Research article

# A survey on the future of radiology among radiologists, medical students and surgeons: Students and surgeons tend to be more skeptical about artificial intelligence and radiologists may fear that other disciplines take over

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## ARTICLE INFO

## ABSTRACT

*Purpose:* To evaluate the opinion and assessment of radiologists, surgeons and medical students on a number of important topics regarding the future of radiology, such as artificial intelligence (AI), turf battles, teleradiology and 3D-printing.

*Method:* An online questionnaire was created using the SurveyMonkey platform targeting radiologists, students and surgeons throughout the German speaking part of Switzerland. A total of 170 people participated in the survey (59 radiologists, 56 surgeons and 55 students). Statistical analysis was carried out using the Kruskal-Wallis test with Dunn's multiple comparison post-hoc tests.

*Results:* While the majority of participants agreed that AI should be included as a support system in radiology (Likert scale 0-10: Median value 8), surgeons were less supportive than radiologists ($p = 0.001$). Students saw a potential threat of AI as more likely than radiologists did ($p = 0.041$). When asked whether they were concerned about "turf losses" from radiology to other disciplines, radiologists were much more likely to agree than students ($p < 0.001$). Of the students that do not intend to specialize in radiology, 26 % stated that AI was one of the reasons. Surgeons advocate the use of teleradiology.

*Conclusions:* With regard to AI, radiologists expect their workflow to become more efficient and tend to support the use of AI, whereas medical students and surgeons tend to be more skeptical towards this technology. Medical students see AI as a potential threat to diagnostic radiologists, while radiologists themselves are rather afraid of turf losses.

## 1. Introduction

Harvard Professor Clayton Christensen first introduced the theory of "disruptive innovation" in his book "The Innovator's dilemma" [1]. A disruptive innovation is one that significantly alters the way businesses or entire industries operate and leads to the displacement of established technologies. In radiology, AI (artificial intelligence) could be such a disruptive technology that might tremendously change the way diagnostic imaging is performed. Further challenges towards the current way radiology operates could be turf losses (takeovers of radiological examinations by other disciplines), growing competitiveness of the job market and teleradiology [2–6]. An opportunity could arise for radiology by establishing itself as a specialist in 3D printing. Seeing a great future in the use of AI in radiology, a vast amount of research is being performed in this field, by academic centers but also by the industry, e.g. by digital giants like Google and Apple [7–10]. With optimal use, AI could help radiologists and ultimately hospitals work more efficiently and thus save money by implementing AI based software to perform easy and repetitive but time-consuming tasks such as nodule detection [11]. With radiologists and AI currently being on the same level of accuracy in detecting nodules [12,13], they could improve their diagnostic accuracy by using artificial intelligence [14]. Not only could

radiologists be supported in detecting abnormalities, they could also take advantage of AI-assisted interpretation and potentially AI-based integration of other clinical information [15–17]. Further application of these developments includes the use in an emergency setting, where cases of pneumothorax, bleedings, renal stones and foreign bodies could be automatically identified, assisting radiologists in the diagnostic process, optimizing it to be faster and more accurate [18]. The use of AI is a growing field in radiology, which can be a concern or even a threat to practicing diagnostic radiologists, as the renowned Geoffrey Hinton, an expert on artificial neural networks, believes [11].

Since the topic of AI implementation into radiology, the takeover of radiological examinations by other disciplines, teleradiology, and 3D printing are subjects of heated discussions, we wanted to know how radiologists, medical students and surgeons perceive these developments. We were interested in the opinions of medical students, as they are the next generation of doctors and possible radiologists, and the opinions of surgeons, as a group of clinicians whose work is strongly influenced by radiology. Thereby we conducted a survey to evaluate the opinions and assessments of radiologists, surgeons and medical students on a variety of potential chances and threats to radiology.

## 2. Materials and methods

The SurveyMonkey platform was used to create an electronic survey with implemented logic that allowed us to ask participants profession-adapted questions following a general questionnaire. The survey was divided into different sections. The first section consisted of a group of demographic questions, followed by questions on the future of radiology such as questions on AI, teleradiology, turf losses, 3D printing and the future of the profession of radiologists. Subsequent sections were separated by profession to avoid the collection of unnecessary data. In addition, radiologists and students were asked about their career choice regarding radiology in the context of AI and surgeons were asked about radiology use in their work environment. These questions are shown in Tables 1–4 and Figs. 1–3.

We planned to interview at least 150 individuals, with at least 50 individuals from each profession. Only medical students from Switzerland were interviewed and the link to the online questionnaire was distributed via social media. This link was openly accessible for medical students. Radiologists and surgeons were contacted in hospitals throughout the German speaking part of Switzerland, where the link was distributed by the secretariats after approval by e-mail. The link was distributed and accessible only during the months of May and June 2018.

There was no obligation to participate and there was no connection to curricular activities. SurveyMonkey and the design of the questionnaire provided respondent anonymity. Statistical analysis was performed using Kruskal-Wallis tests with Dunn's multiple comparison post-hoc tests, using GraphPad Prism (Version 7.1, GraphPad Software Inc, San DiegoCA). A p-value of < 0.05 was considered statistically significant.

## 3. Results

Over a four-week period, a total of 203 individuals filled out the questionnaire, of which 170 completed it. Of these 170 participants, 59 were radiologists (40 diagnostic; 2 interventional; 17 both), 56 were surgeons and 55 were students. Of the participants who completed the questionnaire, 40 % were female, 59 % were male, and 1 % answered other.

### 3.1. AI in radiology

In general, participants favoured the future use of AI in radiology; (Likert scale 0–10 (0 = strongly disagree, 10 = strongly agree), median 8), but radiologists supported this idea significantly more than surgeons

(p = 0.001; Table 1 and Fig. 1). Generally, participants from all professions had less positive views on whether AI should be used alone for image evaluation after achieving high diagnostic accuracy, with a tendency for surgeons to be more skeptical (Likert scale 0–10, median 3, p = 0.097). Participants' opinions did not differ significantly on where the generated data should be stored (p = 0.058). The majority of participants (59 %) answered it should be stored in hospitals, 32 % believed that it should be stored in National (research) institutions, 2 % believed that it should be stored in the industry, and 7 % in other storage places (e.g. the patient should store his own data). In addition, the participants could not agree on where liability should lie in the event of an error committed by the AI, but they agreed that they did not want the interpretation of the AI to be performed at the patient's own risk. Their opinions did not differ significantly (p = 0.558).

### 3.2. The future of radiologists

Using a 21-point Likert scale (−1 0 to 10 : −10 = strongly disagree, 10 = strongly agree), the 170 participants were not confident about the future of radiologists. They only slightly disagreed on the question of whether the profession of the diagnostic radiologist would be endangered in the future (median 0). Concerning this question, radiologists (median -3), surgeons (median 0) and students (median 1) had similar opinions and these differences were not statistically significant (p = 0.206). When asked whether there would be more or less diagnostic and interventional radiologists in the future, participants responded that there would be more interventional (−1 0 to 10 : −10 = maximal fewer; 10 = maximal more: median 2) and less diagnostic radiologists (median −2). This difference was statistically significant (p < 0.001).

Furthermore, participants were even more uncertain whether the profession of the diagnostic radiologist would be jeopardized in the future by new technical innovations such as AI (−1 0 to 10 : −10 = strongly disagree, 10 = strongly agree: median 0). There was a statistically significant difference between the radiologists and the students, with the students' answers being more pessimistic (median 1) than the radiologists' (median -3) (p = 0.041; Table 1 and Fig. 2). Using the eleven-point Likert scale (0-10), we found that radiologists do not fear the loss of their job due to technological developments (median 1). Furthermore, the majority of radiologists expected an acceleration of their work using AI (median 7).

Among the radiologist respondents, 91 % replied that in the current situation they would choose radiology as a specialization again, with 79 % of them confirming that their interest in future technologies, such as AI, is one reason for this. Only 9 % of the radiologists would not choose radiology again.

Of the students participating in this survey, 15 % answered they considered radiology as a possible future specialization. Of the students who did not consider radiology as an option for specialization, 26 % cited the future use of AI as one of the reasons not to choose radiology.

### 3.3. Turf losses in radiology

When participants were asked whether the profession of the diagnostic radiologist will be endangered by takeovers of radiological examinations by other disciplines ("turf losses"), e.g. cardiac imaging performed by cardiologists (Likert scale -1 0 to 10, median 1), there was a statistically significant difference between radiologists and students. While radiologists see turf losses to be quite possible (median 3), students on the other hand are significantly less negative (median -2) (p < 0.001; Table 1, Figs. 3 and 4). When asked whether the profession of the diagnostic radiologist will be endangered in the future, in general the participants were less skeptical in comparison to the threat due to turf wars towards diagnostic radiologists. This difference was statistically significant (p = 0.012).

**Table 1**

Statistical analysis was carried out using the Kruskal-Wallis test with Dunn's multiple comparison post-hoc tests. A p-value of < 0.05 was seen as statistically significant and a p-value of 0.05-0.1 was seen as a trend.

| Question/Statement | Median/Mean | | ANOVA p-value | Dunn's multiple comparisons test p-value |
|---|---|---|---|---|
| Artificial intelligence should be used as a support for evaluating radiological images. Likert scale (0-10) | All: | 8/7.3 | p = 0.002 | STU vs RAD: N.S |
| | STU: | 8/7.5 | | STU vs SUR: N.S. |
| | RAD: | 9/8.2 | | RAD vs SUR: p = 0.001 |
| | SUR: | 7/6.3 | | |
| If artificial intelligence achieves high diagnostic accuracy, it should be used to evaluate radiological images alone. | All: | 3/3.4 | N.S. | N.S. |
| Likert scale (0-10) | STU: | 3/3.7 | p = 0.097 | |
| | RAD: | 3/3.7 | | |
| | SUR: | 2/2.8 | | |
| If a mistake has been made using artificial intelligence, who do you think should be liable? Hospitals (27%) – AI company (27%) - Radiologist (31%) - Risk of Patient (5%) – Others (11%) | | | N.S. | N.S. |
| In 20 years, there will be more / fewer diagnostic radiologists than today. *Likert scale (-10-10) | All: | 1.818182 | N.S. | N.S. |
| | STU: | 1.333333 | | |
| | RAD: | 1.666667 | | |
| | SUR: | 1.25 | | |
| In 20 years, there will be more / fewer interventional radiologists than today. *Likert scale (-10-10) | All: | 2/2.3 | N.S. | N.S. |
| | STU: | 2/2.2 | | |
| | RAD: | 02-Feb | | |
| | SUR: | 3/2.7 | | |
| The profession of diagnostic radiologists will be endangered in the future. Likert scale (-10-10) | All: | 0/-1.1 | N.S. | N.S. |
| | STU: | 1/-0.2 | | |
| | RAD: | 1.666667 | | |
| | SUR: | 0/1.3 | | |
| The profession of the diagnostic radiologist will be endangered in the future by new technologies, such as AI. | All: | 0/-0.7 | p = 0.048 | STU vs RAD: 0.041 |
| Likert scale (-10-10) | STU: | 1/0.4 | | STU vs SUR: N.S. |
| | RAD: | 1.578947 | | RAD vs SUR: N.S. |
| | SUR: | 1/-0.6 | | |
| The profession of the diagnostic radiologist will be endangered in the future by turf losses to other disciplines (e.g. heart imaging by cardiologists). | All: | 1/0.3 | p = 0.001 | STU vs RAD: < 0.001 |
| Likert scale (-10-10) | STU: | 1.538462 | | STU vs SUR: N.S. |
| | RAD: | 3/1.7 | | RAD vs SUR: N.S. |
| | SUR: | 1/0.5 | | |
| Who should have the sovereignty over the produced data? Hospitals (59%) - National (research-) institutions (32%) - Industry (2%) – Others (7%) | | | N.S. p = 0.058 | N.S. |
| 3D Printing will play an important role in medicine in the future. Likert scale (0-10) | All: | 07-Jul | N.S. | N.S. |
| | STU: | 7/7.4 | | |
| | RAD: | 7/6.6 | | |
| | SUR: | 07-Jul | | |
| Who should control the 3D printing? Radiology (42.4%) – Surgery (25.9%) – IT (17.1%) – Others (14.7%) | | | N.S. | N.S. |
| Teleradiology may become an increasingly used area of radiology. Would this be a good development? Likert scale (0-10) | All: | 7/6.7 | N.S. | N.S. |
| | STU: | 7/6.8 | | |
| | RAD: | 7/6.6 | | |
| | SUR: | 7/6.7 | | |

Likert scale 0–10: 0 = strongly disagree; 10 = strongly agree.  
Likert scale -1 0 to 10 : -10 = strongly disagree; 10 = strongly agree.  
\* Likert scale -1 0 to 10 : -10 = maximal fewer; 10 = maximal more.

### 3.4. Teleradiology and 3D-printing in radiology

Teleradiology was considered to be a rather good development (Likert scale 0–10, median 7, no statistically significant difference between the participants; p = 0.986) and radiologists did not feel threatened by it (Likert scale 0–10, median 2). In addition, many radiologists could imagine doing most of their work from home (Likert scale 0–10, median 6). Surgeons did not fear turf losses to radiologists through interventional radiology (Likert scale 0–10, median 3) and welcome 3D illustrations, as they are likely to make everyday life in surgery easier in the future (Likert scale 0–10, median 8). In addition to these 3D illustrations supported by surgeons, all three groups thought that 3D printing would play an important role in the future of medicine in general (Likert scale 0–10, median 7, no statistically significant difference between the participants; p = 0.21). Overall, 42 % would like radiology to be in control of the emerging field of 3D printing, 26 % surgery, only 17 % IT and 15 % others. Participants' opinions did not differ significantly on who should be in control (p = 0.182).

### 4. Discussion

The aim of this study was to investigate the perceptions and attitudes of radiologists, surgeons and medical students towards AI and other developments that might represent opportunities or threats to radiology as a field of work.

Our results show in part substantial differences in the perception of AI among participants. While all three groups agree that AI should be integrated into the diagnostic process of radiological imaging, radiologists tend to support a future use of AI more than surgeons. Students find themselves somewhere in between. However, as students presume that AI might change radiology, and despite them stating that it should be integrated into radiology, they see AI significantly more threatening to radiology than radiologists do. More than a quarter of students who do not consider radiology as their future specialty see AI as one of the reasons not to go into radiology. Our results lead to the question of whether students are too pessimistic regarding the future of radiology or radiologists are too optimistic. With comments like the one by Prof

**Table 2**

Likert scale 0–10: 0 = strongly disagree; 10 = strongly agree.

| Question/Statement | Further results | |
|---|---|---|
| In today's situation, would you again opt for radiology as a specialization?<br>Yes (91%) – No (9%) | - | |
| When answered Yes: Would your interest in future technological developments in radiology (such as artificial intelligence) be one reason for you to re-elect radiology as a specialty?<br>Yes (79%) – No (21%) | - | |
| You are afraid to become unemployed due to technological developments.<br>Likert scale (0-10) | Median | −1 |
| | Mean value | 1.8 |
| | Standard deviation | 2.05 |
| You expect a significant acceleration of your work from new technologies (AI / Artificial Intelligence).<br>Likert scale (0-10) | Median | 7 |
| | Mean value | 6.6 |
| | Standard deviation | 2.33 |
| Could you imagine doing a great deal of you work from home, using teleradiological software?<br>Likert scale (0-10) | Median | 6 |
| | Mean value | 5.9 |
| | Standard deviation | 2.66 |
| Teleradiology is a threat to your job.<br>Likert scale (0-10) | Median | 2 |
| | Mean value | 2.4 |
| | Standard deviation | 2.02 |

Hinton that it was "quite obvious that we should stop training radiologists" [19], students might be intimidated when they consider radiology as a specialty. On the other hand, the majority of publications by radiologists on this topic tend to regard the profession of radiology as future-proof despite new developments [20–24], as long as they position themselves accordingly [25]. Nevertheless, does this also apply to the radiologists surveyed in this study? Our survey suggests that the radiologists asked were not extremely confident about their future either and were uncertain about whether their future will be jeopardized by AI. On the statement: "The profession of diagnostic radiologists will be endangered in the future", radiologists responded with a median of -3 on (Likert scale of -10–10; -10: very unlikely, 10: very likely). This means they think it is rather unlikely that diagnostic radiologists will be endangered in future, but not very unlikely. One has to imagine how for example abdominal surgeons would have answered this question about their own future. Additionally, there was a statistically significant difference when asked if there will be more or less diagnostic/interventional radiologists. All participants, including radiologists, estimated that there would be less diagnostic and more interventional radiologists in the future.

This uncertainty indicates that the future of radiology should be discussed more during medical education, but also among radiologists. Students might overestimate the dangers of AI to radiology, whereas many radiologists might perceive the future of AI in fact to be more negative than how it is portrayed in most radiological publications on this topic. Such efforts could lead to better education of the students about AI and thus attune them to a more positive view of this emerging technology within the field of radiology. Since early exposure to radiology in medical studies has shown a positive effect on the students' attitude towards radiology [26], it should be taught as early as possible together with AI. Kobayashi Y at al. also pointed out the importance of including AI early in the educational program of residents [24].

In addition, the reading of images has drastically increased in recent years for radiologists and with AI support, the number and complexity

**Table 4**

A selection of Questions/Statements answered by students.

| Question/Statement |
|---|
| Are you considering radiology as specialization?<br>Yes (15%) – No (86%) |
| When answered No: Is the future use of Artificial Intelligence (AI) a reason for you not to elect radiology?<br>Yes (26%) – No (75%) |

of the reports might continue to increase as more and more quantitative data is generated. This prospect may not always be very attractive to future radiologists and may influence the willingness of young colleagues to become radiologists in the future. On the other hand, these new possibilities could attract tech-savvy students to choose radiology as their specialty. Moreover, the possibilities AI bears might allow radiology to become a key player in directing patients and patient treatment. The fact that the participants were unable to agree on where liability should lie in the event of an AI error reflects the uncertainty that exists here. Ethical and legal issues of AI are currently the subject of intense debate [27,28]. At the end of an AI-based interpretation, radiologists would be the only ones able to notice mistakes made, whereas they would not have the time to proofread everything, because of the increased numbers of reading judgements. In addition, radiologists may not fully understand the means by which a diagnosis was made using AI, creating a "black box" element [19]. While some authors state that there is currently no evidence of a change in responsibility [29], others are discussing this question intensively [19]. Who is liable depends on the country in which the AI application was used, whether it is considered a product or service by law, and whether the limitations have been clearly communicated to the user [30]. The benefit of AI would be much less if radiologists had to check every interpretation. However, the participants in this survey agreed that they did not want AI-based interpretation to be performed at the patients' own risk. The
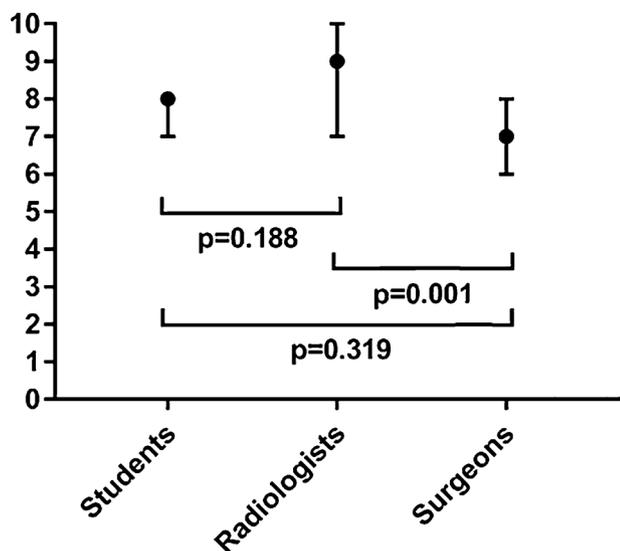
**Table 3**

Likert scale 0–10: 0 = strongly disagree; 10 = strongly agree.

| Question/Statement | Further results | |
|---|---|---|
| Intraoperative 3D illustrations will make everyday life in surgery easier in the future (for example 3D printing of the liver or lung vessels for visualization).<br>Likert scale (0-10) | Median | 8 |
| | Mean value | 7.8 |
| | Standard deviation | 1.98 |
| Interventional-radiographic techniques pose a risk to surgery.<br>Likert scale (0-10) | Median | 3 |
| | Mean value | 3.3 |
| | Standard deviation | 2.25 |

**Fig. 1.** AI should be used in Radiology.
Statement: Artificial intelligence should be used as a support for evaluating radiological images. 0: strongly disagree / 10: strongly agree. Statistical analysis was carried out using the Kruskal-Wallis test with Dunn's multiple comparison post-hoc tests.
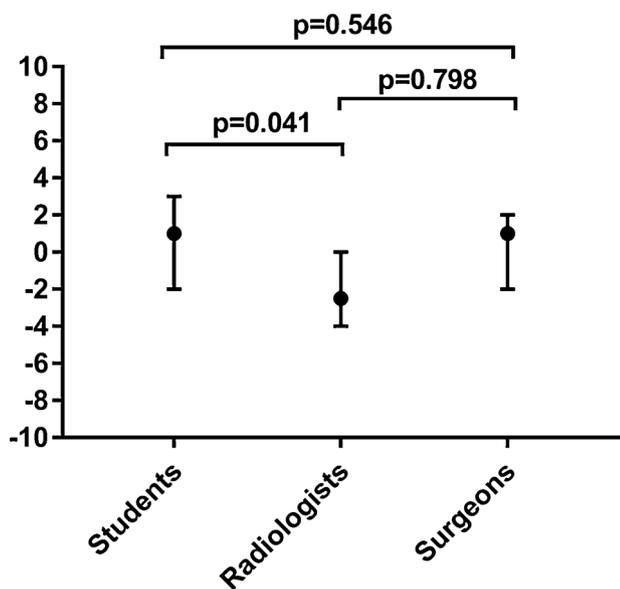Radiologists tend to support future use of AI more than surgeons do.



**Fig. 2.** AI threatens the jobs of radiologists.
Statement: The profession of the diagnostic radiologist will be endangered in the future by new technologies as AI. -10: strongly disagree / 10: strongly agree. Statistical analysis was carried out using the Kruskal-Wallis test with Dunn's multiple comparison post-hoc tests.
Students tend to perceive AI as a bigger threat than radiologists do.



**Fig. 3.** Concern for turf losses.
Statement: The profession of the diagnostic radiologist will be endangered in the future by turf losses to other disciplines (e.g. heart imaging by cardiologists).
-10: strongly disagree / 10: strongly agree.
Statistical analysis was carried out using the Kruskal-Wallis test with Dunn's multiple comparison post-hoc tests.
Radiologists tend to be more negative regarding turf losses than students are.

However, these concerns about turf losses and work force changes might be very country specific, as the health care system in Switzerland is different to others and there might be different threats in different regions. In addition, it seems that there are quite different levels of development in different countries as to how far these turf battles have been fought.

Turf wars seem to be perceived differently by other disciplines, as the surgeons asked in our survey feel less threatened by interventional-radiographic techniques than radiologists do about other disciplines. However, as turf wars in the past posed a danger for radiology, AI could be a chance to start anew and win other turf battles in Switzerland and maybe other countries as well. In the future, not only radiologists or physicists might use AI [24]. The use of AI has the potential to combine radiological information in a much more sophisticated way and increase the value of radiological work. The integration of clinical information offers radiologists the opportunity to be on par with clinicians in patient-centred healthcare.

Teleradiology is not perceived as a threat, but it is rather seen as a positive development in the field of radiology. This perception was shared almost equally among all three groups participating in this survey. Teleradiology could benefit radiologists since it allows them to be more flexible with their working hours. It is somewhat surprising that surgeons also see teleradiology as a positive development. We speculate that surgeons might benefit from a radiology service as well, especially in smaller hospitals, when the alternative would be no radiology service at all, or an on-call service that requires radiologists to go to the hospital at night, which could prolong clinical decisions.

Also well received was 3D printing, which is seen as an important tool for the future of medicine in general, especially by surgeons, e.g. 3D printing of the liver or lung vessels for visualization purposes. With the participants wanting radiology to be in control of 3D printing, this could be a chance for radiology to emerge in this upcoming field, which could utilize the use of AI.

In contrast to a survey of undergraduate students in Germany [31], our survey suggests that medical students might be afraid to specialize in radiology because, among other reasons, they seem to fear the

benefit of using AI would be much less if radiologists would have to review every interpretation.

Interestingly, while radiologists might see a threat in turf losses from radiology to other disciplines, students seem less pessimistic about this. The reason for this could simply be a lack of information. In the past, radiologists have experienced these shifts and takeovers of certain examinations from radiology to other disciplines, whereas students are often uninformed about these changes. Since all participants considered the general threat to the diagnostic radiologist by all factors to be less significant than the threat imposed by turf battles, it points to a general awareness that these takeovers might pose problems for radiologists.
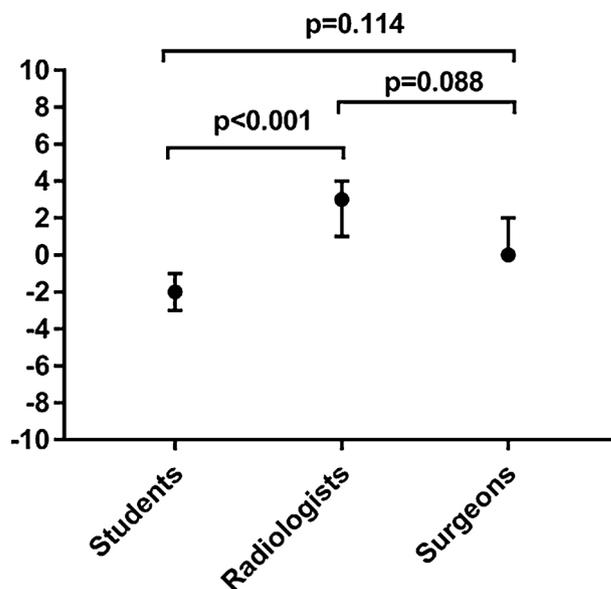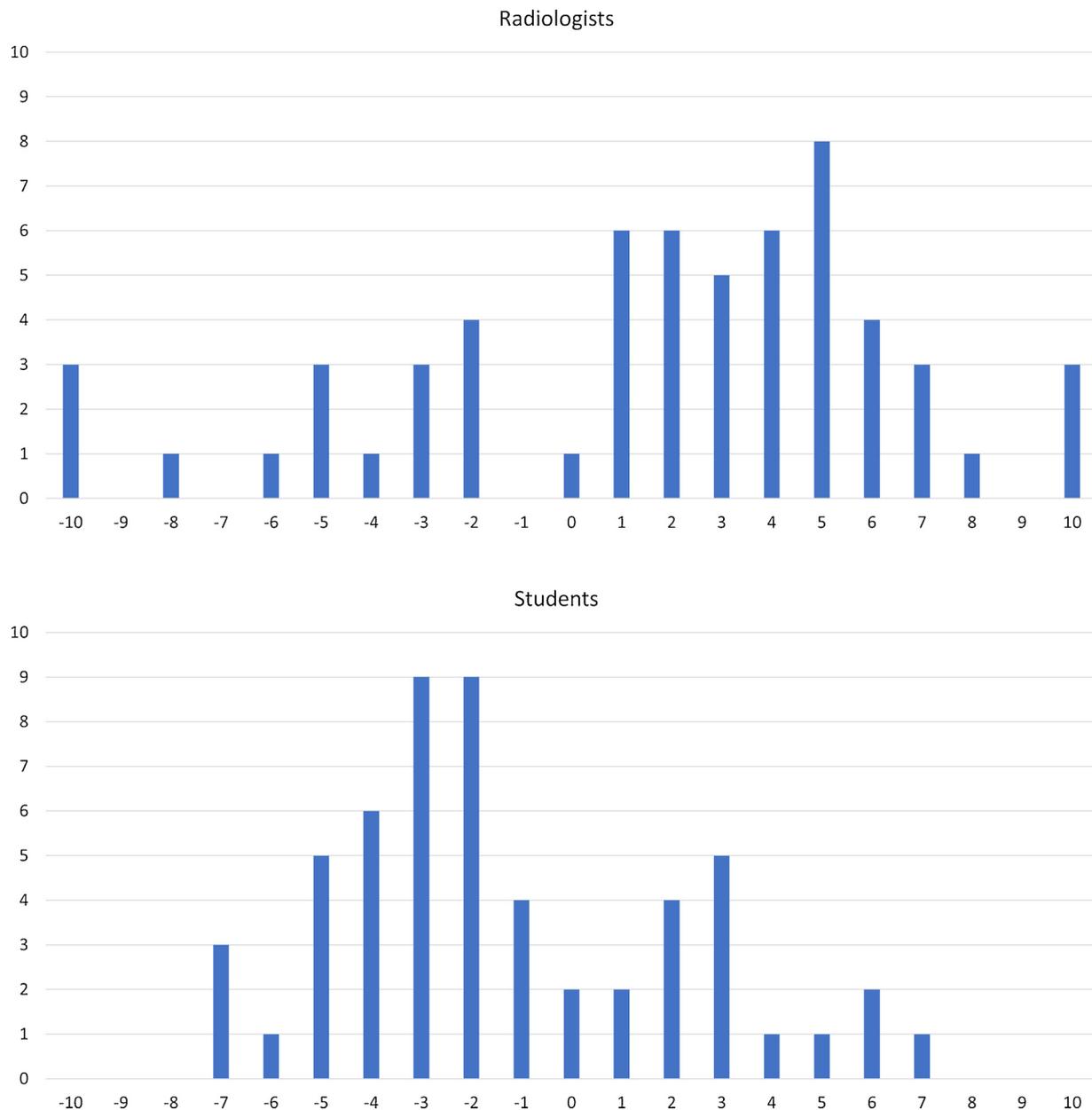
**Fig. 4.** Distribution of answers.
Distribution of answers to the statement: The profession of the diagnostic radiologist will be endangered in the future by turf losses to other disciplines (e.g. heart imaging by cardiologists) by radiologists and students.

unknown future of AI. Our results are in line with a survey performed in Canada that included all medical schools there [32]. We can agree with both Canadian and German studies that AI and its potential impact on radiology should be discussed in the curriculum of medical students.

Limitations of this study include the sole data collection in Switzerland. Results might not be applicable to other countries with other student curricula and different health care systems. Furthermore, we did not differentiate the surveyed students by year of study. Another limitation of this study is the selection of only a few, yet important aspects concerning the future of radiology. Further investigations should address other areas of radiology, such as interventional radiology.

In general, the question must be asked whether statistically significant differences are also clinically relevant. In our study, some differences between the groups participating in the study were quite pronounced, such as median differences of up to five on a scale of -10–10. Other differences were not very large, but statistically

significant, as described above. At this point of our investigation, it is not really possible to say whether these statistically significant differences are clinically relevant. With very large sample sizes, even small, insignificant differences can become statistically significant. As this is a smaller survey with only 170 participants, small differences would probably not have had a significant effect. Whether statistical significance also has clinical effects can, however, only be shown in the future and a follow-up study should be carried out.In conclusion, our study suggests, that radiologists might be more afraid of turf losses than of new technologies such as AI. As far as the future is concerned, the general attitude towards AI as a support system in radiology is rather positive, although there might still be some trust issues regarding the responsibility in case of AI mistakes. Radiologists show a rather positive attitude towards AI to become more efficient and precise, but it does not seem to make them extremely confident about their own future. Medical students also advocate the use of AI in radiology but seem to be far more pessimistic regarding danger AI represents to the profession of

the diagnostic radiologist. This is also reflected in the fact that a large proportion of students answered that AI is a reason not to choose radiology as a specialty. This supposed fear might originate from a lack of information and knowledge. Following the assessment of most radiological publications – in our review of them – AI will not be a threat but rather a welcome addition to the radiological workflow. One must say that the results from our study might be worrisome. Students, and especially the best students, might not choose to go into radiology. Thus, better education about this supposed fear seems to be necessary.

## Declaration of Competing Interest

None.

## Acknowledgements

None.

## References

[1] C. Christensen, The Innovator's Dilemma, first, Harvard Business Review Press, Boston, Massachusetts, 1997.

[2] D.C. Levin, V.M. Rao, J. Berlin, Ensuring the future of radiology: how to respond to the threats, J. Am. Coll. Radiol. 10 (2013) 647–651, https://doi.org/10.1016/j.jacr.2013.01.013.

[3] D.C. Levin, V.M. Rao, Turf wars in radiology: should it be radiologists or cardiologists who do cardiac imaging? J. Am. Coll. Radiol. 2 (2005) 749–752, https://doi.org/10.1016/j.jacr.2005.01.020.

[4] D.C. Levin, V.M. Rao, Turf wars in radiology: the future of radiology depends on research-and on your support of it!, J. Am. Coll. Radiol. 4 (2007) 184–186, https://doi.org/10.1016/j.jacr.2006.08.012.

[5] D.C. Levin, V.M. Rao, Turf wars in radiology: introduction, J. Am. Coll. Radiol. 1 (2004) 23–25, https://doi.org/10.1016/S1546-1440(03)00013-9.

[6] P. Schnyder, P. Capasso, J.Y. Meuwly, Turf battles in radiology: how to avoid/how to fight/how to win, Eur. Radiol. 9 (1999) 741–748, https://doi.org/10.1007/s003300050747.

[7] J.A. Brink, R.L. Arenson, T.M. Grist, J.S. Lewin, D. Enzmann, Bits and bytes: the future of radiology lies in informatics and information technology, Eur. Radiol. 27 (2017) 3647–3651, https://doi.org/10.1007/s00330-016-4688-5.

[8] S.H. Tajmir, T.K. Alkasab, Toward augmented radiologists: changes in radiology education in the era of machine learning and artificial intelligence, Acad. Radiol. 25 (2018) 747–750, https://doi.org/10.1016/j.acra.2018.03.007.

[9] T. Syeda-Mahmood, Role of big data and machine learning in diagnostic decision support in radiology, J. Am. Coll. Radiol. 15 (2018) 587–588, https://doi.org/10.1016/j.jacr.2018.01.028.

[10] M. de Bruijne, Machine learning approaches in medical image analysis: from detection to diagnosis, Med. Image Anal. 33 (2016) 94–97, https://doi.org/10.1016/j.media.2016.06.032.

[11] C. Liew, The future of radiology augmented with Artificial Intelligence: a strategy for success, Eur. J. Radiol. 102 (2018) 152–156, https://doi.org/10.1016/j.ejrad.2018.03.019.

[12] A.S. Becker, M. Marcon, S. Ghafoor, M.C. Wurnig, T. Frauenfelder, A. Boss, Deep learning in mammography diagnostic accuracy of a multipurpose image analysis software in the detection of breast Cancer, Invest Radiol. C 52 (2017) 434–440, https://doi.org/10.1097/RLI.0000000000000358.

[13] P.R. Id, J.I. Id, R.L. Ball, K. Zhu, B. Yang, H. Mehta, T. Duan, D. Ding, A. Bagul, C.P.L. Id, N. Patel, K.W.Y. Id, K.S. Id, F.G. Blankenberg, J. Seekins, T.J.A. Id, D.A. Mong, S.S.H. Id, J. Zucker, A.Y. Ng, M.P. Lungren, Deep learning for chest radiograph diagnosis: a retrospective comparison of the CheXNeXt algorithm to practicing radiologists, PLoS Med. (2018) 1–17.

[14] A. Rodríguez-ruiz, E. Krupinski, J. Mordang, K. Schilling, Detection of breast cancer with mammography: effect of an artificial intelligence support system, Radiology (2019), https://doi.org/10.1148/radiol.2018181371.

[15] A.P. Kansagra, J.P.J. Yu, A.R. Chatterjee, L. Lenchik, D.S. Chow, A.B. Prater, J. Yeh, A.M. Doshi, C.M. Hawkins, M.E. Heilbrun, S.E. Smith, M. Oselkin, P. Gupta, S. Ali, Big data and the future of radiology informatics, Acad. Radiol. 23 (2016) 30–42, https://doi.org/10.1016/j.acra.2015.10.004.

[16] R.M. Summers, Progress in fully automated abdominal CT interpretation, Am. J. Roentgenol. 207 (2016) 67–79, https://doi.org/10.2214/AJR.15.15996.

[17] T. Ayer, Q. Chen, E.S. Burnside, Artificial neural networks in mammography interpretation and diagnostic decision making, Comput. Math. Methods Med. 2013 (2013), https://doi.org/10.1155/2013/832509.

[18] A.T. Kharat, S. Singhal, A peek into the future of radiology using big data applications, Indian J. Radiol. Imaging 27 (2017) 241–248, https://doi.org/10.4103/ijri.IJRI_493_16.

[19] O. Access, What the radiologist should know about artificial intelligence – an ESR white paper, Insights Imaging 2 (2019).

[20] A. Hosny, C. Parmar, J. Quackenbush, L.H. Schwartz, H.J.W.L. Aerts, Artificial intelligence in radiology, Nat. Rev. Cancer 18 (2018) 500–510, https://doi.org/10.1038/s41568-018-0016-5.

[21] S. Jha, E.J. Topol, Adapting to artificial intelligence: radiologists and pathologists as information specialists, JAMA - J. Am. Med. Assoc. 316 (2016) 2353–2354, https://doi.org/10.1001/jama.2016.17438.

[22] D.D. Miller, C.M. Facp, E.W. Brown, Artificial intelligence in medical practice : the question to the answer? Am. J. Med. 131 (2018) 129–133, https://doi.org/10.1016/j.amjmed.2017.10.035.

[23] J.H. Thrall, X. Li, Q. Li, C. Cruz, S. Do, Artificial intelligence and machine learning in radiology: opportunities, challenges, pitfalls, and criteria for success, J. Am. Coll. Radiol. 15 (2017) 504–508, https://doi.org/10.1016/j.jacr.2017.12.026.

[24] Y. Kobayashi, M. Ishibashi, H. Kobayashi, How will "democratization of artificial intelligence" change the future of radiologists? J. Radiol. 37 (2019) 9–14, https://doi.org/10.1007/s11604-018-0793-5.

[25] A.B. Syed, A.C. Zoga, Artificial intelligence in radiology: current technology and future directions, Semin. Musculoskelet. Radiol. 22 (2018) 540–545, https://doi.org/10.1055/s-0038-1673383.

[26] B.F. Branstetter IV, A.L. Humphrey, J.B. Schumann, The long-term impact of preclinical education on medical students' opinions about radiology, Acad. Radiol. 15 (2008) 1331–1339, https://doi.org/10.1016/j.acra.2008.03.015.

[27] J.L. Jaremko, M. Azar, R. Bromwich, A. Lum, L. Hsia, A. Cheong, M. Gibert, B. Gray, C. Reinhold, M. Cicero, J. Chong, J. Shaw, F.J. Rybicki, C. Hurrell, E. Lee, Canadian association of radiologists white paper on ethical and legal issues related to artificial intelligence in radiology, Can. Assoc. Radiol. J. 70 (2019), https://doi.org/10.1016/j.carj.2019.03.001.

[28] F. Pesapane, C. Volonté, M. Codari, F. Sardanelli, Artificial Intelligence as a Medical Device in Radiology: Ethical and Regulatory Issues in Europe and the United States, (2018), pp. 745–753.

[29] J.R. Geis, P. Adrian, F.C.C. Wu, J. Spencer, Ethics of Artificial Intelligence in Radiology: Summary of the Joint European and North American Multisociety Statement, (2019).

[30] J.K.C. Kingston, Artificial Intelligence and Legal Liability, (n.d.).

[31] D. Pinto Dos Santos, D. Giese, S. Brodehl, S.H. Chon, W. Staab, R. Kleinert, D. Maintz, B. Baeßler, Medical students' attitude towards artificial intelligence: a multicentre survey, Eur. Radiol. (2018) 1–7, https://doi.org/10.1007/s00330-018-5601-1.

[32] D.X.X. Gong, P. Nugent, J. Chang, Influence of artificial intelligence on Canadian medical students' preference for radiology specialty: A, Acad. Radiol. (n.d.) 1–12. doi:10.1016/j.acra.2018.10.007.