The Perceptions of Medical Physicists Towards Relevance and Impact of Artificial Intelligence

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Research Article

Keywords: Artificial intelligence, perception, medical physics, educational training, clinical practice

Posted Date: April 26th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-449280/v1

Version of Record: A version of this preprint was published at Physical and Engineering Sciences in Medicine on July 20th, 2021. See the published version at https://doi.org/10.1007/s13246-021-01036-9.

Abstract

Artificial intelligence (AI) is an innovative tool that is revolutionising healthcare and medical physics, possibly impacting clinical practices, research, and the profession. The relevance of AI and its impact on the clinical practice and routine of professionals in medical physics were evaluated by medical physicists and researchers in this field. An online survey questionnaire was designed for distribution to professionals and students in medical physics around the world. In addition to demographics questions, we surveyed opinions on the role of AI in medical physicists' practice, the possibility of AI threatening/disrupting the medical physicists' practice and career, the need for medical physicists to acquire knowledge on AI, and the need for teaching AI in postgraduate medical physics programmes. The level of knowledge of medical physicists on AI was also consulted. A total of 1019 responders from 94 countries participated. More than 85% of the responders agree that AI will play an essential role in medical physicists' practice. AI should be taught in the postgraduate medical physics programmes, and that more applications such as quality control, treatment planning will be performed by AI. Half of them thought AI would not threaten/disrupt the medical physicists' practice. AI knowledge was mainly acquired through self-taught and work-related activities. Nonetheless, many (40%) admitted that they have no skill in AI. The general perception of medical physicists is that AI is here to stay, and it will influence our practice. Medical physicists should be prepared with education and training for this new reality.

Introduction

Artificial Intelligence (AI) is broadly referred to as 'the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.' – Oxford Dictionary.

The term AI was first coined by John McCarthy in 1956 as the science of engineering and making intelligent machines. However, early works in AI had not achieved many breakthroughs due to the limited computing power. It was only in the last decade that AI research in healthcare and medicine had started to show promising results and practical applications, from facial recognition to fully automatic detection, and even finding new biomarkers. It has been recognised as both a productive and disruptive force in healthcare [1]. In particular, radiology, radiotherapy and pathology are the three medical specialities that saw the more prominent AI role [2–5]. Some clinicians may also view AI as a threat to the future of their medical practice [6]. This results in some ambivalence in the attitude towards the acceptance of AI.

Medical physicists are healthcare professionals who work closely with medical practitioners to provide medical services to patients. Conventionally, their job scope includes treatment planning, quality assurance (QA), optimisation of image quality, radiation dosimetry, preparing equipment specifications, etc. [7]. Besides the biomedical engineers and IT personnel, they are probably the next most technically competent individuals in a clinical department. The involvement of medical physicists with AI could be mutually beneficial. Medical physicists have the knowledge and skills on medical physics required for the development, implementation, and use of AI.

On the other hand, the quantity of information obtained using AI can extend the expertise of medical physicists and boost patient care [8]. The medical physicists must be the leaders in implementing AI for routines clinical practice[9]. Despite that, there are currently few medical physicists involved directly in AI projects [10].

The number of research and possibilities of applications AI in medical physics is increasing rapidly. European Federation of Organisations For Medical Physics (EFOMP) white paper proposed that training and education programs are needed to prepare the medical physicist for this revolutionary transformation in healthcare and medicine [11]. Based on this white paper, the curriculum has been discussed, aiming its expansion to include AI for the education and training of European medical physicists, based on their needs [12, 13]

The practice and daily routine of medical physicists were also affected by AI [2]. Big data and deep learning will profoundly change the profession in general and future research [11]. In the future, in a scenario where AI is used more widely, some stand up for incorporating AI into the medical physics graduate program curriculum to better adapt the professionals to this new reality. A medical physicist should collaborate with computer scientists in the management of AI applications [14]. This proposition, however, still divides opinions.

Several studies have focused on healthcare professionals' perception and attitude towards AI [15–21]. In medical physics, the only study on the perceptions, practices, and education needs about AI focused on European medical physics experts and their needs [10]. This referred study's data are from a web-based survey applied to a total of 219 responders from 31 countries (93%, n = 203 of European countries and 7% of non-European countries). Hence, this survey aims to determine the awareness of medical physicists regarding AI and their perception of the relevance and impact of AI in the practice of medical physics, including opinions of medical physicists experts, researchers, trainees and postgraduate students in medical physics around the world.

Methodology

An online survey questionnaire (see <link rid="Sec1">Appendix</link> Table A.1) was designed and distributed to professionals, trainees and students in the medical physics field using Google Form (Google LLC, Mountain View, CA, USA) and Smart Survey (SmartSurvey Ltd, Tewkesbury, Gloucestershire, UK), specifically to China respondents. There were 13 multiple-choice questions (MCQ) about the participants' perception of AI, and six questions about their profile. The MCQs were designed using a 5-point Likert scale with the descriptor of agreement. Participants were also free to provide general comments. After a pilot test, the questionnaire was launched publicly and disseminated via regional and international professional organisations such as the AAPM, AFOMP, ALFIM, EFOMP, FAMPO, IOMP, IPEM, MEFOMP, SEAFOMP. The survey is global and was held from February until May 2020, reaching 1019 global respondents. This research was approved by the University of Malaya Research Ethics Committee (UM.TNC 2/UMREC).

The survey included questions about the role of AI in medical physicists' practice and its increasing possibilities of applications such as in quality control and treatment planning. The participants' opinions were also asked concerning the possibility of AI threatening/disrupting the medical physicists' practice and career, the need for medical physicists to acquire at least some basic knowledge of AI and the need to teach AI in postgraduate medical physics programmes.

Some questions about the participants' knowledge of AI (the origin of that knowledge, basic understanding, working knowledge, relevant skills, proficiency, limitations) were also included. The survey was anonymous, only composed of questions about the respondent's profile covering demographic factors (e.g., nationality, gender, age, academic qualifications, occupation).

We used Mann Whitney U, Spearman correlation and Kruskal Wallis + post hoc pairwise comparisons as statistical tests for analyses purpose. The demographics of the study are presented using per cent. We explore the association of gender, age, country economic status, academic qualifications and medical physics practice on the responses (Table 1). The data were recategorised based on age groups (baby boomer, generation-X, -Y and -Z), country economic status, academic qualifications and physicist practice.

Table 1

Re-categorisation of data and statistical tests used.

Description	Category	Test statistics*
Gender	1. Female 2. Male	Mann Whitney U
Age group	1. Baby boomer (>56 years old) 2. Generation X (40 – 56 years old) 3. Generation Y (24 – 39 years old) 4. Generation Z (<24 years old)	Spearman Correlation
Country economic status (based on World Bank classifications)	1. Low income 2. Lower middle income 3. Upper middle income 4. High income	Spearman Correlation
Academic qualifications	1. PhD 2. Master 3. BSc	Spearman Correlation
Medical physics practice	1. Academic 2. Clinical 3. Mixed-field	Kruskal Wallis + post hoc pairwise comparisons

Note: *These statistical tests were used for all questions, except for Q11 and Q12 where chi-square of independence was used.

Results

Demographics

A total of 1019 responders from 94 countries participated in this survey. The highest number of respondents is from the UK (10%), followed by Malaysia (8%), the USA (8%), Australia (6%) and Japan (5%). Fig 1 shows the geographical distribution of survey respondents. Amongst them, 35% are female, 65 % are male. The highest number of responders comes from Generation-Y, sometimes also called the

Millenials, contributing to 59% of the total responders. The second largest group were from Generation X (28%), followed by the baby boomers (11%).

In terms of academic qualifications, 91% holds one or multiple postgraduate degrees. Amongst them, 34% holds a PhD degree. However, only 5% were board certified. Seventy-nine per cent of the respondents are currently working as academic and/or clinical physicists, while 10% carry multiple roles. Eleven per cent of them are currently undertaking a postgraduate course. 67% are affiliated with hospitals, and 34% works in universities. The rest of the responders are affiliated with research institutes, consultancy, government agencies, regulatory bodies, etc. There are also 20% that have multiple affiliations.

Survey results

Fig 2 shows the survey summary for Q1 to Q10 and Q13. An exceedingly high number of survey respondents (91%) agree that AI will play an essential role in medical physicists' practice. In comparison, 85% agrees that more and more applications such as quality control, treatment planning will be performed by AI.

When asked about their opinions if AI will threaten/disrupt the medical physicists' practice and career, the polls are more spread out. Half of them do not agree with this notion, while 25% thinks otherwise. Albeit the apprehension, 92% acknowledges that all medical physicists should acquire at least some basic knowledge of AI. Towards that end, 87% express support that AI should be taught in the postgraduate medical physics programmes.

More than half (62%) of the responders claimed that they had a basic understanding of AI relevant to their field, while 21% did not agree. However, only 34% could confidently say they have a working knowledge of AI, while 24% neither agreed nor disagreed, and 41% did not have a working knowledge of AI. In terms of skills, only 22% think they have the relevant expertise in AI, while 25% sat on the fence, and 53% did not have the appropriate skills. Upon further probing, only 14% could confidently claim that they are proficient in AI, design, code, and implement an AI program; 15% were undecided, while 71% did not agree.

Fig 3 shows AI knowledge mainly was gained through self-taught (41%) and work-related activities (25%). Attending courses and postgraduate training only contributed to 12% and 5%, respectively. We also noticed similar approaches towards developing AI skills, with 39% being self-taught. Attending courses and postgraduate training only contributed to 10% and 7%, respectively. Interestingly, while only 16% claimed that they did not know AI, a more significant percentage (40%) admitted that they had no AI skill.

Contemporary AI systems are not without limitations. Just over half of the responders (59%) thought they understood the limitations of AI, while 16% did not agree. In terms of AI acceptance of AI, 67% thought they are ready to learn and apply AI in their practice, while 15% did not agree.

Table 1 shows the results of statistical tests on the different factors affecting the levels of agreement and method of knowledge and skill acquisitions, comparing across gender, age groups, country economy status, academic qualifications and practices.

Males, more often, strongly agrees that AI will play an essential role in the practice, and they possess the working knowledge and skills in AI. Gender association was found in the method of knowledge acquisition. More male responders claimed that they were self-taught, while more females learned from work-related activities.

Table 2

Results of statistical tests on the different factors affecting the levels of agreement and method of knowledge and skill acquisitions, comparing gender, age groups, country economy status, academic qualifications and medical physics practices.

	Questions	**Gender**	**Country economy status**	**Academic qualifications**	**Medical physics practices**
	Statistical Test	Mann Whitney U	Spearman Correlation (r, p-value)	Spearman Correlation (r, p-value)	Kruskal Wallis (p-value)
1	AI will play an important role in the practice of medical physicists.	**0.019**	0.016 0.616	0.050 0.110	0.068
2	More and more applications such as quality control, treatment planning will be performed by AI	**0.001**	**-0.073** **0.021**	**0.066** **0.035**	0.192
3	AI will threaten/disrupt the medical physicists' practice and career.	0.094	0.061 0.052	-0.058 0.068	0.924
4	All medical physicists should acquire at least some basic knowledge of AI.	0.385	**0.096** **0.002**	0.002 0.949	0.520
5	AI should be taught in the postgraduate medical physics programme	0.750	**0.115** **<0.001**	0.030 0.343	0.552
6	I have a basic understanding of AI (relevant to my field).	0.311	**-0.170** **<0.001**	**0.170** **<0.001**	**<0.001**
7	I have a working knowledge of AI (relevant to my field).	**0.023**	**0.134** **<0.001**	**0.134** **<0.001**	**<0.001**
8	I have relevant skill in AI.	**0.045**	**0.091** **0.004**	**0.091** **0.004**	**<0.001**
9	I am proficient in AI (able to design, code and implement).	0.558	0.005 0.884	0.005 0.884	**0.006**
10	I understand the limitations of AI	0.325	**0.121** **<0.001**	**0.121** **<0.001**	**<0.001**
11*	My knowledge in AI are developed through:	**0.019**	0.138	**<0.001**	**<0.001**
12*	My skill in AI are developed through:	0.288	**0.047**	**0.004**	**<0.001**

13	I am ready to learn and apply AI in my practice	0.541	**0.191** **<0.001**	-0.032 0.305	0.159

Note: **Bold font** indicates significant differences, $p < 0.05$. * Q11 and Q12 report the Pearson chi-square p-values.

There was a weak correlation between the age group with Q1, 7 and 13. Older medical physicists agree that AI will play an essential role in medical physics practice, and they are ready to learn and apply AI to their practice. Younger medical physicists tend to acknowledge that they had a working knowledge of AI relevant to their field.

The country economic status affected the perception of medical physicists. Higher-income countries correlated with higher academic qualifications ($r = 0.210$, $p<0.001$). medical physicists from higher-income countries were more likely to think that QC and treatment planning will be taken over by AI, and claim to have a basic understanding of AI relevant to their field. This corroborates the findings that more medical physicists from higher-income countries claimed they could design, code and implement AI. More medical physicists from the lower-income countries believed that all MP should acquire some basic knowledge of AI and education via postgraduate programmes. They were also keen to learn and apply AI in their practice. The country economic status association was found in the method of skill acquisition. More responders from upper-middle-income countries claimed that they learned from postgraduate programmes.

A significant correlation was found between academic qualifications and Q2, 6 - 8, and Q10. Medical physicists with a PhD degree were more likely to think that AI will have more and more application in the medical physics profession. They were also more likely to say that they had a basic understanding, knowledge, and skills of AI and understand the limitations of AI.

Q6-10 showed a significant difference in academic, clinical physicists' opinions and those involved in both areas, henceforth called mixed-field physicists. Pairwise comparisons show that academic and mixed-field physicists were more likely to agree that they have a basic understanding, working knowledge and skills in AI, and understood the limitations of AI. However, the academic physicists were also more proficient in AI and able to design, code and implement AI.

Significant difference in preferences of methods of knowledge acquisition ($\chi^2 = 36.4$, $p < 0.001$) and skill development ($\chi^2 = 28.1$, $p < 0.001$). While the academic and clinical physicists were mostly self-taught, the mixed-field physicists do not have any particular preferences. However, a fairly large proportion of the academic and clinical physicists claimed they have no knowledge or skill in AI.

Discussion

Almost everyone agrees that AI is essential and will only continue to play increasing roles in medical physics. More and more tasks such as quality control and treatment planning can be performed by AI systems, supporting medical physicists' work. AI can help automate and speed up processes, thereby allowing medical physicists to focus on areas that required improvement. In countries suffering from a shortage of qualified medical physicists, AI could help fill human resource deficiency.

A pertinent concern raised was that dependencies on AI in handling crucial tasks in clinical medical physics might result in the decline in the competencies of the physicists.

Many believed that AI would change medical physics practice; if not disruptive, it would most certainly change the current state of practice. However, only half of the responders agree that it will threaten/disrupt the medical physicists' practice and career. The optimists look at AI as another tool that can help enhance the role of the physicist rather than replace it. Nevertheless, one needs to acknowledge that there is a certain amount of distrust of AI, which may stem from the lack of knowledge around it.

The appropriate use of AI in medicine would require careful verification of the applications. It is also important to acknowledge that the human touch and soft skills are also an essential part of the professions, especially in the interaction between our medical specialists and patients. AI are merely tools; ultimately, it is the human using it that must understand and assume responsibility to understand the capabilities and limitation of the machine.

Given the inevitable presence of AI in medical physics, and how much technology can replace human would depend on one's preparedness to understand it. Towards that end, education is the key.

Currently, medical physics is often taught as postgraduate programmes. While students may be exposed to some form of computing or programming courses in the programme, the emphasis on AI may not be extensive.

This survey shows that while most agree that AI knowledge should be taught to new generations of medical physicists, the approach to do this is still being debated. Many argued that AI and machine learning courses should be taught in an undergraduate course instead of a postgraduate course. One of the reasons cited was that postgraduate courses are usually one to two years, covering all conventional aspects of medical physics. It would be insufficient to provide extensive education and training on practical AI and machine learning techniques. One of the responders said,

"We are a discipline that cannot simply afford and hence rely on an approach that lacks evolution in time. The best place where we can equip the next generation of medical physicists is graduate programs that can provide a diverse and strong knowledge base to tackle practical problems of the real world practice of medical physics. This type of academic preparedness supplemented with clinical training as in residency programs is THE best way to produce best clinical physics practitioners."

Due to the limited time in postgraduate education, there needs to be a balance in the amount of time dedicated to training the clinical medical physics skills with the time and resources needed to equip them to tackle real-world problems. Perhaps, one needs to ask the pertinent question, do we want to train medical physicists or computer programmers? One needs to consider that medical physics goes way beyond manipulating image data sets and creating computerised treatment plans.

Questions that asked about the responders understanding and skills of AI showed an insightful trend. While 62% of the responders claimed to have a basic knowledge of AI, the number quickly reduced by half for those who have a working knowledge of AI. Understanding how AI works do not mean one has the necessary skill to be a computer programmer, which in this case, is a mere 14% of the responders. In reality, most of us have used or at least were acquainted with AI that comes as part of the vendor-supplied packages, rather than coding and designing in-house AI programme.

AI systems, just like any other tools, also have their limitations. It is essential for medical physicists to understand how it works and its limitations. For example, AI in treatment planning systems would perhaps expedite treatment plans and produce plans that are, on average better than a junior trainee. However, without a proper understanding of their limitations, system errors could promulgate silently. The “black-box” nature of some AI techniques such as deep learning may also be factors that hinder their acceptability in the community.

In terms of training and education in AI, the survey showed that many medical physicists (41%) acquire and develop their knowledge and skills through their effort, i.e. self-taught. Perhaps this is due to the lack of AI education and training in the previous and current medical physics education programmes. Notably, there is a misbalance in gender concerning the knowledge and skills for AI. This may be related to the mode of knowledge & skill acquisition as more male MP claimed to be self-taught while female medical physicists preferred to learn from work-related activities. This means that if AI knowledge and skills are delivered in a more structured manner, AI knowledge could be higher in female medical physicists with precise medical physics practice applications. More often, medical physicists gain knowledge and skills via multiple pathways, not limited to a single path.

Conclusion

Medical physicists’ general perception is that AI is here to stay, and it will definitely influence our practice. AI will likely enhance rather than replace medical physicists. Medical physicists’ role is crucial in understanding and evaluating AI’s performance to optimise and reap the maximum benefit from AI systems [11]. This is a new and evolving domain of a medical physicist. While AI-based technologies would simplify and automate many routine works, medical physics needs hands-on practice; just like medicine, it is an art. Losing this skill will inadvertently endanger patients. We also need to understand and acknowledge the limitation of AI and not be completely reliant on AI-based technologies.

We have to start preparing with education; else, we will run the risk of becoming irrelevant [10, 22]. EFOMP white paper also pointed out that it is essential that the medical physics professional education and training incorporate competency in this aspect [11]. Fundamentals of AI should be taught in undergraduate physics / medical physics programme and professional medical physics education. AI knowledge and training can be imparted in a more structured manner via medical physics work-related activities to enable higher uptake of the skills.

Global medical physics organisations can play a significant role in providing up-to-date information on AI in medical physics clinical practice guidelines. Leadership in steering the medical physics profession in preparation for the AI-enhanced future is critically needed.

Acronym Definitions

AAPM - American Association of Physicists in Medicine

AFOMP - Asia-Oceania Federation of Organizations for Medical Physics

ALFIM - Latin American Medical Physics Association

EFOMP - European Federation of Organisations for Medical Physics

FAMPO - Federation of African Medical Physics Organizations

IOMP - International Organization for Medical Physics

IPEM - Institute of Physics and Engineering in Medicine

MEFOMP - Middle East Federation of Medical Physics

SEAFOMP - South East Asian Federation of Organizations for Medical Physics

Declarations

Funding

No source of funding

Conflicts of interest/Competing interests (include appropriate disclosures)

No conflict of interest

Availability of data and material (data transparency)

The data may be made available if requested.

Code availability (software application or custom code)

Not applicable

Authors' contributions (optional: please review the submission guidelines from the journal whether statements are mandatory)

KHN, JCS, VP conceived the idea, designed and executed the survey. JHDW analysed the data. JCS, JHDW, KHN, and VP prepared, edited the manuscript and approved the final submitted manuscript.

Ethics approval (include appropriate approvals or waivers)

This research was approved by the University of Malaya Research Ethics Committee (UM.TNC 2/UMREC).

Consent to participate (include appropriate statements)

Informed consent was obtained from all individual participants included in the survey.

Consent for publication (include appropriate statements)

Not relevant.

Acknowledgement

We thank the following organisations for publicising and disseminating the survey: AAPM, AFOMP, ALFIM, EFOMP, FAMPO, IOMP, IPEM, MEFOMP, SEAFOMP, ACPSEM. We also thank all the respondents who supported this survey.

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Appendix

Table A.1

	Please rate your agreement with the following questions: ***Answer range from: 1(Strongly agree) to 5 (Strongly disagree)**
1	AI will play an important role in the practice of medical physicists. *
2	More and more applications such as quality control, treatment planning will be performed by AI. *
3	In my opinion, AI will threaten/disrupt the medical physicists' practice and career. *
4	All medical physicists should acquire at least some basic knowledge of AI. *
5	AI should be taught in the postgraduate medical physics programme. *
6	I have a basic understanding of AI (relevant to my field). *
7	I have a working knowledge of AI (relevant to my field). *
8	I have relevant skills in AI. *
9	I am proficient in AI (able to design, code and implement). *
10	I understand the limitations of AI. *
11	My knowledge of AI is:
	A Self-taught
	B Learned by attending courses
	C Learned from postgraduate training
	D Learned from work-related activites
	E No knowledge
12	My skill in AI is developed through:
	A Self-taught
	B Learned by attending courses
	C Learned from postgraduate training
	D No skill
13	I am ready to learn and apply AI in my practice. *
	Tell us about you:
14	I am:
	A Male

	Please rate your agreement with the following questions: ***Answer range from: 1(Strongly agree) to 5 (Strongly disagree)**	
	B	Female
15	My age is: [Free number replies, acceptable from 18 to 100 years old]	
16	My highest qualification(s) attained:	
	A	PhD
	B	Master
	C	Bachelor
	D	Board certification
17	I am currently a/an:	
	A	Academic physicist
	B	Clinical physicist
	C	Postgraduate student
	D	Trainee/resident
	E	Retired
	F	Other
18	I am affiliated with:	
	A	University
	B	Hospital
	C	Research institute
	D	Government agency
	E	Regulatory body
	F	Consultancy
	G	Other
19	I am from [Choose one option from countries of the world]	
20	Your comment (if any): [Free text replies]	

Figures

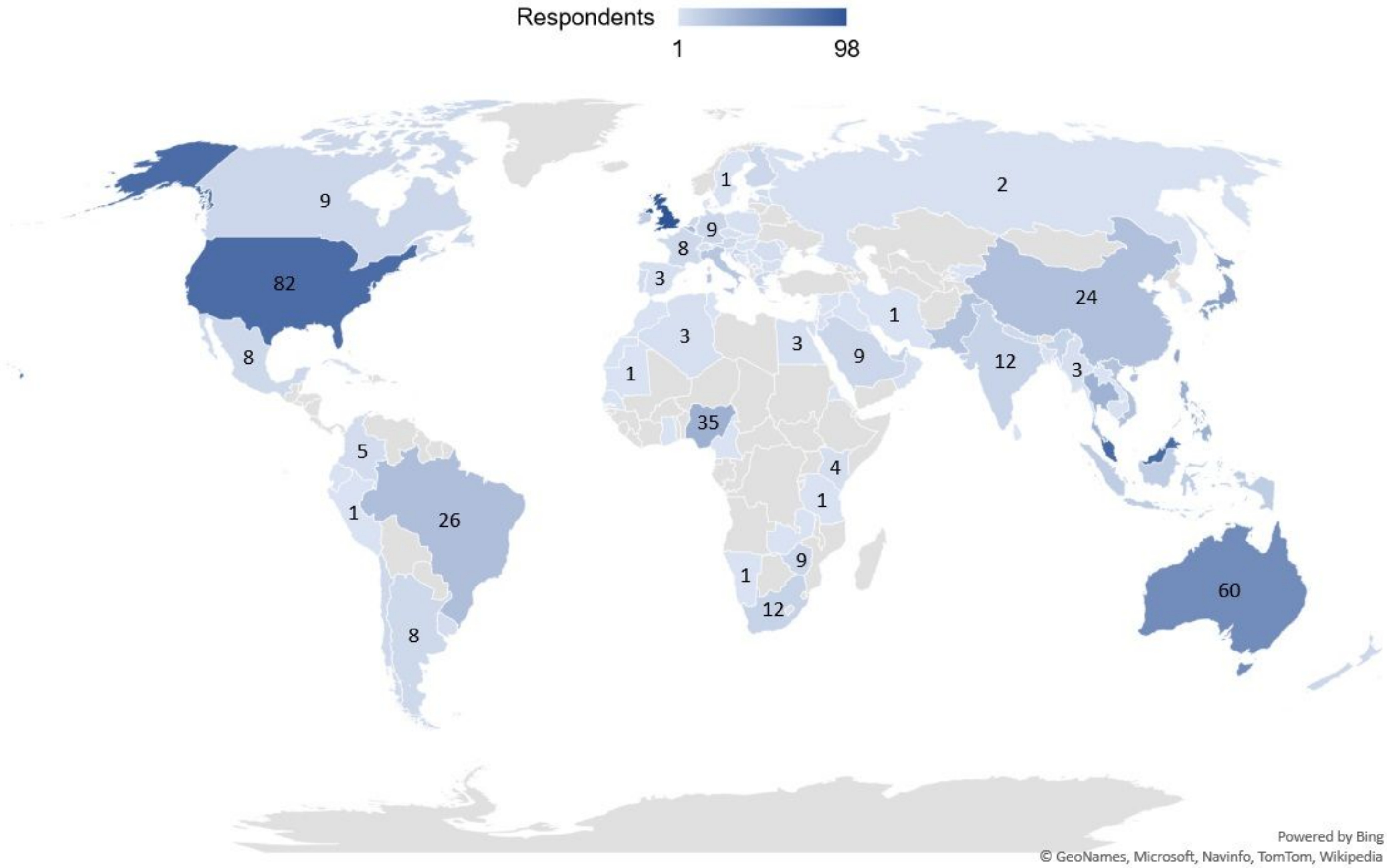

Figure 1

Geographical distribution of the respondents according to country. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

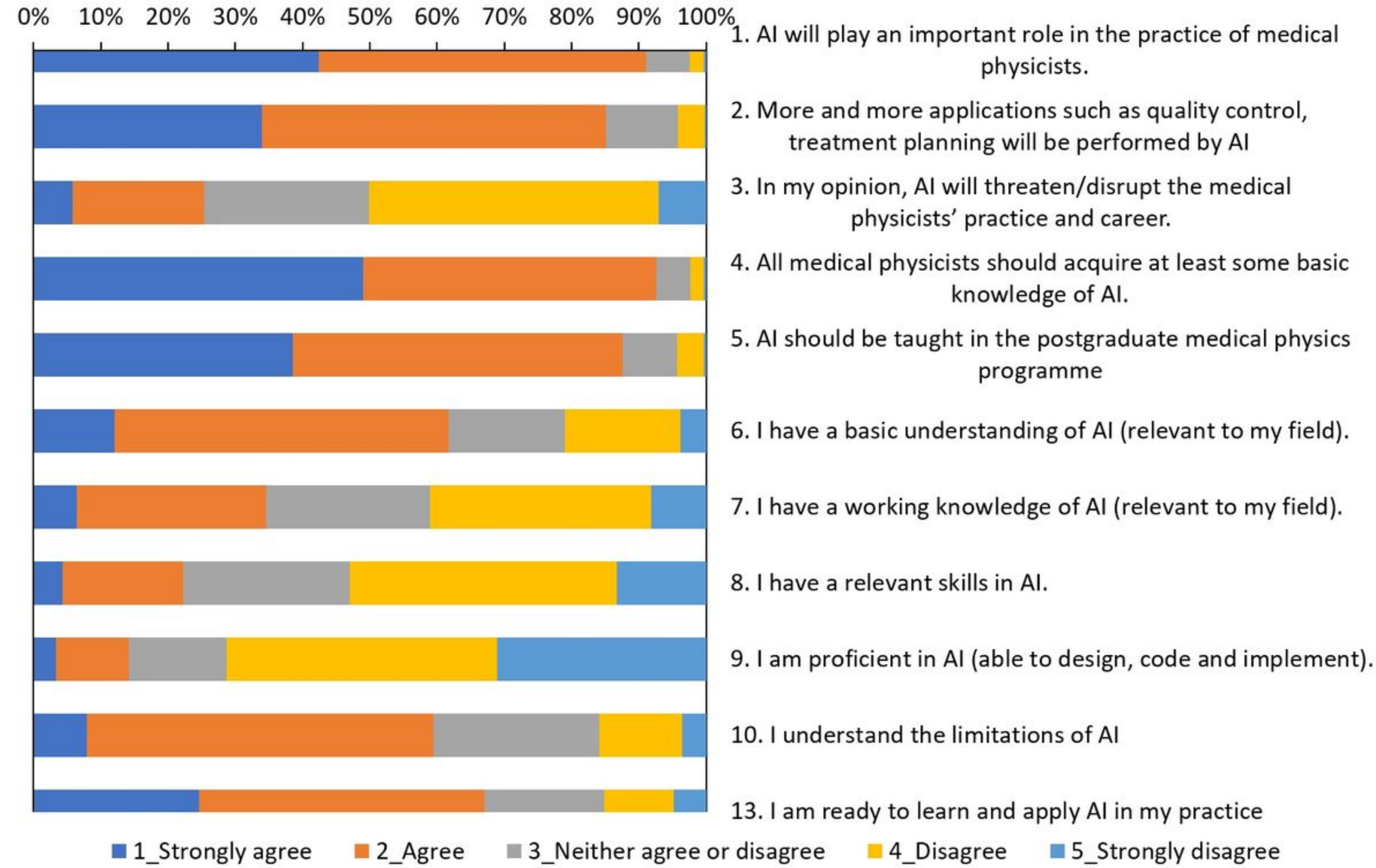

Figure 2

Survey results for Q1 to Q10 and Q13 showing the responders' perception towards AI in medical physics.

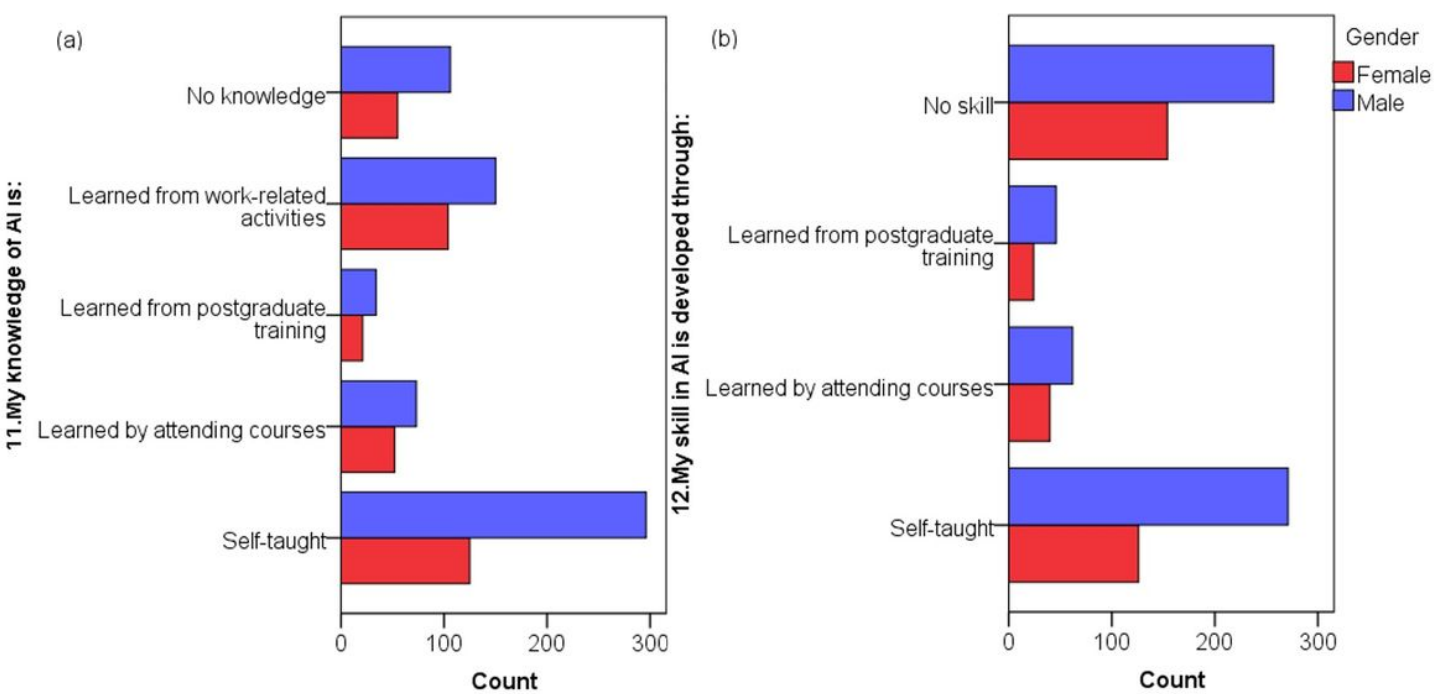

Figure 3

The pathways to acquire (a) knowledge and (b) skills of AI.