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Research Article

# Singapore radiographers' perceptions and expectations of artificial intelligence - A qualitative study

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## ABSTRACT

**Introduction:** With the emergence of artificial intelligence (AI) in medical imaging, radiographers are likely to be at the forefront of this technological advancement. Studies have therefore been conducted recently to understand radiographers' opinions on AI adoption. This study extends that work by using a qualitative approach to further explore radiographers' knowledge, perceptions, and expectations of AI.

**Method:** Six online focus groups were conducted with 22 radiographers from the three public healthcare clusters in Singapore. They were purposively sampled, and participants were recruited from a broad demographic background with varying years of working experience and designations. The focus group sessions were transcribed verbatim and thematic analysis was performed on their responses.

**Results:** Participants demonstrated limited knowledge of AI. Their perceptions of AI were mixed, recognising its benefits in increasing efficiency and improving patient care, but also aware of its limitations in accuracy and bias. On how patients may perceive AI, participants felt that patients would accept AI if they felt it improves their care but may reject it once they lose trust in it. Expectations wise, participants envisioned several applications in pre-, peri–, and post-procedural workflows including order vetting, patient positioning, language translation, and artefact removal. On radiographers' role and career opportunities, some participants see an opportunity for radiographers to specialise in AI, becoming involved in algorithm development and its clinical implementation.

**Discussion:** Our findings suggest that widespread implementation of AI would require limited knowledge amongst radiographers and current AI limitations to be addressed. While radiographers are positively anticipating the integration of AI into their practices, they should also become actively involved in the development of AI tools such that those they envisioned. This would help align optimal use of AI tools and radiographer role changes. Patients' acceptance and reactions to AI also warrant further research.

## RÉSUMÉ

**Introduction:** Avec l'émergence de l'intelligence artificielle (IA) en imagerie médicale, les radiographes sont susceptibles d'être à l'avant-garde de cette avancée technologique. Des études ont donc été menées récemment pour comprendre les opinions des radiographes sur l'adoption de l'IA. Cette étude prolonge ce travail en utilisant une approche qualitative pour explorer davantage les connaissances, les perceptions et les attentes des radiographes en matière d'IA.

**Méthodologie:** Six groupes de discussion en ligne ont été organisés avec 22 radiographes provenant des trois groupes de soins de santé publics de Singapour. L'échantillon a été choisi de manière sélective, et les participants ont été recrutés dans un large éventail démographique, avec des années d'expérience professionnelle et des désignations différentes. Les sessions des groupes de discussion ont été transcrites textuellement et une analyse thématique a été effectuée sur leurs réponses.

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**Résultats:** Les participants ont démontré une connaissance limitée de l'IA. Leur perception de l'IA était mitigée, reconnaissant ses avantages en termes d'efficacité et d'amélioration des soins aux patients, mais également conscients de ses limites en termes de précision et de partialité. En ce qui concerne la perception de l'IA par les patients, les participants ont estimé que les patients accepteraient l'IA s'ils avaient le sentiment qu'elle améliore leurs soins, mais qu'ils la rejetteraient s'ils perdaient confiance. En ce qui concerne les attentes, les participants ont envisagé plusieurs applications dans les flux de travail pré-, péri- et post-procédure, y compris le contrôle des commandes, le positionnement du patient, la traduction de la langue et la suppression des artefacts. En ce qui concerne le rôle des radiographes et les possibilités de carrière, certains participants voient une opportunité pour les radiographes de se spécialiser dans l'IA, en s'impliquant dans le développement d'algorithmes et leur mise en œuvre clinique.

**Discussion:** Nos résultats suggèrent qu'une mise en œuvre généralisée de l'IA nécessiterait d'aborder les connaissances limitées des radiographes et les limitations actuelles de l'IA. Si les radiographes anticipent positivement l'intégration de l'IA dans leurs pratiques, ils devraient également s'impliquer activement dans le développement d'outils d'IA tels que ceux qu'ils envisagent. Cela permettrait d'aligner l'utilisation optimale des outils d'IA et les changements de rôle des radiographes. L'acceptation et les réactions des patients à l'IA méritent également des recherches plus approfondies.

*Keywords:* Artificial intelligence; Radiography; Radiographers; Focus group discussion

## Introduction

Artificial intelligence (AI) widely encompasses the theory and development of computer systems to carry out tasks that typically involve human intelligence, including decision making, visual perception, translation, prediction and speech recognition [1]. Recent advancements in technology have propelled AI developments into various sectors including healthcare [2]. With the goal to replicate or even surpass human intelligence and behaviour, automated systems and processes were designed to demonstrate highly complex performance [3].

AI can potentially provide numerous benefits in radiography, such as reducing menial and repetitive tasks, improving imaging workflow, and providing clinical decision support to radiographers to maximise image acquisition quality and quality of care to patients [1,4]. The European Federation of Radiographer Societies [5] acknowledges the prevalence of AI adoption and its benefits. However, they also recommended more research to be done to explore the knowledge and perception of AI integration amongst radiographers, the impact of AI on patients and how it might impact the radiography profession. There is no doubt that AI will be increasingly integral to radiography, hence giving prominence to research studies on the opinions of radiographers on AI adoption in practice [4].

Recently, studies have been done in several countries to explore the perspectives of radiographers on AI, including Ghana, the United Kingdom (UK) and the United Arab Emirates (UAE). Studies by Abuzaid et al [6]. and Rainey et al [7]. indicated that the perceived knowledge of AI is significantly lacking, with low confidence in the usage of associated terminologies. Nonetheless, the majority of radiographers were receptive to AI adoption and were excited about the benefits that it could bring to practice, including the positive impact it could bring on patients [6,8–11]. At the same time, several concerns were raised, including errors in AI system output, patients' data security and job insecurity [8–10]. On the other hand, other studies reported that AI would not disrupt radiographers' job security but rather act as an assistive tool for them [6,9].

Most of this body of research was conducted using close-ended survey questions. While this was helpful in obtaining a broad cross-sectional view, the opportunity to gain in-depth insights into the responses was limited. Some of the studies had free-response questions, but they reported minimal responses given that respondents were not expected to respond to the open-ended segment of the surveys [7,8]. This study therefore extends this body of work by using focus group discussions to gain further insights into radiographers' perspectives on AI. Furthermore, there are no published studies on this topic in the Asian context. Given the above, this qualitative study aims to further probe the knowledge, perceptions, and expectations of AI in Singapore radiographers.

## Methods

This paper is guided by the Consolidated Criteria for Reporting Qualitative Research (COREQ) [12].

### *Research team and reflexivity*

#### *Personal characteristics*

The research team consisted of two female final year diagnostic radiography undergraduates, two male diagnostic radiography faculty members as their academic supervisors, and one male and three female clinical radiographers working in the public healthcare sector in Singapore as co-investigators. The student researchers had minimal research experience and were undertaking this study as part of their honours thesis. The faculty members have doctorate degrees and research backgrounds in AI and radiography; one of them is a radiographer by training and has prior clinical experience. The research team has a deep interest in AI and its impact on the radiography profession.

#### *Relationship with participants*

The focus group discussions (FGDs) were led by the student researchers, and they were mainly unknown to the participants prior to this study. The participants understood that this study

was conducted as part of their thesis. The participants were recruited by the co-investigators, who were known to the participants as colleagues but were not in a managerial relationship.

### *Ethical considerations*

This study was approved by the Singapore Institute of Technology Institutional Review Board (approval number SIT-IRB-2021088). Upon voluntary recruitment, a participant information sheet was shared with the participants, highlighting the purpose of the study. Participants were also informed of the procedures, and that their participation was entirely voluntary and can be withdrawn at any time, with no consequences to their status or relationship to the university. Written informed consent of their participation including being video recorded was subsequently obtained. Verbal consent of their participation was also included in the video recording. The participants were also briefed on the measures in place to safeguard their privacy and confidentiality of the data they provide. They were also briefed to not disclose any confidential information regarding their institution of practice.

### *Study design*

The study was conceived by the faculty members and designed collaboratively with the student researchers. The student researchers undertook the initial data analysis, with the faculty members and co-investigators involved in interpreting the results.

Phenomenology was implemented for the research study to explore radiographers' perceptions and expectations of AI. It allows a detailed examination of the individual's experiences and how they view the impact of AI on the profession [13].

Participants were recruited from all three public healthcare clusters in Singapore, and from a broad demographic background with varying years of working experience and designations via purposive sampling. Upon indication of interest, direct communication with the prospective participants was established through email or text messaging. They were asked to fill out an online form for their details, demographics, and availability. An information sheet on the scopes of AI in healthcare along with a brief of what the focus group session entails were also shared to better prepare the participants for the FGDs. 22 participants were invited and agreed to participate with no participants dropped out (participant details to come in Results).

Focus group discussions was used as the methodology to facilitate the in-depth exploration of individual beliefs and attitudes with supplementation of their reasoning [14]. In addition, we also wanted group interaction, as it serves as an advantage to encourage contributions of participants' views and perspectives during active discussion [15]. Group norms and the extent of concurrence to a perspective could also be identified in the process [16,17]. For these reasons focus group discussions was used as the methodology instead of surveys or individual interviews.

### *Setting*

The participants were grouped by their institution of practice for the FGDs, with each discussion consisting of three to four participants. We chose the small group setting where most participants were familiar with one another having likely worked together. We felt the small and familiar groups would make the participants more confident and comfortable to give their views in an environment they perceive to be safe to do so. This will help to promote group dynamics and maximise participant discourse during the FGDs [17]. The FGDs were conducted online through the virtual conferencing platform, Zoom, aligned to safe distancing measures enacted due to the COVID-19 pandemic. Participants joined the online FGDs in the comfort of their homes or in a separate area in their workplace. Participants who attended the FGDs at their workplace may have had colleagues nearby, but we were unable to ascertain this. The two student researchers co-facilitated each FGD, and to avoid undue perceived pressure on the participants, the faculty and co-investigators were not present.

### *Data collection*

The FGD questions were cross-checked with two other faculty members to ensure that the questions were well structured, clear, easily understood, and not offensive. Some minor rewording of the questions was made and finalised (see Appendix). The questions were then pilot tested with three participants, with no subsequent changes made to the questions. Only a suggestion to share an information sheet on the scopes of AI were made and heeded.

Six online FGDs were conducted, with no repeat session attended by the same participant. The FGDs were conducted from August to November 2021 and each lasted between 90 and 150 min. The student researchers collected field notes during the discussions to assist in analysis. All FGDs were video recorded on the Zoom platform following participants' consent. The FGDs were held until data saturation was reached to maximise the information gathered on the phenomenon and was used to determine the study's sample size [18,19]. Data saturation was observed, by the research team, to have been reached at the sixth FGD, and the recruitment of study participants was halted then.

All the FGD recordings were professionally transcribed verbatim. The returned transcripts were verified by the researchers for completeness and accuracy. The transcripts were then shared with the participants according to their attended FGD for member check and feedback [20]. Five participants responded to acknowledge the accuracy of their responses with some correction and clarification of the language used. The data was subsequently corrected for grammar.

### *Data analysis*

Thematic analysis was conducted according to Braun & Clarke [21]. Data from all transcripts were first read and coded

Table 1
Participants' Demographics.

| Participant | Age | Gender | Working Experience (Years) | Designation | Healthcare Cluster |
|---|---|---|---|---|---|
| Rg_1 | 27 | Male | 1 | Radiographer | Singhealth |
| Rg_2 | 24 | Female | 1 | Radiographer | NUHS |
| Rg_3 | 28 | Female | 1 | Radiographer | Singhealth |
| Rg_4 | 23 | Female | 1 | Radiographer | Singhealth |
| Rg_5 | 24 | Female | 1 | Radiographer | Singhealth |
| Rg_6 | 34 | Male | 10 | Principal Radiographer | Singhealth |
| Rg_7 | 27 | Male | 3 | Radiographer | Singhealth |
| Rg_8 | 34 | Female | 10 | Senior Radiographer | NHG |
| Rg_9 | 31 | Female | 9 | Senior Radiographer | NHG |
| Rg_10 | 30 | Male | 5 | Radiographer | NHG |
| Rg_11 | 31 | Male | 8 | Radiographer | NHG |
| Rg_12 | 36 | Male | 9 | Senior Radiographer | NUHS |
| Rg_13 | 32 | Female | 6 | Senior Radiographer | NUHS |
| Rg_14 | 36 | Female | 14 | Senior Radiographer | NUHS |
| Rg_15 | 29 | Female | 4 | Radiographer | NUHS |
| Rg_16 | 30 | Female | 8 | Senior Radiographer | Singhealth |
| Rg_17 | 27 | Male | 4 | Radiographer | Singhealth |
| Rg_18 | 37 | Male | 12 | Senior Radiographer | Singhealth |
| Rg_19 | 37 | Male | 12 | Principal Radiographer | Singhealth |
| Rg_20 | 32 | Male | 6 | Senior Radiographer | NHG |
| Rg_21 | 42 | Male | 18 | Principal Radiographer | NHG |
| Rg_22 | 24 | Female | 1 | Radiographer | NHG |

There are three public healthcare clusters in Singapore. They are Singapore Health Services (Singhealth), National University Health System (NUHS), and National Healthcare Group NHG). Public healthcare clusters are regional integrated healthcare networks that includes acute and community hospitals, primary care providers, nursing homes and other long term care providers to serve the population in that region across the care continuum [31]. The public healthcare clusters together employ more than 70% of the local radiography workforce [30].

independently by the two student researchers. Subsequently, the two researchers reviewed and discussed their codes and refined them until a consensus set of codes was reached. The two researchers then organised the codes into themes. The themes were then shared and discussed with the entire research team, who refined the themes for relevance to the research question, accuracy to the codes, and distinctness between the themes. Microsoft Excel was used to manage the data. The final coding tree is shown in the Appendix as Fig. 1.

## Results

### *Participant demographics*

FGD participants ($n = 22$) included 11 male and 11 female radiographers aged between 23 and 42 years old (median 30.5 years) (Table 1). Their working experience ranged from 1 to 18 years (median six years), and their designation ranged from 'radiographer' to 'principal radiographer'. Principal Radiographers are typically staff with at least 10 years of experience, who hold leadership roles within the department, and have specialised in an area of radiography. Radiographers are typically staff who have recently qualified and have less than 5 years of experience. All participants were working in public institutions under one of the three public healthcare clusters in Singapore: National University Health System (NUHS) ($n = 5$), National Healthcare Group (NHG) ($n = 7$), and Singapore Health Services (SingHealth) ($n = 10$).

Four themes emerged from the data: (1) knowledge of AI and its applications, (2) perceptions on the use of AI in radiographic practice, (3) patients' perceptions as viewed by radiographers, and (4) prospective applications and expectations of AI.

### *Knowledge of AI and its applications*

Radiographers acknowledged the emergence of AI not just in healthcare but also in many other fields. Some radiographers were able to name some AI concepts including machine learning, with deep learning and neural network as subsets, as well as data analytics.

> *"I think AI is a big topic. It's not what we think. For example, how do you build AI involving machine learning (and) neural network? (This) requires big data." (Rg_17)*

However, some of the responses were rather vague, showing a superficial understanding of AI concepts. Others even outrightly mentioned that they don't have much knowledge of AI.

> *"We understand that AI is actually a technology and actually a machine." (Rg_18)*

Respondents demonstrated varying ability to identify current AI applications in radiography. Some radiographers were unsure if certain technologies such as digital radiography, automatic exposure control (AEC), and post-processing were considered AI, indicating some misconceptions about AI.

*"I'm not aware of any … Maybe it's not really AI but right now there's digital machines or mobile X-rays (that) automatically help us to crop images. So there [are] lesser steps for me to do in post-processing." (Rg_4)*

In contrast, some respondents were able to identify current or upcoming applications of AI in radiography either in public institutions or made known through existing literature. They identified the retrieval of protocol, anatomical referencing, and image post-processing including grid suppression and image reconstruction as forms of AI being utilised in their practices.

*"The current machine that we have actually can allow us to post-process the image. Such that we can just use ROI (region of interest) and then click on wherever you want." (Rg_22)*

*Perceptions on the use of AI in radiographic practice*

Radiographers recognised multiple areas in which AI may benefit radiography. Many radiographers suggested how AI-driven innovations may increase efficiency in their workflow and streamline their work processes by optimising decision-making processes and reducing redundancies in administrative tasks.

*"If you can identify patients that really need the scans… (we) can utilise our manpower appropriately to prioritise those examinations that require the radiographers." (Rg_20)*

Respondents also felt AI adoption could benefit patients directly, including providing more individualised care, reducing waiting time, diminishing errors, and safety lapses.

*"Definitely it is something that help(s) patients, like detecting dangers, (hence) reduc(ing) mistakes and harm to the patient… currently it is already helping us to speed up processes…" (Rg_16)*

However, radiographers also reflected on the limitations that AI may face in radiography, notably its inability to deliver patient-centric care.

*"If a patient comes in (from) a RTA (road traffic accident), you need to angle your tube, (and) detector. You need to put sponge(s), secure the patient down with micropore tape to keep them in certain position(s)… All these can't be done with a machine, you need a radiographer to be there to comfort the patient (and) encourage (them) to move to certain position(s)… Then you need to manually set the exposure technique according to how you assess the patient's condition to be, how big-sized the patient is. Is the patient in any cast (or) immobilisation device?" (Rg_3)*

Some radiographers were also concerned about AI system-specific limitations. Poor robustness and low accuracy of the AI algorithms used were constraints brought up by multiple radiographers. Few even highlighted that AI models may not be generalisable in all contexts due to presence of bias.

*"Maybe your data is based on 200 studies, and your patient's problem fall(s) out of that AI algorithm… A lot of that struggle with AI technology right now in diagnostics is that. Do we have enough (data such) that we can cover all bases?" (Rg_14)*

*"Sometimes the race can (have) an impact … if you put in too much data (from) the same race, you might make the AI have certain bias(es)…" (Rg_15)*

*Patients' perceptions as viewed by radiographers*

On how patients may perceive AI, radiographers felt that acceptance of AI could be subjective to the individuals, depending on how they perceive the kind of care they receive. Respondents felt that patients would react positively to AI being adopted in their patient care if AI is considered as part of normal healthcare developments, provided the standard of care remains consistent.

*"As long as it's beneficial to the patient, they don't mind… They don't care that it's AI, as long as it's good enough for them (and able to) diagnose their condition. Then they are fine with it." (Rg_5)*

However, patients could react negatively if they distrust the AI system for more invasive care or are unsure of the implications on their personal data. Negative outlooks could also be elicited when they encounter a problem with the system.

*"When things go wrong, then I will probably not know whom to blame. Do I blame the robot, or can I blame the hospital or something? So, there is a lot of anxiety there." (Rg_6)*

Radiographers suggested that these differences in patient reactions could be influenced by intrinsic and extrinsic factors. Intrinsic factors named include age, level of AI knowledge, and financial capabilities of the patient.

*"If you're talking about uncles (or) aunties who don't know what everything is, (they will) say (since) everything is decided by the computer then what (would) I need you for? Why am I paying you?" (Rg_21)*

Patient reactions could be dependant on external factors like the involvement of the government to persuade the public and the outlook in the community to adapt over time. Respondents felt that when it eventually becomes acceptable practice, patients would be more accepting of AI being used in patient care delivery.

*"They probably would like to check if the product is government approved… If you do the right marketing, everyone will think AI is good, and they will love to try it because it seems to give them (a) better life." (Rg_15)*

*Prospective applications and expectations of AI*

Radiographers identified how AI could aid in various aspects of their workflow in the future. In terms of pre-procedural planning, they felt AI could help in administrative matters such as

the vetting of orders, scheduling of appointments and clinical documentation. It could also potentially aid the radiographer in patient preparation and examination planning, including a physical assessment of the patient's habitus and ability to stand or indication of any pre-procedural preparation.

*"Clinical decision support… would really help us in terms of ensuring that all the requests are appropriate. … (It) could be workflow-based, like how we can optimise our appointments or scan protocolling." (Rg_20)*

Respondents thought support during the examination could also be rendered by AI, like in patient positioning or allowing a reduction in patient radiation dose. It could also facilitate multiple aspects of image acquisition with assistance in language translation, confirmation of the correct marker, contrast administration, and movement of the imaging system.

*"Using AI to check the marker placed by radiographers … check the laterality of the image itself to make sure that it's the correct side that's matched to the ordered study." (Rg_8)*

AI was also viewed to potentially assist in post-procedural image processing like removing artefacts or in standardisation of the images, allowing for reproducibility of the radiographs. It could also expedite the image reporting process by highlighting critical findings.

*"If AI could be implemented into the image storage area where they can actually detect any urgent findings and … automatically raise the reporting process to a more urgent reporting." (Rg_16)*

On how AI might affect their roles and career opportunities, radiographers had diverging views. A few radiographers were concerned that job opportunities in radiography might be reduced with AI integration.

*"AI is an automation, so if we get more things automated, why do you need to employ more people to do the same thing?" (Rg_12)*

However, several were optimistic that AI implementation might expand career opportunities instead. They introduced the idea that a new "AI specialisation" may be created, warranting more jobs in radiography. Radiographers who choose to specialise in AI may be equipped with computer science knowledge and could govern, create, and audit AI processes or troubleshoot. They can also calibrate and generate data for future AI algorithms and systems.

*"You would probably have a division to calibrate AI, feed data to the AI algorithms… We may need certain troubleshooting subject experts and (guidance on) how we can implement it effectively." (Rg_20)*

Other radiographers believed that AI innovations would make little to no impact on the number of job opportunities in radiography. The notion that AI serves to complement rather than replace radiographers or that AI could never replace the profession was brought up by numerous participants.

*"I don't foresee how AI can replace a radiographer's job because it relies (on) a lot of personal experience. You need to be there to physically assess the patient (because) patient(s) come in all shape(s) and sizes, presentation(s)." (Rg_3)*

Instead, they suggested the possibility that AI may lead to a reshuffling of human resources to maximise patient outcomes and efficiency. This could be done through job extension to include AI audit, data collection and data cleaning.

*"I may not need so (many) gen(eral) rad(iography) radiographer(s). I would be able to use my manpower (in) other important areas and modalities." (Rg_9)*

*"Maybe, we can be the ones that's doing the auditing… We can help to filter out chest X-rays that are positively identified for pneumonia so that we can feed the AI algorithm so that it can become more accurate in future." (Rg_7)*

## Discussion

Our findings indicate that participants have limited knowledge of AI concepts and current applications of AI in medical imaging. On participants' perceptions of the use of AI, they saw the benefits as increasing efficiency, optimising decision-making, and improving patient care and safety. They thought the limitations were its inability to provide the human touch, and the algorithms' accuracy, robustness, and generalisability. On how patients may perceive AI in radiography, participants felt that patients would accept AI if they feel it improves their care, but may reject it once they lose trust in it. They also felt that patients' reactions will be influenced by intrinsic factors like age and knowledge, and external factors like the community's general outlook towards AI. In terms of expectations of AI, participants envisioned several future useful applications in pre-, peri–, and post-procedural workflows, including order vetting, patient positioning, language translation, and artefact removal. On how radiographers' role and career opportunities will change, while some participants were concerned about reduced job opportunities, others thought that manpower will be maintained and redeployed to improve service delivery. Some participants in fact see a growth opportunity for radiographers to specialise in AI, becoming involved in algorithm development and its clinical implementation and management.

### *Knowledge of AI and its applications*

Radiographers in this study showed only a basic understanding of AI. This is consistent with research by Abuzaid et al [6]. indicating a knowledge gap amongst radiographers, and which Chen et al [22]. attributed to limited exposure or efforts to familiarize with AI topics. Participants recognised AI as an existing technology but were unable to elaborate on AI concepts, again similar to reported findings on radiographers' lack of confidence in AI terminologies [7]. Some participants acknowledged their lack of AI knowledge with minimal efforts to educate themselves, similar to many UK radiographers who considered themselves without any skills in AI [7].

Radiographers in this study could identify some current applications of AI including automation in X-ray tube positioning, protocol selection and post-processing, similar to Irish radiographers [11]. More specific examples like grid suppression and image reconstruction were also pointed out by radiographers in this study. However, it is difficult to ascertain whether such applications are indeed AI-based due to the lack of knowledge on the technical aspects of the systems.

*Perceptions on the use of AI*

Consistent with the views of radiographers from Ghana, participants in this study raised the potential of AI promoting efficiency in their workflow by automating administrative tasks and optimising decision making [8,23]. Through for example the AI innovations the participants suggested, radiographers see that AI could potentially allow them to care for a larger number of patients with a same workforce, a point also mentioned by Botwe, Akudjedu, et al [9].

Despite this, many radiographers in our study expressed concern about the limited accuracy and robustness of existing AI models, though most could not articulate the reasonings behind them. However, a few of them were able to explain that credibility and validity of AI systems are highly dependant on the algorithms' context and could be biased. AI bias in medical imaging is an important topic and has been demonstrated in recent studies. For example, a study on 3 large chest radiograph datasets showed that when AI algorithms are trained on the overall population, it results in an under-diagnosis bias in sub-populations such as women, people of colour, or patients of lower socio-economic status [24]. In another example, Gichoya et al. found that AI can robustly and reliably predict race from medical images, suggesting that race bias and race-specific errors could exist in AI algorithms today [25]. These biases raise the ethical issue of perpetuating or exacerbating health inequities if such algorithms are implemented in clinical practice. Approaches to addressing AI bias have been suggested. For example, Nonori et al. suggests using open science practices such as sharing of datasets so that they can become representative or sharing of source code so that algorithms can be tuned for different populations [29].

The radiographers' opinions on patient reactions seemingly vary, where most of them situated themselves as the patients on the receiving end of the AI-based services. Radiographers anticipated patients to react positively to AI, in line with findings from Ryan et al., [11] with the younger and more knowledgeable patients being more receptive to AI as suggested by York et al [26]. However, others were wary of poor reactions by patients, as invasive care and more demanding examinations would lower the acceptability of AI-based systems, similar to Malamateniou et al [27]. Perspectives introduced were largely based on the radiographers' experiences with similar changes to radiography systems that occurred previously during their practice.

*Expectations of AI*

Congruous with findings by Chen et al., [22] radiographers were receptive to new AI technologies, viewed to be able to lighten their workload and ease their work processes. Radiographers similarly concur with the excitement for AI in medical imaging, with its assistance in radiation dose optimisation and the production of quality radiographic images [8,9]. In addition to similar suggestions by radiographers in the study by Ryan et al., [11] new suggestions of AI applications from this study include order vetting, assistance in patient positioning and language translation. Language translation is highly relevant to multilingual countries like Singapore and others.

Some participants in this study were concerned that their job security might be threatened as AI automates more tasks for radiographers. This fear is not unique, as radiographers from Ghana and Ireland shared this opinion [8,10,11]. However, most participants shared the opinion of Botwe, Akudjedu, et al [9]. that AI could only play a supporting role and cannot replace radiographers, as it is limited in delivering quality patient care and adapting to varying patient presentations. Moreover, the European Federation of Radiographer Societies [5] recommends that AI release radiographers from non-essential tasks.

Some radiographers in our study believe that AI could offer significant opportunities for role extension and specialisation. This sentiment is consistent with opinions from previous studies [9,11]. However, the previous studies did not identify potential extended roles. Participants from this study suggested that radiographers could play an increasing role in AI audit, data collection and data cleaning. Malamateniou et al [27]. recommended that clinical practitioners, alongside vendors, be involved in AI audits to ensure the accuracy and reliability of the algorithms used. As suggested by participants in this study, data collection and cleaning are other potential areas that radiographers can participate in as they will be the ultimate end-users of the AI systems.

*Implications for practice*

Radiographers in this study demonstrated general receptiveness to AI adoption as it is perceived to be beneficial in increasing efficiency. Thus, Singapore and other societies with severe staffing concerns could benefit from implementing AI to supplement their current manpower needs. However, given the limited AI knowledge amongst radiographers, the radiography profession may not be ready for the widespread adoption of AI in practice. This warrants preparatory actions from healthcare institutions and those involved in undergraduate and continuing professional education curricula to incorporate AI education for radiographers and radiography students.

To assist in the readiness of AI adoption in Singapore, radiographers should also actively take part in the development of AI models for radiography applications. They can start by participating in data collection and data cleaning for the al-

gorithm development. With increased knowledge and interest, radiographers should then be involved in developing AI algorithms. In addition, given the current challenges in obtaining accurate and reproducible AI systems, radiographers should be involved in judiciously evaluating the performance of potential algorithms before its use in clinical practice. Clinical trials should also be carried out in their intended clinical pathways to ascertain their suitability. Radiographers then can continue to be involved in AI audits, to ensure the accuracy and reliability of the algorithms used. Radiographers can also be involved in shaping accountability and medicolegal frameworks for the use of AI in radiography applications [28].

With the envisioned practices radiographers would like to see being integrated into their workflow, radiographers should actively scrutinise how these practices could be implemented, its feasibility, and what AI knowledge they should equip themselves with. Only with their thorough comprehension of the mechanisms of the AI-based systems would they be able to convincingly manage the reactions of patients to be more accepting of the improved systems.

Even as AI systems are implemented in practice, they should only be utilised to optimise decision-making, while radiographers should exercise clinical judgement and be the final clinical decision-makers. Thus, radiographers should feel assured that AI would more likely act as a beneficial aid in clinical practice rather than a threat to their careers. Creating an AI specialisation could be an avenue for radiographers who are especially interested in AI technology. However, more information regarding the interest level of radiographers should be obtained. Radiographers' job scopes may be revolutionised, and the profession must be prepared to adapt to changes with increasing AI implementation.

### *Limitations and future research*

Conducting the FGDs online may have restricted the flow of the discussion amongst participants as it does not serve as a natural setting, though it allowed the less vocal participants to contribute better. As some of the FGDs extended close to two hours, participant fatigue could be a degrading factor in the quality of the responses given. While familiarity amongst participants was encouraged with the inclusion of radiographers from the same institution within each focus group, the differences in their designation could have affected the openness of some of the responses from junior radiographers with a possible inclination to concur with opinions made by more senior radiographers. Not all participants responded for the transcript check, though we tried to mitigate that by having 2 independent coders in the initial coding.

There were also limitations in our sample, which could have meant that the phenomenon we were studying was not fleshed out as fully as it could be. Recruitment of participants via word of mouth could have created a more homogenous sample than is the case. Radiographers from private institutions and those in the administrative and technical divisions of the public institutions were not included. Colleagues in administration and technical roles could have contributed more data on perspectives like policy, financial, and IT infrastructure. Radiographers from private institutions, while they make up less than one-third of the local workforce, [30] could have contributed additionally on perspectives such as patient expectations. We had only one participant above 40 years of age. Though this demographic makes up less than 30% of the local workforce, [30] they could have different perspectives on AI and technology in general.

Further research is recommended with the involvement of other stakeholders including radiographers from private institutions, radiologists, management staff and AI engineers or vendors to explore their perspectives on the acceptance of AI implementation in radiographic practices. Similarly, radiographers from education, research and management tracks may add additional perspectives. As radiographers become involved in designing AI, research should also be carried out to understand radiographers' experience and the associated barriers and facilitators. A study including healthcare patients on their possible reactions to AI could also be considered. Future studies could also delve into the modes of provision and extent of AI education amongst radiographers.

## Conclusion

This study has explored the knowledge of AI and its applications amongst radiographers in Singapore, their perceptions on the use of AI in radiographic practice and how they view patients' perceptions, along with their expectations of AI in the future. AI can benefit the radiography profession in Singapore, but widespread AI implementation is not recommended presently due to its persisting limitations and limited knowledge amongst radiographers. While radiographers are positively anticipating the integration of AI into their practices, they should be better prepared for imminent modifications brought about by AI and education should be put in place to ensure that radiographers are prepared to embrace AI technologies when the time comes. With patients as the recipients of healthcare, their acceptance and reactions to AI being implemented in radiographic practices should be carefully managed to provide a holistic provision of care. Radiographers should stay involved in the conversation of AI in radiography to maximise their potential as a profession as AI becomes increasingly adopted in practice.

## Appendix

### *Online FGD Guiding Questions*

#### *Introductory questions*

Can you share your name, institution, if you are in any modalities and any special radiography-related interests that you have taken up or are currently a part of?

What is your current understanding of artificial intelligence (AI)?

*Workflow and implementation of AI*

What is the current workflow in your modality? In terms of examination planning, image acquisition, and image processing.

Could you elaborate more on the use of AI in your current workflow, if any?

How else do you think AI could be implemented in your workflow?

*Patient care*

How do you think AI might impact patient care in radiography?

How do you think patients might react to the adoption of AI in the practice of radiography?

*Job opportunities*

How do you foresee AI impacting the number of job positions in radiography?

*Ending question*

Do you have anything else that you would like to add to this discussion?

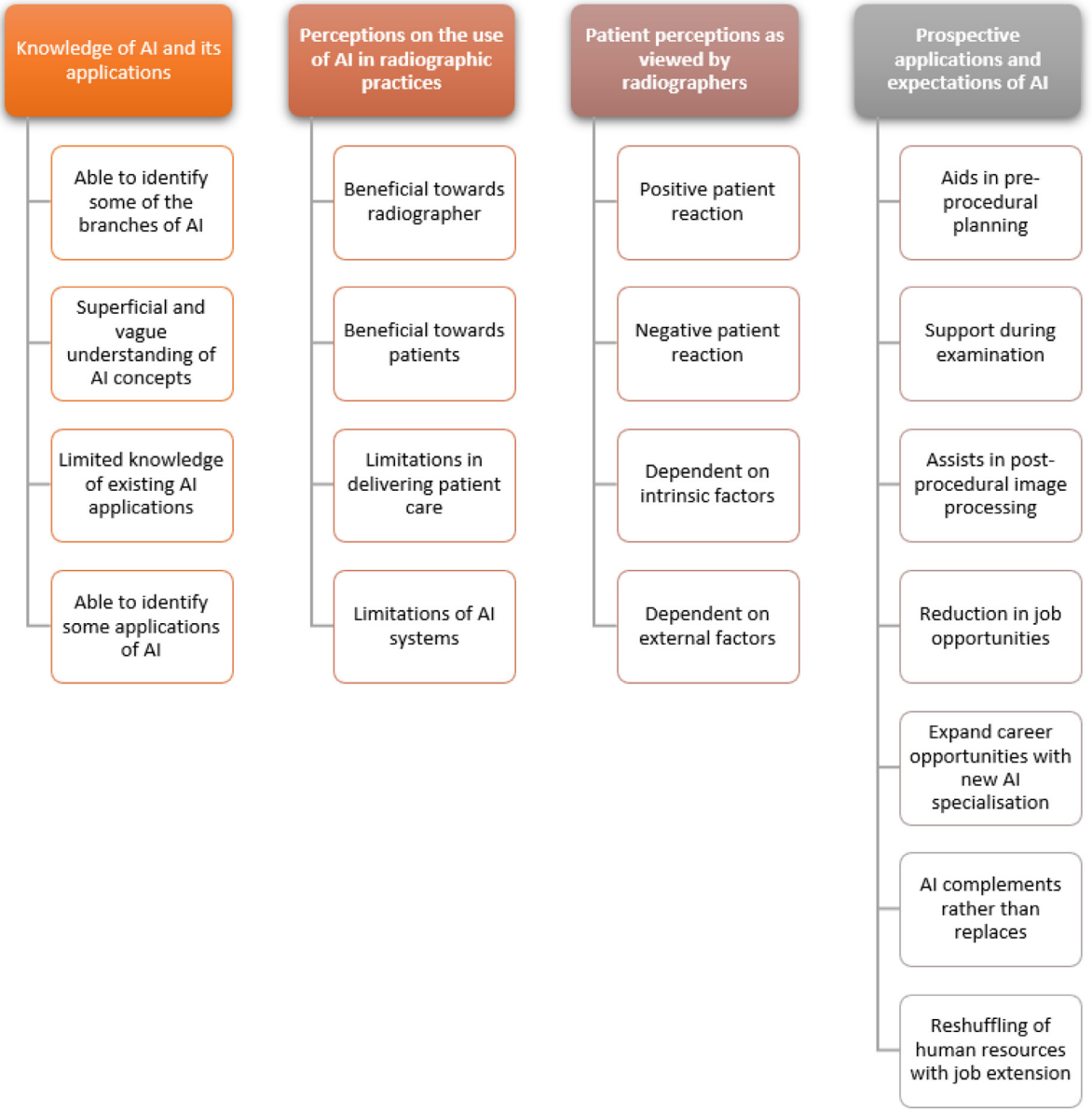


Fig. 1. Coding Tree.

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