accept the integration of artificial intelligence into radiology practice. *Acad Radiol* 2020 Oct 29. https://doi.org/10.1016/j.acra.2020.09.014. S1076-6332(20)30553-5.
31. Abuzaid MM, Elshami W, McConnell J, Baird M. Changing the model of radiography practice in the UAE: a snapshot of a profession in transition. *Radiography* 2021;**27**(1):54–8. https://doi.org/10.1016/j.radi.2020.05.014.
32. Wuni AR, Courtier N, Kelly D. Developing a policy framework to support role extension in diagnostic radiography in Ghana. *J Med Imag Radiat Sci* 2020 Oct 17. https://doi.org/10.1016/j.jmir.2020.09.013. S1939-8654(20)30308-8.
33. Mahomed S. Healthcare, artificial intelligence and the Fourth Industrial Revolution: ethical, social and legal considerations. *South Afr J Bioeth Law* 2018;**11**: 93–5. https://doi.org/10.7196/SAJBL.2018.v11i2.00664.