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RADIOLOGICAL EDUCATION

# Medical students' attitude towards artificial intelligence: a multicentre survey

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## Abstract

**Objectives** To assess undergraduate medical students' attitudes towards artificial intelligence (AI) in radiology and medicine.

**Materials and methods** A web-based questionnaire was designed using SurveyMonkey, and was sent out to students at three major medical schools. It consisted of various sections aiming to evaluate the students' prior knowledge of AI in radiology and beyond, as well as their attitude towards AI in radiology specifically and in medicine in general. Respondents' anonymity was ensured.

**Results** A total of 263 students (166 female, 94 male, median age 23 years) responded to the questionnaire. Around 52% were aware of the ongoing discussion about AI in radiology and 68% stated that they were unaware of the technologies involved. Respondents agreed that AI could potentially detect pathologies in radiological examinations (83%) but felt that AI would not be able to establish a definite diagnosis (56%). The majority agreed that AI will revolutionise and improve radiology (77% and 86%), while disagreeing with statements that human radiologists will be replaced (83%). Over two-thirds agreed on the need for AI to be included in medical training (71%). In sub-group analyses male and tech-savvy respondents were more confident on the benefits of AI and less fearful of these technologies.

**Conclusion** Contrary to anecdotes published in the media, undergraduate medical students do not worry that AI will replace human radiologists, and are aware of the potential applications and implications of AI on radiology and medicine. Radiology should take the lead in educating students about these emerging technologies.

**Key Points**

- *Medical students are aware of the potential applications and implications of AI in radiology and medicine in general.*
- *Medical students do not worry that the human radiologist or physician will be replaced.*
- *Artificial intelligence should be included in medical training.*

**Keywords** Artificial intelligence · Education, medical · Radiology · Surveys and questionnaires

**Abbreviations**

| | |
|---|---|
| AI | Artificial intelligence |
| CSV | Comma Separated Values (a file format) |
| IQR | Interquartile range |
| MRI | Magnetic resonance imaging |

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## Introduction

Over the past few years, the emerging fields of artificial intelligence (AI) and especially deep learning have attracted a great deal of attention in radiology [1–3]. These techniques have mainly been employed for visual tasks such as classification of images (e.g. diagnosis on chest X-rays) or automated segmentation of regions of interest in an image (e.g. segmentation of tumour tissue in brain MRI) [4]. Even major news outlets referred to these topics, most prominently with various newspapers echoing the claim that algorithms potentially outperform human radiologists in recognising pneumonia [5].

However, even prior to these recent developments, various prominent figures (such as Geoffry Hinton, a pioneer in the field of artificial neural networks) have suggested that radiology as a subspecialty could in future be eclipsed by specialised

**Table 1** Fifth part of the questionnaire – demographics and self-reported tech-savviness

| | | | | | |
|---|---|---|---|---|---|
| | Agree entirely | Rather agree | Rather disagree | Disagree entirely | N/A |
| I consider myself a tech-savvy person | 60/263 (22.8%) | 106/263 (40.3%) | 77/263 (29.3%) | 17/263 (6.5%) | 3/263 (1.1%) |
| | Median | Quartiles | Min/Max | | N/A |
| Age (years) | 23 | 21 / 26 | 19 / 58 | | 13/263 (4.9%) |
| | Male | Female | | | N/A |
| Gender | 166/263 (63.1%) | 94/263 (35.7%) | | | 3/263 (1.1%) |

algorithms able to interpret images as well or even better than human observers. Subsequently, during scientific meetings and even on social media, renowned radiologists and scientists shared stories of being approached by residents and undergraduate students concerned that the pursuit of radiology training might be an erroneous career choice [6].

Recently, debates surrounding these issues have cooled down somewhat and the challenges certainly facing radiology in the advent of commercially available AI products are now the subject of more considered discussion. However, it remains unknown whether medical students in general are concerned that AI could replace the radiologist or any other physician. Besides the anecdotal episodes mentioned above, little is known about the attitude of medical students towards AI and deep learning. To address this issue, we performed a multicentre survey amongst undergraduate medical students to assess their feelings on AI in radiology, specifically, and medicine in general and to evaluate whether these students worry that machines might replace radiologists or other physicians in the foreseeable future.

## Materials and methods

We designed an electronic survey using the SurveyMonkey web-application (SurveyMonkey Europe UC). The questionnaire contained several sub-sections, each addressing different aspects (see Tables 1, 2, 3, 4 and 5). The first section was aimed at evaluating whether the students had already heard of deep learning and AI in the context of radiology and whether they felt they had a basic grasp of the underlying technologies. The second section was introduced with a statement that AI is already being employed in relatively common software such as speech- and text-recognition, spam-filters and recommendation algorithms. The respondents were then asked to state whether or not they had already heard this in the media, on social media, during lectures or from friends/family.

In the third and fourth sections, the students were presented with various statements and asked to indicate their level of agreement on a four-point Likert scale (disagree entirely, rather disagree, rather agree, or agree entirely) [7]. While the third section aimed at specific possible applications of AI in radiology, the fourth section had a broader scope and tried to assess the students' general fear of algorithms replacing human radiologists and other physicians.

The last section consisted of questions regarding respondent demographics as well as one question regarding whether the respondents considered themselves tech-savvy or not.

The questionnaire was sent out via email and advertised on social media to undergraduate medical students at three major German universities (University of Cologne, University of Bonn, University of Mainz). Participation was voluntary and had no relation to the students' curricular activities. The students were informed that the results of the survey would be used for further statistical evaluation and scientific publication. Respondent anonymity was guaranteed by design.

After the closing date for questionnaire submissions, results were downloaded as a CSV file. For simplified descriptive statistics the categories 'disagree entirely' and 'rather disagree' were summarised as disagreement while 'rather agree' and 'agree entirely' were summarised as agreement. For all other statistical analyses, the original categories were preserved. Statistical analysis was performed using R 3.4.0 with RStudio 1.0.136 [8, 9]. Comparison of the distribution of responses

**Table 2** First section of the questionnaire – AI and deep learning as a topic in radiology

'Deep Learning' and 'Artificial Intelligence' are currently being broadly discussed in the radiological community.

| | Yes | No | N/A | *p*-values (male vs. female / tech-savvy vs. non-tech-savvy) |
|---|---|---|---|---|
| Were you already aware of these topics in radiology? | 138/263 (52.5%) | 123/263 (46.8%) | 2/263 (0.8%) | < 0.001 / <0.001 |
| Do you personally have a basic understanding of the technologies used in these topics? | 81/263 (30.8%) | 179/263 (68.1%) | 3/263 (1.1%) | < 0.001 / <0.001 |

**Table 3** Second part of the questionnaire – previous exposure from different sources to AI as a topic in general

Other applications we use in daily life already use artificial intelligence (e.g. speech-/text-recognition, spam-filters, recommendation algorithms). Were you aware of this?

| | Yes | No | N/A | *p*-values (male vs. female / tech-savvy vs. non-tech-savvy) |
|---|---|---|---|---|
| From the media | 224/263 (85.2%) | 35/263 (13.3%) | 4/263 (1.5%) | 0.915 / 0.788 |
| From social media | 173/263 (65.8%) | 77/263 (29.3%) | 13/263 (4.9%) | 0.857 / 0.056 |
| From lectures | 147/263 (55.9%) | 104/263 (39.5%) | 12/263 (4.6%) | 0.026 / 0.790 |
| From friends / family | 161/263 (61.2%) | 87/263 (33.1%) | 15/263 (5.7%) | 0.014 / 0.082 |

across sub-groups was performed using the Wilcoxon signed rank test. A $p$-value of <0.05 was regarded as statistically significant. Figures were plotted using the ggplot2 package [10].

## Results

Over a 2-week period, a total of 263 undergraduate students responded to the questionnaire. Of these, 166 were female and 94 were male (three respondents did not indicate their gender) and the median age was 23 years (interquartile range [IQR] 21 – 26). Almost two-thirds (63.1%) of respondents considered themselves tech-savvy (Table 1).

Of all respondents, a little over half were aware that AI is a hot topic in radiology (52.5% yes vs. 46.8% no). However, only one-third of respondents stated that they had basic knowledge of the underlying technologies (30.8% yes vs. 68.1% no). For both questions there was a statistically significant difference when comparing male and female respondents as well as when comparing those considering themselves tech-savvy and those not (all comparisons $p$<0.001, Table 2). In both cases, male and tech-savvy respondents were more likely to have answered yes to these questions.

As for students already having heard about AI in their day-to-day life, an overwhelming majority stated they had already heard of it from the media (85.2% yes), but also on social media (65.8% yes). Only a smaller number had also already heard about AI during university lectures (55.9% yes) or from friends and family (61.2% yes). For both questions male respondents were significantly more likely to answer yes than females ($p$=0.026 and $p$=0.014), while there was no difference when polled on tech-savviness (Table 3).

Concerning the more radiology-specific questions, there was a broad agreement that AI could be applied to automatically detect pathologies in imaging examinations (83.7% agreement vs. 15.2% disagreement). However, a small majority disagreed that AI could potentially make an automated diagnosis from imaging examinations (42.2% agreement vs. 56.7% disagreement). In both cases, male gender and tech-savviness were associated with higher agreement ($p$-values between 0.017 and <0.001). A majority of students agreed that AI could potentially perform automated indication of appropriate imaging examinations (56.7% agreement vs. 41.4% disagreement). More detailed results can be found in Table 4.

While the vast majority agreed that AI will revolutionise radiology (77.2% agreement) and medicine in general (73% agreement), most disagreed that human physicians in general (96.6% disagreement) as well as radiologists could be replaced in the foreseeable future (82.9% disagreement). Nevertheless, one-third of respondents were somewhat concerned by the recent developments in AI (37.7% agreement) and less than half stated that these developments make radiology or medicine more exciting to them (30.8% and 44.5%, respectively). The vast majority, however, agreed that the use of AI will improve radiology (85.8% agreement) and medicine as a whole (83.6% agreement). Moreover, 70.1% of

**Table 4** Third section of the questionnaire – applications for AI in radiology

What potential applications for AI in radiology do you see?

| | Agree entirely | Rather agree | Rather disagree | Disagree entirely | N/A | *p*-values (male vs. female/tech-savvy vs. non-tech-savvy) |
|---|---|---|---|---|---|---|
| Automated detection of pathologies in imaging exams | 106/263 (40.3%) | 114/263 (43.4%) | 36/263 (13.7%) | 4/263 (1.5%) | 3/263 (1.1%) | <0.001 / 0.001 |
| Automated diagnosis in imaging exams | 32/263 (12.2%) | 79/263 (30.0%) | 122/263 (46.4%) | 27/263 (10.3%) | 3/263 (1.1%) | <0.001 / 0.017 |
| Automated indication of appropriate imaging exams | 35/263 (13.3%) | 114/263 (43.4%) | 90/263 (34.2%) | 19/263 (7.2%) | 5/263 (1.9%) | 0.736 / 0.633 |

**Table 5** Fourth section of the questionnaire – feelings and attitudes towards AI and deep learning in medicine and radiology

In your personal opinion, how accurate are the following statements?

| | Agree entirely | Rather agree | Rather disagree | Disagree entirely | N/A | *p*-values (male vs. female / tech-savvy vs. non-tech-savvy) |
|---|---|---|---|---|---|---|
| Artificial intelligence will revolutionise radiology | 76/263 (28.9%) | 127/263 (48.3%) | 54/263 (20.5%) | 1/263 (0.4%) | 5/263 (1.9%) | <0.001 / <0.001 |
| Artificial intelligence will revolutionise medicine in general | 94/263 (35.7%) | 98/263 (37.3%) | 55/263 (20.9%) | 11/263 (4.2%) | 5/263 (1.9%) | <0.001 / <0.001 |
| The human radiologist will be replaced in the foreseeable future | 6/263 (2.3%)) | 34/263 (12.9%) | 124/263 (47.2%) | 94/263 (35.7%) | 5/263 (1.9%) | 0.008 / 0.788 |
| The human (non-interventional) physician will be replaced foreseeable future | 2/263 (0.8%) | 15/263 (5.7%) | 79/263 (30.0%) | 162/263 (61.6%) | 5/263 (1.9%) | 0.258 / 0.982 |
| In the foreseeable future all physicians will be replaced | 1/263 (0.4%) | 3/263 (1.1%) | 41/263 (15.6%) | 213/263 (81.0%) | 5/263 (1.9%) | 0.375 / 0.903 |
| These developments frighten me | 28/263 (10.7%) | 71/263 (27.0%) | 104/263 (39.5%) | 54/263 (20.5%) | 6/263 (2.3%) | <0.001 / 0.027 |
| These developments make radiology more exciting to me | 21/263 (8.0%) | 60/263 (22.8%) | 112/263 (42.6%) | 64/263 (24.3%) | 6/263 (2.3%) | 0.612 / 0.001 |
| These developments make medicine in general more exciting to me | 31/263 (11.8%) | 86/263 (32.7%) | 101/263 (38.4%) | 40/263 (15.2%) | 5/263 (1.9%) | <0.001 / 0.002 |
| Artificial intelligence will never make the human physician expendable | 136/263 (51.7%) | 73/263 (27.8%) | 38/263 (14.5%) | 11/263 (4.2%) | 5/263 (1.9%) | 0.868 / 0.528 |
| Artificial intelligence will improve radiology | 73/263 (27.8%) | 154/263 (58.6%) | 28/263 (10.6%) | 2/263 (0.8%) | 6/263 (2.3%) | <0.001 / 0.013 |
| Artificial intelligence will improve medicine in general | 72/263 (27.4%) | 148/263 (56.3%) | 34/263 (12.9%) | 4/263 (1.5%) | 5/263 (1.9%) | <0.001 / <0.001 |
| Artificial intelligence should be part of medical training | 65/263 (24.7%) | 122/263 (46.4%) | 54/263 (20.5%) | 13/263 (4.9%) | 9/263 (3.4%) | <0.001 / <0.001 |

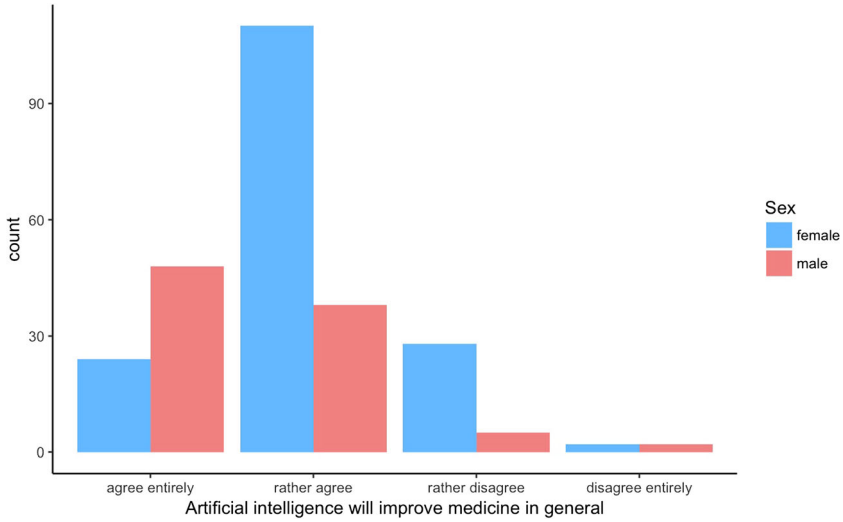


**Fig. 1** Example of distribution of answers from the questionnaire, comparing for gender subgroups. Male respondents were more confident that the application of AI will be beneficial

respondents agreed on the need for AI to be included in medical training. More in-depth results are provided in Table 5.

In general, wherever there was a statistically significant difference between gender or degree of tech-savviness, males and more tech-savvy respondents tended to be more confident on the impact of technology on radiology and medicine, were less concerned and expressed more interest in AI being part of medical training (Figs. 1 and 2).

## Discussion

Without a doubt, AI and deep learning will have a major impact on the future of radiology and medicine in general [11–13]. When these topics first arose at various scientific meetings, it seemed radiologists were most concerned they might lose their jobs in the foreseeable future. Consequently, anecdotal examples of final year students fearing that radiology training could be a poor career choice were shared. However, apart from these anecdotes, there has not been a systematic survey amongst undergraduate medical students regarding their general attitude towards AI in medicine and radiology.

In our study, we found that while most medical students do not necessarily have an understanding of the basic technical principles underlying AI, most of them had already heard about it and half of them were even aware that it was recently being discussed in radiology. Although most did not think that algorithms will be able to make specific diagnoses in imaging examinations, most students were convinced that AI will be able to automatically detect pathologies in imaging examinations and even automatically indicate appropriate examinations. However, contrary to the anecdotes of fearful students being reluctant to choose radiology training, we found that the overwhelming majority of students were confident that in the foreseeable future there will still be the need for human physicians and radiologists. Interestingly, over half the respondents stated that recent developments did not add to their excitement for medicine or radiology. This particular question was unfortunately not very clear as

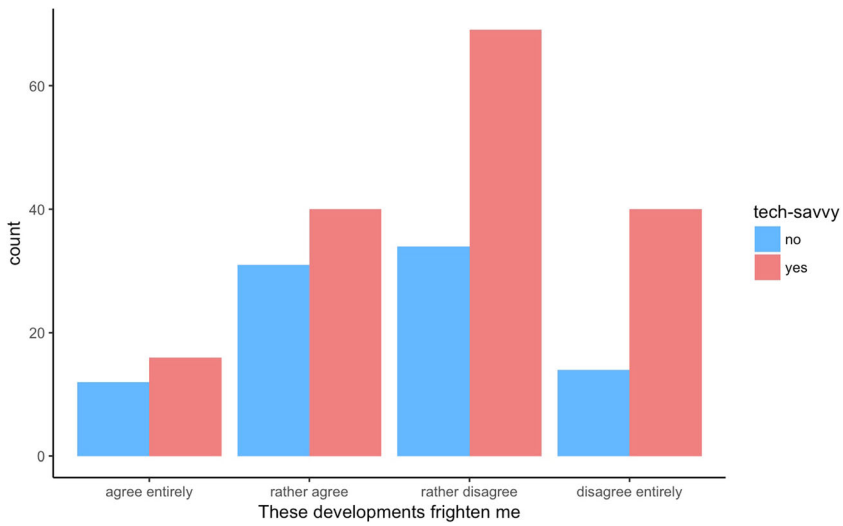


**Fig. 2** Example of distribution of answers from the questionnaire, comparing for subgroups of self-reported tech-savviness. Tech-savvy respondents were less frightened of the potential negative impacts of AI in medicine

to its intended meaning. Responses could be interpreted as suggesting that recent developments in AI in fact make respondents somewhat reluctant to pursue these fields. However, even though this result remains somewhat ambiguous, when coupled with the response that they did not fear replacement by AI, it could also be interpreted that their excitement for medicine and radiology remains mostly unchanged, with a small proportion of respondents even stating that it added to their excitement. Nevertheless, undergraduate medical students are well aware that AI will likely revolutionise radiology and medicine in general, with a broad agreement that this revolution will help to bring improvements to the field.

It is still unclear whether or not these hopes are justified, and which parts of medicine and radiology will first benefit (or suffer) from the use of AI. Impressive results have already been made (e.g. outside the radiology field – Google's paper on retinopathy detection and Stanford's paper on skin cancer detection), and for some applications data suggest that properly trained algorithms can perform comparably to humans [14, 15]. Nevertheless, we are still a long way from AI being fully integrated in clinical workflows.

Over the last few months, the general tone in the discussion of AI in radiology has shifted from fear of complete replacement to a more differentiated statement: "AI will not replace the radiologist, but radiologists that use AI will replace those that do not". Knowledge and a basic understanding of the key principles in deep learning and AI will probably be crucial for future generations of radiologists and physicians in general. We found that there were some differences in attitude and knowledge regarding AI and deep learning, depending on gender and self-reported tech-savviness. Considering the huge impact these technologies could potentially have on the future of medicine and radiology, there is a strong need to incorporate basic training in these topics into undergraduate and postgraduate medical curricula, hopefully also compensating for these differences. Interestingly, the respondents in our study seemed well aware of this and expressed an interest in topics of this kind being integrated into medical training.

However, it should be noted that this study has some limitations and it may not be possible to extrapolate results to other countries and other training curricula. Moreover, as we examined only the attitude of undergraduate medical students, it could be argued that postgraduate students or even more senior physicians do not share the students' rather optimistic views. A potentially interesting topic for further study would be to investigate these different groups as well, in order to also address their specific concerns. Likewise, it could be of interest to specifically examine if those more skeptical of the impact of AI on radiology do indeed tend to avoid radiology training. However, this aspect should be put into perspective with the general quota of undergraduates applying for radiology training and should be carefully separated from other personal traits that may impact their choice of specialty.

As one of the first sub-specialties to broadly discuss the impact of AI on medicine, radiology should therefore take the lead in educating undergraduate students on these emerging technologies, emphasising the specific challenges that may lay ahead. More specifically, basic knowledge of the technical background of AI in medicine and radiology should be conveyed in terms of what data are needed for which type of task and how AI algorithms should be evaluated.

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## Compliance with ethical standards

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**Conflict of interest** The authors of this paper declare no relationships with any companies whose products or services may be related to the subject matter of the article.

**Statistics and biometry** No complex statistical methods were necessary for this paper.

**Informed consent** Written informed consent was not required for this study because this study involved no patients. Participation in the questionnaire was voluntary and had no relation to the students' curricular activities. Respondents were informed on the nature and purpose of the questionnaire and anonymity was guaranteed.

**Ethical approval** Institutional Review Board approval was not required because this study involved no patients. Participation in the questionnaire was voluntary and had no relation to the students' curricular activities. Respondents were informed on the nature and purpose of the questionnaire and anonymity was guaranteed.

**Methodology**
- prospective
- cross-sectional study
- multicentre study

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