UNIVERSITY OF NAIROBI

Department of Diagnostic Imaging and Radiation Medicine

THE ROLE OF ARTIFICIAL INTELLIGENCE IN DIAGNOSTIC RADIOLOGY: KNOWLEDGE, ATTITUDE, AND PRACTICE OF RADIOLOGISTS AND RADIOLOGY RESIDENTS IN KENYA

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DECLARATION

This is my original work, and to the best of my knowledge, it has not been presented anywhere else

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ABBREVIATIONS

AI:	Artificial Intelligence
ANN:	Artificial Neural Networks
CAD:	Computer Assisted Detection
CAR:	Canadian Association of Radiologists
CNN:	Convoluted Neural Networks
CT:	Computed Tomography
DL:	Deep Learning
DDIRM:	Department of Diagnostic Imaging and Radiation Medicine
DIRM:	Diagnostic Imaging and Radiation Medicine
DR:	Diagnostic Radiology
ERC:	Ethics and Research Committee
KAR:	Kenya Association of Radiologists
KNH:	Kenyatta National Hospital
ML:	Machine Learning
MRI:	Magnetic Resonance Imaging
PACS:	Picture Archiving and Communication System
UON:	University of Nairobi

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OPERATIONAL DEFINITIONS

- **Artificial neural networks (ANN)** are "statistical and mathematical methods that are a subset of machine learning that resemble the central nervous system in its main task of adaptive learning and generalization" (1). It comprises of an input node layer, output layer, and "hidden layers" (2).

- **Convolutional neural networks (CNNs)** are "a subset of DL that analyze two-dimensional and three-dimensional inputs"(2). CNN's are therefore gaining popularity in Diagnostic Radiology (DR) since images are mostly represented in two or three-dimensional formats.

- **Deep learning (DL)** refers to neural networks with multiple layers of nodes (3). The multiple layers in DL are applied to recognize features varying from simple (intensity, lines, textures, edges) to complex (shapes, body organs, lesions) (3).

- **Health informatics** refers to the use of information technology for organization and analysis of medical records with the goal of improving outcome in the healthcare industry

- **Machine learning (ML)** refers to computed algorithms that learn from labelled inputted data from which they are able to identify and deduce patterns (4). ML can be classified into three types: unsupervised, supervised, and semi-supervised (5).

- **Radiomics** is the "process of extracting numerous quantitative features from an image to create large data sets in which each abnormality is described by hundreds of parameters" (6)
- **Radiography:** refers to the "process of obtaining images (radiographs) of internal structures of the body using X-rays" (7).

- **Transfer learning** refers to an "ML technique that applies knowledge learned from a previous task to a different but related task" (2).

ABSTRACT

Background. Phenomenal developments in Artificial Intelligence/ Machine Learning (AI/ML) have led to the creation of powerful computerized algorithms with proven capabilities in the performance of some tasks in the radiology workflow. Predictions of the impact that AI/ML will have in the field of Diagnostic Radiology (DR) range from rendering radiologists obsolete to drastic changes in its practice. This has resulted in varied attitudes and perceptions of AI among radiologists and radiology residents. It is, therefore, key that radiologists be well versed with terminologies, concepts, and applications of AI/ML in DR to enable them to accurately project their potential effects and prepare them for the same.

Objective This study assessed the knowledge, attitudes, and practice of radiologists and radiology residents towards AI/ML in the field of DR in Kenya.

Methodology. A cross-sectional descriptive study method was used. The study was primarily conducted among members of the Kenya Association of Radiologists (KAR). Eligible persons included radiologists and radiology residents based in Kenya.

Data was collected by sharing a web-based questionnaire on the association's WhatsApp platform, which had a membership of 199. Total sampling technique was used. Study variables were be calculated by the use of percentages and frequencies. Pearson's Chi-square and Mann-Whitney U test were utilized to compare categorical data and study groups, respectively.

This study is of help in identifying the level of knowledge of AI in DR, its utilization in daily practice, and the prevailing attitudes and perceptions surrounding it. The data was analysed using Statistical Package for Social Sciences (SPSS) version 26.

Results

A considerable majority of the participants had basic knowledge on Artificial intelligence, for they had read/watched/attended an AI presentation (n = 73, 65.8%). Less than half of the participants were knowledgeable on machine learning, artificial neural networks and deep learning concept. The use of AI in detection in radiology emerged as the most mentioned application (37.4%), with the remaining applications such as segmentation, speech recognition, registration, workflow management, protocol optimization and others only accounting for less than 20% individually.

Utilization of AI application in daily radiology practice was scarce, with only 12.6% utilizing AI. Slightly more than two-thirds (68.5%) felt that the future practice of radiology would change as a result of AI. Nearly half of the participants felt that AI/ML application has both positive and negative effect on the field of radiology (44.1%), while the rest considered IA/ML as holding the potential to make radiology exciting and good (55.9%). Approximately two-thirds of the participants indicated their willingness to be involved in the process of development and training of ML algorithms so that they can do some of the tasks that a radiologist does (67.6%). At least 64% of the participants indicated that they had read an article on AI application in radiology. Around two-thirds of the participant felt that the current knowledge on AI applications has no bearing on their decision to pursue a career as a radiologist (61.3%).

Conclusion

The results from this study show that consultant radiologists and radiology residents have a basic knowledge of AI while lacking knowledge on related concepts. Consultant radiologists and residents generally have a positive attitude towards AI application in Radiology. The utilization of AI applications in daily radiology practice in Kenya is still low.

Recommendation

To bridge the knowledge gap, a course on AI/ML applications in Radiology should be introduced to the residency program while continuous medical education should be provided to radiologists.

CHAPTER ONE: INTRODUCTION

1.1 Background

The field of Artificial Intelligence (AI) has witnessed exponential growth in the 21st century (8). The phenomenal changes in AI have catapulted the development of society as we know it, with resultant radical shifts in the performance of tasks in diverse fields and industries, both in theory and technique (1). The Canadian Association of Radiologists(CAR) defines AI as a "branch of computer science dedicated to the development of computer algorithms to accomplish tasks traditionally associated with human intelligence, such as the ability to learn and solve problems"(3). Day to day AI applications include automated personal assistants, for instance, the popular Google Alexa, phone conversation behavioural algorithms, intelligent e-commerce shopping recommendations, and self-driving vehicles(3). AI tools are becoming more reliable and easy to integrate into daily tasks(3).

The field of DR is not only a product of technology but also evolves and advances as a result of it. DR applies imaging technology and radiation for diagnosis and therapy. It has gained heavily from advances in physics, engineering, and computer science. ML improves efficiency in the analysis and diagnosis of medical images and is predicted to greatly diminish the radiologists' workload(5).

As AI tools become more proficient and are eventually integrated into the radiological workflow, it is essential that radiologists familiarize themselves with the fundamental concepts and technical terms(3). Studies predict that radiologists trained in the fields of programming and health informatics, which are key pillars of AI/ML, will be more employable in the future(9).

Even though the majority of the existing research data is primarily on the role of AI/ML in computer-assisted image detection, ML is predicted to impact all the steps of the radiology workflow(10). This workflow includes " order scheduling and patient screening, automated clinical decision support and examination protocoling, image acquisition, automated detection of findings and features, automated interpretation of findings, image management (display and archiving), postprocessing (image segmentation, registration, and quantification), image quality analytics, automated dose estimation, radiology reporting and analytics, and automated correlation and integration of medical imaging data with other data source"(2).

There is no data available on the knowledge, attitude, and practice of AI/ML in DR, in Kenya and Africa. In a survey done among medical students from 19 colleges in the United Kingdom (UK), the majority(88%) believed that AI would play a critical role in the medical industry in the future(11). Almost half of the students reported that they had "a basic understanding of the principles that underpin AI."In addition, 49% reported that "they were less likely to consider a career in DR due to AI"(11). This was very concerning because there is an acute shortage of radiologists in the UK. Some students believed that some medical specialities would be wiped out completely as a result of AI(11).

In a study conducted by Gong et al. among 322 Canadian medical students, 48.6% agreed that they experienced anxiety caused by their perception of AI when considering Radiology as their line of speciality (12). Worse still, one-sixth of the participants who would otherwise pursue DR as their first choice reported that they would not consider it due to their anxiety about AI(12).In another study, Pinto Dos Santos et al. established that there was a prevailing lack of knowledge on AI among medical students(13). Furthermore, he identified that their knowledge on the topic was acquired from the mainstream media rather than peer-reviewed journals, and the majority of them agreed that training on AI should be incorporated into the medical school curriculum(13). Interestingly, both studies cited above established that participants with prior knowledge of AI were less anxious about it and were more willing to embrace the technology in their future practice.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Two decades ago, an algorithm called "Deep Blue" defeated a renowned chess grandmaster in a chessboard game (14). In 2016, a general-purpose algorithm invented by google defeated the champions of the complex Asian board game Go (14). Closer home, mammography, and colon CAD applications have demonstrated comparable, if not better, performance when compared with seasoned radiologists (5). In a study done at Mie Chuo Medical Center in Japan, an ML algorithm was able to create a classification model using inputted morphologic and hemodynamic data for cerebral aneurysms (12). This model had an accuracy of 78.1%, which was more than the judgment of an experienced vascular neurosurgeon (15). ML in DR is part of current practice and not a prediction of a future event (14).

Within DR, radiologists visually assess medical images to detect, characterize, and monitor diseases and then report their findings (16). Such an assessment is usually influenced by one's training and experience and can be prone to subjectivity (16). On the other hand, AI excels in quantitative assessment rather than qualitative reasoning, enabling it to recognize complex patterns in the imaging data provided. (16). As a result, the accuracy and reproducibility of report findings are consequently enhanced by the use of AI applications (16). Other than its current comparability to human analysis, ML is not subject to performance limitations as a result of fatigue, emotions, and distraction as humans are (14). In addition, like humans, ML will improve as time goes on, owing to increasing quantities of radiological data available and increasing computer "experience" (16). Such data is already being provided by readily available tools, for instance, Picture Archiving and Communication System (PACS). Radiologic images, when paired with clinical outcome data, has given birth to the field of radiomics (17). In oncology, the incorporation of DL into radiomics tools has assisted in cancer prognostication (6).

Currently, the integration of AI tools is widely adopted in the field of aviation. The recent Boeing 737 MAX aeroplane disasters owing to the failure of automated systems has attracted negative publicity to AI applications. With the intense push to also incorporate AI into the field of radiology, J. Mongan and M Kohli highly recommend that medicine should also learn lessons from aviation on how AI systems should not be implemented (18). They conclude that; a malfunctioning AI tool

will provide a new safety hazard, proper integration of AI tool is key, employees using an AI system at work must be trained on its function and also potential dysfunction, AI tools should have prompt and lasting override mechanisms, and conflict of interest from regulators may expose patients to potential harms (16). Yao et al. recommend criteria to be used before the integration of AI applications into clinical practice, namely, research standardization, generalizability, and reproducibility (19).

The field of AI/ML is pushing the science of ethics to its limits. The existing legal and ethical principles have been found insufficient in this area(20). One of the key questions is who should be held accountable in case of ethical breaches. There is increasing consensus that creators of AI algorithms should be held accountable for their consequences(21). This necessitates "ethical training for AI practitioners and students"(22). The second question pertains to who should regulate or enforce such accountability. Members of Parliament and academics have been suggested to play that role (15). The ethical principles of "autonomy, beneficence, confidentiality, non-maleficence, and justice" are key in the practice of medicine. These principles should also apply to the use of AI in radiology. As such, patients should be informed when AI is included as a part of their treatment. Secondly, the clinician should be acquainted with the accuracy of the AI tool, its shortcomings, and also the reason for its recommendation (population used in the data model)(23). The principle of confidentiality is particularly challenging since many AI models may require the inputting of sensitive data for them to give an accurate interpretation, hence the importance of informed consent(23).

Among radiologists, AI is perceived in a spectrum ranging from "total acceptance and great enthusiasm to denialism, anxiety, insecurity, scepticism, and apprehension" (24). In a study done among radiology residents, their anxiety was demonstrated as follows: "Trainees were more likely to express doubts on whether they would have pursued DR as a career had they known of the potential impact AI is predicted to have on the speciality, P¼0.0254 and were also more likely to plan to learn about the topic, P¼0.0401"(24).

AI is a friend, not an enemy, and it will inevitably occupy an invaluable place in clinical radiology workflow (24). AI will undoubtedly improve the radiologist's efficiency and worklist prioritization by sifting through immense quantities of imaging data in seconds (24). This would "avail quality

time for radiologists with their patients and also avail time for teaching and research" (24).

In a study done at a DR Residency program, it was shown that despite the current developments in AI /ML in DR and their potential ramifications, there was a lack of awareness among both consultant radiologists and residents with regards to AI tools they already used (25). The low reported exposure to scientific articles on the topic of AI/ML in DR was thought to be likely due to the scarcity of such articles in the leading radiology journals at that time (25). Additional reasons likely included the fact that informatics and AI/ML applications in DR were relatively current advances that they had not been trained on (25). The fact that residents were more bothered by the implications of AI/ML on their future careers, and their eagerness to learn about it, was attributed to the early stage of their careers and concern about its potential ramifications on their future jobs (25). This particular study concluded that there was a need for both radiologists and DR residents to become acquainted with AI and ML to enable them to integrate such applications into their practice (25).

In a study conducted among attending radiologists, radiology residents, and fellows from large hospitals in Saudi Arabia, a significant lack of knowledge about AI (22%) was identified(26). The "responses to the question related to the use of AI on a daily basis illustrated that 76 (82%) of the participants were not using any AI software at all during the daily interpretation of diagnostic images"(24). The AI tools reportedly used for daily tasks were "CAD, voice-to-text converters, and dictation software," and there was "a significant difference in the proportion of radiologists using AI software on a daily basis for diagnostic radiology ($P < 0.05$)"(24). The majority of the respondents(71%) demonstrated a willingness to help develop AI algorithms for application in DR(26).

In a survey done in 2019 among the European Society of Radiologists (ESR) members, some participants (58.1%) stated that the "radiologists' job opportunities and workload" were going to increase while others (41.9%) stated that they would decrease(27). "Breast, oncologic, thoracic, and neuroimaging were the most likely to be strongly impacted by AI", as well as imaging modalities such as "mammography, CT, and MRI"(27). The majority (61.5%) believed that AI would change the "Radiologists-patient relationship," whereby the majority were positive that it would make the relationship more interactive(25). There was a 100% agreement that radiologists must play a

leading role in the creation and validation of AI tools in DR(27).

In conclusion, most studies point towards a positive technologically driven practice of DR rather than the extinction of radiologists. Gloomy predictions of AI on the radiologists' career were largely unfounded and have had a negative effect on 'would be radiologists," which is likely to worsen the deficit of radiologists that already exists(28). Many of such predictors of doom have since revoked their thinking(29). The danger to radiologists is overblown, and the change in the practice of DR will most likely change in a direction friendly to radiologists(29). Concerning the question " will AI replace radiologists?" the right answer should be "radiologists who use AI will replace radiologists who don't"(29).

2.2 PROBLEM STATEMENT

Experts in AI, including Geoffrey Hinton, who has been christened the 'grandmaster of DL,' have warned that radiologists may soon be rendered obsolete (9). According to Chockley K and Emanuel E, ML is the most existential threat to DR as a speciality (14). These strong sentiments are informed by the phenomenal advances in AI/ML.

However, The CAR whitepaper on AI calls the imminent demise of Radiologists owing to AI/ML a misconception. It further states that "the complex work performed by radiologists includes many other tasks that require common sense and problem-solving skills that cannot be achieved through AI; these include consultation, protocoling, review of previous examinations, quality control assessment, identification/dismissal of image artefacts, cancer staging, disease monitoring, interventional radiology procedures for diagnostic or therapeutic purpose, reporting, management guidance, expertise in multidisciplinary discussions, patient reassurance, education and development of departmental policy" (2). The whitepaper asserts that image interpretation can necessitate the integration of knowledge from varying disciplines (for instance, anatomy and physiology) and clinical specialities such as surgery or pathology, a function that a computer algorithm would be incapacitated in doing(2).

However, this whitepaper also warns that the radiologists ought to be ready for computerization of

image interpretation functions, especially two-dimensional modalities, and recommends that "residency programs should integrate health informatics, statistics, and computer science courses in AI in their curriculum" (2). Liew C calls AI a double-edged sword, which, if properly wielded, will propel DR into the next century while also warning radiologists against a 'wait-and-see' approach (9). He goes ahead to recommend a concession in the tug-of-war between the noble speciality of DR that has always endeavoured to utilize the best technology for the benefit of patients, and a multi-billion dollar imaging industry dominated by giant multinational corporations such as General Electric, Siemens, and Phillips (9).

In Kenya, the use of AI in daily clinical work is almost non-existent. Its use is almost limited to big private hospitals located in Nairobi, with utility mostly restricted to speech recognition and Computer-Assisted Detection (CAD) tools. This could be attributed to the low socioeconomic status in Kenya since the integration of AI into daily clinical use requires investment in computerized diagnostic equipment. Human resource scarcity could also be another factor considering that most public hospitals in Kenya do not have attending radiologists.

Currently, the use of AI tools in DR at KNH is non-existent, even though the hospital has the capacity for integration of the most commonly used AI tools, namely CAD in breast/ colon imaging and speech recognition tools. Interpretation of images at KNH, even in mammography, is done by the radiologist unassisted. This can be largely attributed to the lack of PACS at KNH. PACS software usually enhances radiologic collaborations, workflow, visualization, and overall efficiency. In simpler terms, a PACS system provides a platform for the integration of AI. There is a current focus on the creation of PACS that are able to run multiple AI applications. Once images are loaded into PACS, AI tools will then be able to rapidly sift through the images and carry out complex quantitative analysis and detect pathology. This will reduce the radiologist's workload and also help to reduce radiological errors. To be able to enjoy the benefits of AI in radiology, KNH will undoubtedly need to invest in PACS. This study aims to assess the understanding of basic concepts and terminology of AI and its clinical applications in the field of DR among the radiologists and radiology residents at UON/KNH and other facilities in Kenya. It will further assess the knowledge-seeking behaviour on developments in AI/current information on the topic.

Perceptions and attitudes of the respondents towards the encroachment of AI into the field of DR will also be evaluated.

2.3 JUSTIFICATION AND SIGNIFICANCE

Since 1895 when Wilhelm Roentgen discovered 'x-rays,' nothing has come even remotely close to the disruption potential posed by AI(9). Recent advances in AI, including the onset of high-functioning ANN and powerful computed capacities, when applied to current radiological digital data, have led to the creation of AI tools that will potentially revolutionize the practice of DR(30). Some authorities predict that these advances may render radiologists obsolete in a short duration of time, whereas others are more positive, predicting a "subtle change by the end of which radiologists are projected to take a bigger and more critical role in the health industry"(30).

In spite of the above seismic changes anticipated in the field of DR, there are scanty published studies on this topic in Africa and Kenya. Furthermore, only a few studies are available globally on the same. This study will, therefore, add welcome data to the meagre pool that is currently available on this topic. As it stands, there are also no formal educational discussions or activities on the field of AI at the UON/KNH DDIRM. The current UON DDIRM curriculum does not offer health informatics and computer science courses in AI. According to Recht M and Bryan RN, radiologists with AI training in DR will be preferable during job interviews in the near future(31). This study is therefore meant to 'break the ice' and create interest in the subject of AI in DR, and hopefully trigger educational activities in AI/ML in the DDIRM at UON/KNH and other facilities in Kenya. This could be more specific in the form of lectures, journal reviews, and group discussions.

2.4 RESEARCH QUESTION

What is the knowledge, attitude, and practice of radiologists and radiology residents in Kenya on AI and its role in Radiology?

2.5 OBJECTIVES

2.5.1 Primary objective

1. To assess the knowledge, attitude, and practice of radiologists and radiology residents on AI and its role in DR in the DDIRM at UON/ KNH and other facilities in Kenya

2.5.2 Specific Objectives

1. To assess familiarity with the basic concepts and terminologies on AI
2. To evaluate the awareness of existing AI applications in radiology
3. To assess the utilization of existing AI applications in daily practice
4. To evaluate perception and attitude on AI in radiology
5. To assess the knowledge-seeking behaviour on current information on AI

CHAPTER THREE: METHODOLOGY

3.1 STUDY DESIGN

A cross-sectional descriptive study method was used. The distribution of variables and characteristics of the study subjects with regards to the topic of study was then adequately described.

3.2 STUDY SITE

Study subjects were primarily recruited from the DDIRM in the UON/KNH. Participation was also extended to radiologists and radiology residents from other Kenyan facilities via the KAR WhatsApp platform. The DDIRM at UON was started in 1974/1975. It is the oldest DIRM residency program in the country. Its first intake of radiology residents occurred in 1977. Since commencement, the program has successfully trained approximately 185 radiologists from within the African continent. In addition, the department operates a radiography and ultrasonography diagnostic centre. The department is also a renowned centre of research into the various radiological disciplines. Currently, the department has nine attending/ faculty consultant radiologists and 56 DIRM residents.

KNH is the oldest hospital in Kenya, founded in 1901. It is also the largest referral hospital in the country and the teaching hospital for UON. The DDIRM at KNH is one of the most equipped in the country. It possesses a 3T MRI machine, multi-slice CT machines, ultrasound units, digital image intensifiers, mammography units, and digital X-ray machines, among others. It currently has 17 attending consultant radiologists. This department is also a renowned centre of research.

3.3. STUDY POPULATION

Persons included in the study were all the attending/faculty consultant radiologists and all radiology residents in Kenya. These are the clinical decision-makers in the radiology patient workflow and will, therefore, be impacted by the changes AI/ML will have in the practice of DR.

3.4. SAMPLING AND RECRUITMENT

Total sampling technique, which is a type of non-probability sampling technique, was used. This means that all the attending/faculty consultant radiologists and all DIRM residents at UON/KNH were recruited. The participation of all radiologists and radiology residents in other facilities in Kenya was also sought. The characteristic of interest was formal training in Diagnostic Imaging and Radiation Medicine, whether completed or ongoing. Given the challenges of recruiting radiologists and residents both from within UON/KNH and other facilities in Kenya due to the prevailing Covid-19 pandemic, an online WhatsApp group was used for total sampling and recruitment.

Total sampling was advantageous in that it provided deep insights into the phenomenon of this study. In addition, it reduced the risk of missing potential insight from eligible persons who would have been excluded from the study. Lastly, this sampling technique eradicated selection bias and helped to recruit a decent study population.

3.5. STUDY TOOLS

A web-based anonymous questionnaire created on questionpro was used (https://www.questionpro.com/a/editSurvey.do?surveyID=8100744). It was then distributed to the radiologists and residents via WhatsApp group. No identifying information was requested. This anonymity of the online questionnaire encouraged honest feedback since it reduced the fear of embarrassment. On the flip side, it necessitated more follow up of the potential respondents to help improve the response rate. Online questionnaires are in general associated with a relatively low response rate. The study was piloted using one consultant radiologist and one radiology resident. Any necessary changes were made to the questionnaire before dissemination for the actual study.

The questionnaire contained 18 questions. A total of 13 similar questions were asked to all the respondents. Seventeen questions were Multiple Choice Type, and one question was open-ended.

3.6. DATA COLLECTION PROCEDURES

A web-based questionnaire was distributed via WhatsApp as a non-serialized link. Constant reminders were sent to the study subjects periodically. The study participation was closed after two months. This allowed residents time to participate in the study since they were undertaking their exams during the study period. Besides, the study duration provided sufficient time to realize a good response rate. Informed consent was sought at the beginning of the questionnaire form.

3.7. DATA MANAGEMENT AND ANALYSIS

3.7.1 Data handling

All the data collected was automatically entered into a spreadsheet, after which it was exported as an Excel document for analysis. The web-based platform used guaranteed anonymity. It was impossible to trace the questionnaire back to the respondent (the respondent data was encoded in a manner that could not subsequently be decoded).

3.7.2 Data analysis

Data was analyzed using the SPSS version 26 software.

Categorical variables were calculated by the use of percentages and frequencies. Pearson's Chi-square test was used to compare categorical data. The Mann-Whitney U test was also utilized to compare groups. However, due to the similarity of findings from the Mann-Whitney U test and Chi-square test, only the chi-square test's findings were incorporated in the tables.

3.8. ETHICAL CONSIDERATIONS

Informed consent was obtained from participants at the beginning of the web-based questionnaire (APPENDIX B). There was a "next" prompt button below the informed consent form. The clicking of this button by the participant was a confirmation of consent. Participant confidentiality was also maintained through anonymity. No identifying personal data was taken. Secondly, the respondents' data, once received, was encoded in a way that couldn't be decoded or traced back to them. The data collected was only accessed by the primary investigator and supervisors. Research ethics approval was obtained from UON/KNH ERC.

3.9. QUALITY CONTROL MEASURES

The questionnaire was standardized by mostly using Multiple Choice type questions. Questions were short, clear, and orderly. Any questions asked sought to address the aim of the research. A pilot study was conducted by engaging one consultant radiologist and one radiology resident.

3.10. DISSEMINATION PLAN

The results of this study will be published in peer-reviewed journals and presented at scientific conferences. Feedback to the UON/KNH and the participants was provided. The results of this study will arouse radiologists to play an active role to be better prepared as AI/ML is gradually incorporated into the daily practice of radiology.

3.11. STUDY LIMITATIONS

There were few previous studies on the topic of AI/ML in Kenya and Africa. This presented an opportunity for this study to be, to my best knowledge, one of the pioneers for research on this topic in Kenya and Africa.

CHAPTER FOUR: RESULTS

A total of 111 radiologists and radiology residents were recruited into the study. Of these, 57 were radiologists, while 54 were radiology residents.

4.1 Socio-Demographic Characteristics

A presentation of the socio-demographic characteristics of the respondents is presented in table 1.

Table 1: Socio-Demographic Characteristics of Radiologists and Radiologist Residents

Variable		Frequency	Percent (%)
Category of clinician	Consultant	57	51.4
	Registrar	54	48.6
	Total	111	100
Category of consultancy	General Radiologists	46	80.7
	Specialized Radiologists	11	19.3
	Total	57	100
Years of experience	Less than 2 Years	14	24.6
	3-5 Years	13	22.8
	6-10 Years	13	22.8
	11-15 Years	9	15.8
	Above 15 Years	8	14
	Total	57	100
Place of employment	Radiologist-County Hospital	18	31.6
	Radiologist-Public university/National Teaching and Referral Hospital	19	33.3
	Radiologist- Private University/Private Teaching Hospital	4	7
	Radiologist-Private Hospital /Private Practice	13	22.8
	Other	3	5.3
	Total	57	100
Year of study for resident/registrar	First Year	13	24.1
	Second Year	11	20.4
	Third Year	17	31.5
	Fourth	13	24.1
	Total	54	100
University studying in	Public University	48	88.9
	Private University	6	11.1
	Total	54	100
Gender	Male	45	40.5
	Female	66	59.5
	Total	111	100

A total of 111 individual responses were collected, representing a response rate of 55.7%) (111/199) for radiologists and radiology residents who are members of the KAR WhatsApp group. There were 43 men (40.5%) and 66 women (59.6%). Consultant radiologists represented 57 respondents (51.4% of the population) while radiology residents accounted for 54 respondents (48.6%). Of the consultant radiologists, 46 (80.7%) were general radiologists while the remaining were sub-specialized radiologists (11/57, 19.3%). A breakdown of the consultant radiologists in terms of years of experience revealed that the majority (70.2%, 40/57) had worked for 10 years and below, the remaining 29.2% (17/57) had worked for more than 10 years. Public hospital radiologists were the largest group to respond, 37 in total (64.9%), and private practice radiologists were the minority, with 20(35.1%). Senior radiology residents constituted the majority of residents (30/57, 55.6%), followed by junior residents at 24(44.4%). Nearly all the residents were from a public university (48/54, 88.9%), with only six residents from private universities (11.1%).

4.2 Familiarity with the Basic AI Concepts and Terminologies

Knowledge of Radiologist and Radiology registrars on different aspects of AI was examined as presented in table 2 and 3.

Table 2: Knowledge of Radiologists and Radiology Residents on Various AI Concepts

Variable		Frequency	Per cent
Read an article/watched/attended AI presentation	Yes	73	65.8
	No	38	34.2
	Total	111	100
Knowledgeable about Machine learning (ML) concept	Yes	49	44.1
	No	62	55.9
	Total	111	100
Knowledgeable about Artificial neural networks (ANN) concept	Yes	23	20.7
	No	88	79.3
	Total	111	100
Knowledgeable about Deep learning (DL) concept	Yes	24	21.6
	No	87	78.4
	Total	111	100

Almost three-quarters of the participants indicated to have read/watched/attended an AI presentation (n = 73, 65.8%). Nearly a half of the participants (n= 49, 44.1%) were knowledgeable on machine learning concept. Less than a fifth of the participants were knowledgeable about

artificial neural networks (n = 23, 20.7%) and about Deep learning (n= 24, 21.6%).

Table 3: Knowledge on Basic AI Concepts Based on Category of Participants (Consultants vs Residents)

Variable			Category of clinician		Total	p-value
			Consultant	Resident		
Read an article or watched/attended a presentation on Artificial intelligence (AI)	Yes	N	40(70.2%)	33(61.1%)	73(65.8%)	0.314
	No	N	17(29.8%)	21(38.9%)	38(34.2%)	
	Total	N	57(100%)	54(100%)	111(100%)	
Knowledgeable about Machine learning (ML) concept	Yes	N	21(36.8%)	28(51.9%)	49(44.1%)	0.024
	No	N	36(63.2%)	26(48.1%)	62(55.9%)	
	Total	N	57(100%)	54(100%)	111(100%)	
Knowledgeable about Artificial neural networks (ANN) concept	Yes	N	7(12.3%)	16(29.6%)	23(20.7%)	0.111
	No	N	50(87.7%)	38(70.4%)	88(79.3%)	
	Total	N	57(100%)	54(100%)	111(100%)	
Knowledgeable about Deep learning (DL) concept	Yes	N	9(15.8%)	1(27.8%)5	24(21.6%)	0.125
	No	N	48(84.2%)	39(72.2%)	87(78.4%)	
	Total	N	57(100%)	54(100%)	111(100%)	

A majority of consultant radiologists (n =50, 70.2%) and radiology residents (n=33, 61.1%) had read an AI article/ watched a presentation/ attended a presentation on AI. A minority of consultant radiologists are knowledgeable about machine learning (n=21, 36.8%) while majority of residents (n=28, 51.9%, p= 0.024)) are knowledgeable about machine learning. Less than 30% of both consultant radiologists (n=7, 12.3%; n=9, 15.8%) and residents (n=23, 20.7%; n= 24, 21.6%) were knowledgeable about Artificial neural networks (ANN) and Deep learning (DL) concepts respectively. Of significance was the realization that residents were still more knowledgeable than consultant radiologists in ANN and DL. In terms of p-values, only the variable ‘knowledgeable about ML’ was dependent on category of participants ($p<0.05$).

4.3 Awareness on Existing AI Applications in Radiology

Table 4: Awareness of Existing AI Applications in Radiology

Applications	N	Percent
Detection	68	37.40%
Segmentation	22	12.10%
Speech recognition	17	9.30%
Registration	25	13.70%
Workflow management	23	12.60%
Protocol optimization	19	10.40%
Others	8	4.40%
Total	**182**	**100.00%**
Mentions for Three Applications		
First Application	82	73.87%
Second Application	69	62.16%
Third Application	55	49.55%

Analysis of the responses revealed that only 183 responses, as opposed to 333, were realized from the study, with 82, 69 and 55 responses for the first application, second application and third application, respectively. Findings of the multiple response questions revealed that AI application in detection was the most common response (n= 68, 37.4%). Other AI applications in radiology represented less than 20% of the total responses and include: segmentation (n=22, 12.1%), speech recognition (n= 17, 9.3%), registration (n=25, 13.7%), workflow management (n=23, 12.6%), protocol optimization (n=19, 10.4%) and others (n=8, 4.4%).

Table 5: Potential Areas of AI Applications Based on Consultant Radiologists and Radiology Residents Views

Artificial Intelligence Applications		Category of clinician		Total
		Consultant	Resident	
Detection	N	38(66.7%)	33(61.1%)	71(63.9%)
Segmentation	N	12(21.1%)	13(24.1%)	25(22.5%)
Speech recognition	N	7(12.3%)	10(18.5%)	17(15.3%)
Registration	N	17(29.8%)	9(16.7%)	26(23.4%)
Workflow management	N	13(22.8%)	10(18.5%)	23(20.7%)
Protocol optimization	N	10(17.5%)	9(16.7%)	19(17.1)
Others	N	3(2.7%)	5(9.3%)	8(7.2%)
Total	N	57(51.4%)	54(48.6%)	111(100%)

Further analysis showed that for both consultant radiologist (n =38, 66.7%) and resident (n= 33, 61.1%), AI application in detection had the highest mention. However, there were differences in the second and third highest mentions for consultant and residents in regards to AI application in radiology. The former mentioned registration (n= 17, 29.8%) and workflow management (n=13, 22.8%) respectively while the latter mentioned segmentation (n=13, 24.1%) and speech recognition (n=10, 18.5%) and workflow management (n=10, 18.5%).

4.4 Utilization of Existing AI Applications in Radiology

Table 6: Utilization of AI in Daily Work

AI/ML Utilization in daily work	Frequency	Per cent
	14	12.6
No	97	87.4
Total	111	100
Utilization based on Consultants Place of Work		
Radiologist County Hospital	2	22.2
Radiologist Public University/National Teaching and Referral Hospital	3	33.3
Radiologist Private Hospital	4	44.5
Total	9	100

A considerable majority of consultant radiologists and radiology residents had not used any AI/ML application in their work (n=97, 87.4%). This trend was also confirmed from cross-tabulation based on the category of radiologists, as supported in table 7. Of the consultants who answered in the affirmative, most of them (44.5%) were working in the private sector, with the remaining working in national teaching and referral hospital (33.3%) and county hospital (22.2%).

Table 7: Daily Work Utilization of AI-based on Consultant Radiologists and Radiology Residents Views

AI/ML application in daily work		**Category of clinician**		**Total**	**p-value**
		Consultant	**Resident**		
Yes	N	9(15.8%)	5(9.3%)	14(12.6%)	
No	N	48(84.2%)	49(90.7%)	97(87.4%)	0.31
Total	N	57(100%)	54(100%)	111(100%)	

Table 8: Perception and Attitude of AI in Radiology

Variable		Frequency	Per cent
AI/ML influence on Radiologist job in the next 10-20 years?	Have Little or No Influence	29	26.1
	Drastically Change My Job	76	68.5
	Make my Job Obsolete	6	5.4
	Total	111	100
General view of AI/ML applications in the field of radiology?	Good for My Work	17	15.3
	Bad for My Work	3	2.7
	Both Good and Bad for My Work	49	44.1
	Makes Radiology more Exciting for Me	38	34.2
	There is Nothing I Can Do About It	4	3.6
	Total	111	100

Approximately two-thirds of the participants felt that AI/ML would drastically change the job of radiologists (n=76, 68.5%), while around a quarter of the participants were of the view that AI/ML will have little or no influence on the radiologists' job. Only 6 participants (5.4%) considered AI/ML as a threat to making the radiologists' job obsolete. Nearly half of the participants felt that AI/ML application has both positive and negative effect on radiology work (n= 49, 44.1%) while 17(15.3%) considered IA/ML as good for radiology work, and slightly more than a third of the participants view AI/ML as making radiology exciting (n=38, 34.2%). Three participants (2.7%) considered AI/ML as bad for their work, while 4 participants (3.6%) felt helpless about the impact of AI/ML in radiology. Further analysis of perception and attitude towards AI according to consultant radiologists and radiology residents revealed similar results, with the majority of both consultants (n= 38, 66.7%) and residents (n= 38, 70.40%) believing that AI/ML will drastically change their job while most of the consultants (n=23, 40.4%) and residents (n=26, 48.1%) view AI applications as both good and bad for their work. Perception and attitude of AI in Radiology according to the category of participants did not reveal any dependency (p = 0.485, 0.176).

Table 9: Perception and Attitude of AI in Radiology based on Category of Participant (Consultants vs Residents)

Variable			Category of clinician		Total	p-value
			Consultant	Resident		
AI/ML influence on	Have Little or No Influence	N	17(29.8%)	12(22.2%)	29(26.1%)	0.485
	Drastically Change My Job	N	38(66.7%)	38(70.40%)	76(68.5%)	
	Make my Job Obsolete	N	2(3.5%)	4(7.4%)	6(5.4%)	

Radiologist job in the next 10-20 years?	Total	N	57(100%)	54(100%)	111(100%)	
General view of AI/ML applications in the field of radiology?	Good for My Work	N	11(19.3%)	6(11.1%)	17(15.3%)	0.176
	Bad for My Work	N	2(3.5%)	1(1.9%)	3(2.7%)	
	Both Good and Bad for My Work	N	23(40.4%)	26(48.1%)	49(44.1%)	
	Makes Radiology more Exciting for Me	N	21(36.8%)	17(31.5%)	38(34.2%)	
	There is Nothing I Can Do About It	N	0(0%)	4(7.4%)	4(3.6%)	
	Total	N	57(100%)	54(100%)	111(100%)	

Table 10: Perception of AI/ML on Career Prospects as Radiologists

Potential of current knowledge of AI/ML applications on the practice of Radiology effects on the decision to pursue career as radiologist	**Frequency**	**Percent**
No	68	61.3
Yes	9	8.1
Maybe	34	30.6
Total	111	100

Around two-thirds of the participants felt that the current knowledge on AI applications does not affect their decision to pursue a career as a radiologist (n=68, 61.3%) as opposed to 34 participants who felt that maybe their current knowledge on AI/ML would have affected their decision to pursue a career as a radiologist. Only 9 participants felt that their current knowledge of AI/ML application would have affected their decision to pursue a career as a radiologist.

Table 11: Perception on willingness to contribute to the integration of AI application in Radiology Practice.

Willingness to help make or train an ML algorithm so it can do some of the tasks that a radiologist does	**Frequency**	**Per cent**
Yes	75	67.6
No	36	32.4
Total	111	100

Results in Table 11 indicates that slightly more than two-thirds of the participants indicated their

willingness to help make or train an ML algorithm so that it can do some of the tasks that a radiologist does (n= 75, 67.6%).

Table 12: Perception of AI/ML on Career Prospects as Radiologists based on Category of Participant (Consultants vs Residents)

Potential of current knowledge of AI/ML applications on the decision to pursue a career as a radiologist		Category of clinician			
		Consultant	Resident	Total	p-value
No	N	39(68.4%)	29(53.7%)	68(61.3%)	0.278
Yes	N	4(7%)	5(9.3%)	9(8.1%)	
Maybe	N	14(24.6%)	20(37%)	34(30.6%)	
Total	N	57(100%)	54(100%)	111(100%)	

Less than 10% of radiologists (n=4, 7%) and residents (n=5, 9.3%) did not consider their current knowledge on AI as having the potential to change their career decision to pursue radiology. Slightly more than a third of residents felt that their current knowledge of AI applications could alter their career decision (n= 20, 37%), while only 14 radiologists (24.6%) were of similar views. Potential of current knowledge of AI/ML applications on the decision to pursue a career as a radiologist was found to be independent of the category of radiologist (p=0.287).

Table 13: Perception on willingness to contribute to the integration of AI application in Radiology Practice based on Category of Participants (Consultants vs Residents)

Willingness to help make or train an ML algorithm so it can do some of the tasks that a radiologist does		Consultant	Resident		
Yes	N	41(71.9%)	34(63%)	75(67.65)	0.313
No	N	16(28.1%)	20(37%)	36(32.4%)	
Total	N	57(100%)	54(100%)	111(100%)	

Further analysis on knowledge seeking behaviour on current information revealed that the majority of consultant radiologists (n= 41, 71%) and radiology residents (n= 34, 63%) were willing to help make or train an ML algorithm so it can do some of the tasks that a radiologist does. Perception on willingness to contribute to the integration of AI application in Radiology Practice was shown to be independent of the category of radiologist (p = 0.313).

4.5 Knowledge Seeking Behavior on AI

Table 14: Knowledge-Seeking Behavior on AI Current Information

Last time you read a scientific article on the topic of AI/ML in radiology	Frequency	Per cent
Never Read One	40	36
Less than 6 Months ago	34	30.6
6 to 12 Months Ago	22	19.8
More than 1 Year Ago	15	13.5
Total	111	100

Results in table 14 on the readership of scientific article showed that forty participants (36%) have never read an article on AI/ML while around a third of the participants (n=34, 30.6%) have read an article less than six months ago. Twenty-two participants (19.8%) were found to have read an AI article 6-12 months ago as opposed to the remaining 15 participants (13.5%) that read an article more than a year ago.

Table 15: Knowledge-Seeking Behavior on AI Current Information according to Different Cadre of Radiologist

Last time you read a scientific article on the topic of AI/ML in radiology		Category of clinician			
		Consultant	Resident	Total	p-value
Never Read One	N	12(21.1%)	28(51.9%)	40(36%)	0.003
Less than Months ago	N	24(42.1%)	10(18.5%)	34(30.6%)	
6 to 12 Months Ago	N	14(24.6%)	8(14.8%)	22(19.8%)	
More than 1 Year Ago	N	7(12.3%)	8(7.2%)	1(13.5%)5	
Total	N	57(100%)	54(100%)	111(100%)	

On readership of AI scientific article, majority of radiology residents (n= 28, 51.9%) had never read an article on AI/ML, which demonstrates that only 48.1% of residents have read an AI/ML article. The majority of consultant radiologists (n = 45, 78.9%) have read a scientific article on AI. Both consultant radiologists (n =39, 68.4%) and residents (n=28, 51.9%) felt that their current knowledge of AI applications does not affect their decision to pursue a career as a radiologist. Readership of an article on AI in radiology was demonstrated to be dependent on the category of radiologist (p= 0.003).

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 DISCUSSION

A total of 111 responses were obtained, with female respondents accounting for the majority of the participants. Radiology practice is largely dominated by general radiologists, contrary to western countries. This is attributed to the nascent stage of radiology practice in African countries as compared to developed countries (32). The workplace setting for the majority of radiologists is in the public sector, also confirmed in a Nigerian study (33). A considerable majority of consultant radiologists had been practising for more than five years. Similar findings were reported in a study conducted among African radiographers(34). Radiology residents largely study in public universities, also reported in a Nigeria study on Radiology residents (35).

The main finding of this study was that majority of participants knew about AI but did not have in-depth knowledge of AI concepts. This was evident by the fact that most of the respondents did not understand the concepts and terminologies used in AI. This suggests that AI has not has been given the attention it deserves amongst consultant radiologist and residents. The result of limited knowledge of AI is consistent with findings from a related study conducted in Ghana (34). Surprisingly, the findings showed that only the majority of residents were knowledgeable on the machine learning concept. This could be linked to interest amongst residents because they feel that AI applications are going to play a significant role in their future profession (36). Limited knowledge on all the AI concepts tested amongst consultant radiologists could be attributed to low prioritization of the need to acquire theoretical knowledge about AI due to high workload (32) as well as due to limited supportive infrastructure in their stations of work (32).

Different Applications of AI in radiology were reported, with the application on detection attracting the highest number of responses. This aligns with the results reported in previous findings(16,36), where the use of AI in detection was ranked the first for AI applications in Radiology. This is informed by the need to have effective detection systems with high sensitivity and specificity (37). Surprisingly in terms of other AI applications utilization in radiology, little difference was observed. The only difference was in the application of AI in registration as reported more by consultants as opposed to registrars. This is attributed to the reason that the preprocessing step of registration may involve complex tissue deformations that may prove challenging in daily work experience (16).

The utilization of AI applications in radiology in the participants' daily work is still low. The low usage of AI applications in radiologists' daily practice proves that we are still at the dawn of AI (38). This also shows that the local radiology environment is still not friendly for AI applications use like in western countries (33), whereby the workforce fails to see a possible role. Many health institutions in low-income countries such as Kenya lack the necessary physical and digital infrastructures such as advanced imaging equipment, reliable internet connection and PACS in their health care systems, and hence low adoption of AI-based applications in radiology.

This survey reported that participants largely consider AI applications as holding potential on radiology practice but do not view it as a threat to their job. Previous surveys (26,39) have also shown that AI has the potential to change the radiologist's daily workload, though whether such changes will entail more focused or less focused radiologists' role is still a subject of debate (5). The general picture that emerged from the findings is that consultant radiologists and radiology residents viewed AI/ML as most likely to change their work. This indicates optimism about the future of AI in radiology, with less effect on radiologist's satisfaction. Most of the consultant radiologists and radiology residents felt that AI applications in the field of radiology are both good and bad. This could imply that the current knowledge about the potential effect of radiology at both theoretical and practical level is speculative. A good proportion of consultant radiologists and residents also consider AI application as making radiology more exciting. This situation could be related to the expectation that AI application will revolutionize the radiology profession by freeing radiologists from tedious or difficult tasks (such as segmentation and quantification), focusing more on cognitive tasks for improved quality in the radiology practise (16,32,34).

The sentiments of consultant radiologists and radiology residents on their career prospects were largely optimistic. The findings revealed that the majority of the participants could not change their decision to pursue a career as a radiologist because of their current knowledge of AI/ML applications in the practice of Radiology. This suggests that to the consultants and residents, AI does not have a negative influence on their decision about radiology as a career. This contradicts the findings by Dahmash et al. (40) that showed that AI has a negative influence on the decisions of medical students to pursue careers as radiologists. A major reason for this difference could be because consultant radiologists and residents in the current study view AI applications in radiology as a friend and not a foe as far as their careers are concerned. This also aligns with previous studies

that have documented that radiologists and registrars do not consider AI applications as a threat to their profession(14,41–43).

Positive and favourable perception was revealed by the majority of participants in regard to their willingness to contribute to the integration of AI applications in the radiology practice**.** This possibly indicates the readiness amongst the consultants and residents to embrace AI applications in their practice. This supports the results by Abuzaid et al. (44) that demonstrated the willingness of most radiologists to contribute to the integration of AI into their radiology practice.

Slightly over a third of the participants had never read a scientific article on the topic of AI/ML in radiology, with the majority of these participants being residents. This implies that a good proportion of radiologists have a vague understanding of AI. This situation could be linked to the low exposure to recent scientific articles about this subject since only a few articles have been published in major radiology journals (26). Another possible reason that may account for the lack of readership amongst registrars is the absence of AI-related units in the current residency programs curricula. Interestingly, most of the consultant radiologists had read an AI article on radiology over the past month. A possible explanation for this may be due to motivation to learn new applications/technologies linked to their daily radiology practice (42).

The findings demonstrated that most of the participants felt that AI/ML applications have both positive and negative effect on radiology work as opposed to a third of participants that viewed AI as having the potential to make radiology work more exciting. This highlights that most radiologists and residents still see AI applications as having strengths and opportunities for the radiology practice, as well as weakness and threats for the practice. This point may have been inferred in the fact that very few participants considered AI/ML as either good or bad for radiology work in the study. This is in support of other studies that have shown that AI application in interventional radiology is a strength as well as an opportunity, while on the other hand, the promise of AI-augmented radiology could end up pushing radiologists further from practice (29,42,45,46). However, given that those who viewed AI as good for radiology and likely to make radiology exciting constituted nearly half (49.5%), it can be argued that most of the radiologists and radiology residents are inclined to view AI applications in DR favourably as a strength and opportunity. This is in agreement with the study by the European Society of Radiology (ESR) that showed that

radiologists believe that AI applications are more of a strength and opportunity to their practice (27).

To my best knowledge, this is one of the pioneer studies on the topic of AI/ML among this study group in Africa. However, there are studies that have examined the perspective of radiographers on the integration of AI in medical imaging practice in Africa (7,34)

5.2 CONCLUSION

Aside from the majority who are knowledgeable about AI, only very few have sufficient in-depth knowledge about AI and its related concepts. AI algorithms in radiology have various applications in the clinical radiology workflow, wherein detection role is considered as one of the major application. The utilization of AI applications in Radiology is still very low.

Consultant radiologists and radiology residents in Kenya possess a favourable attitude towards the adoption of AI in the radiology practice. Most radiologists believe that their working activity will benefit from AI, as shown by their willingness to train AI/ML algorithms to undertake some radiology tasks. Hence it can be concluded that consultant radiologists and radiology residents have an open attitude towards AI applications.

Consultant radiologists are more proactive in seeking information on AI-related concepts than the residents, as evidenced by their readership habits on AI articles. Fear of replacement and career doubt because of the potential ramifications of AI applications on the radiology practice is generally low amongst consultant radiologists and radiology residents.

5.3 RECOMMENDATION

The study recommends that the subject of informatics with emphasis on AI/ML applications in DR should be incorporated in the radiology residency curriculum. Continuous medical education of radiologists on AI and its applications should also be carried out on a regular basis. The study also recommends that sensitization of radiologists and residents should put an emphasis on the proven benefits of AI applications and their potential to impact the radiology practice positively. Based on the acceptance that AI will drastically change radiology work practice, the study recommends that AI applications be introduced quite gently in ways that minimize the creation of risks to workflow speed.

On practice, the study recommends that strategies to promote the use of AI applications should encourage the adoption of simple and helpful applications in AI first such as speech recognition. Their usage is more likely to advance the adoption of AI application in other areas of the radiology workflow.

TIME FRAME

Activities	**2020**												**2021**										
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**			
Proposal development																							
Departmental clearance																							
RC clearance																							
Ethics Approval																							
Data collection																							
Data entry and analysis																							
Manuscript Preparation																							
Submission of Final dissertation																							

BUDGET

Item	**Total amount**
Data collection and analysis	40,000
Report writing	10,000
Stationery	10,000
Miscellaneous	5,000
Total	**65,000**

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APPENDICES

Appendices I: QUESTIONNAIRE

1) Gender a) Male b) Female
2) Category of Clinician a) Consultant b) Registrar/Resident
3) What category of consultant do you fall under if the answer in question 2 above is consultant?

a) General Radiologist b) Specialized Radiologist

4) How many years of practice do you have as a consultant radiologist?

a) Less than 2 years b) 3-5 Years c) 6-10 Years d) 11-15 Years e) Above 15 years

5) As a consultant, how would you describe your place of employment?

a) Radiologist- County hospital

b) Radiologist-Public university/National teaching and referral hospital

c) Radiologist- Private university/Private teaching hospital

d) Radiologist-Private hospital /private practice

e) Other

6) If the answer in Question 2 above is registrar, which year of study are you currently in?

a) First year

b) Second Year

c) Third Year

d) Fourth Year

7) As a registrar/resident, which university are you studying in?

a) Public university b) Private University

8) Have you heard of the artificial intelligence (AI) concept?

a) No b) Yes

9) Are you familiar with Machine Learning (ML) concept?

a) No b) Yes c) Yes and trained

10) Are you familiar with artificial neural networks (ANN) concept?

a) No b) Yes c) Yes and trained

11) Are you familiar with Deep Learning (DL) concept?

a) No b) Yes c) Yes and trained

12) Do you use any AI/ML application in your daily radiology work?

a) No b) Yes

13) List 3 applications of AI/ ML in radiology that you are aware of.

1._____

2._____

3._____

14) How will AI/ML influence your job in the next 10-20 years?
    a) No to little influence
    b) The job will be drastically different
    c) The job will be obsolete

15) What is your general view of AI/ML in the field of radiology?

    a) Good for my work
    b) Bad for my work
    c) Both good and bad for my work
    d) Makes radiology more exciting for me
    e) There is nothing I can do about it

16) Would you be willing to help make or train an ML algorithm so it can do some of the tasks that a radiologist does?
    a) No b) Yes

17) When did you last read a scientific article on the topic of AI/ML in radiology?
    a) Never read one
    b) More than 1 year ago
    c) 6 to 12 months ago
    d) 1 to 6 months ago

18) Would your current knowledge of the potential effects of AI/ML on the practice of Radiology have changed your decision to pursue a career as a radiologist?
    a) No b) Yes c) Maybe

Appendices II: INFORMED CONSENT FORM FOR ONLINE SURVEY

You are invited to participate in my survey **[Knowledge, attitude, and practice of radiologists and radiology residents on the role of artificial intelligence in diagnostic radiology in Kenya].** It will take approximately 5 minutes to complete the questionnaire. Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important for us to learn your opinions. Your survey responses will be strictly confidential, and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures, you may contact Dr. Edward Mwaniki at +254734133108 or by email: edwardmwaniki7@yahoo.com. Thank you very much for your time and support.