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Q. Waymel, S. Badr, X. Demondion, A. Cotten, T. Jacques

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Impact of the rise of artificial intelligence in radiology: What do radiologists think?

Quentin WAYMEL, MD [1], Sammy BADR, MD, MSc [1], Xavier DEMONDION, MD, PhD [1,2], Anne COTTEN, MD, PhD [1,2], Thibaut JACQUES, MD, MSc [1,2]

[1] Department of Musculoskeletal Radiology, University Hospital of Lille, Lille, France.
[2] Lille Medical School, University of Lille, Lille, France.

Address for correspondence: Dr Thibaut JACQUES.
Department of Musculoskeletal Radiology, University Hospital of Lille, 59000Lille, France.
E-mail : thibaut.jacques@chru-lille.fr

Abstract

Purpose: The purpose of this study was to assess the perception, knowledge, wishes and expectations of a sample of French radiologists towards the rise of artificial intelligence (AI) in radiology.

Material and method: A general data protection regulation-compliant electronic survey was sent by e-mail to the 617 radiologists registered in the French departments of Nord and Pas-de-Calais (93 radiology residents and 524 senior radiologists), from both public and private institutions. The survey included 42 questions focusing on AI in radiology, and data were collected between January 16th and 31st, 2019. The answers were analyzed together by a senior radiologist and a radiology resident.

Results: A total of 70 radiology residents and 200 senior radiologists participated to the survey, which corresponded to a response rate of 43.8% (270/617). One hundred ninety-eight radiologists (198/270; 73.3%) estimated they had received insufficient previous information on AI. Two hundred and fifty-five respondents (255/270; 94.4%) would consider attending a generic continuous medical education in this field and 187 (187/270; 69.3%) a technically advanced training on AI. Two hundred and fourteen respondents (214/270; 79.3%) thought that AI will have a positive impact on their future practice. The highest expectations were the lowering of imaging-related medical errors (219/270; 81%), followed by the lowering of the interpretation time of each examination (201/270; 74.4%) and the increase in the time spent with patients (141/270; 52.2%).

Conclusion: While respondents had the feeling of receiving insufficient previous information on AI, they are willing to improve their knowledge and technical skills on this field. They share an optimistic view and think that AI will have a positive impact on their future practice. A lower risk of imaging-related medical errors and an increase in the time spent with patients are among their main expectations.

Index terms: Artificial intelligence (AI); Radiologists; Machine learning; Survey

Introduction

Artificial Intelligence (AI) is a burning topic and is at the core of many recent technological breakthroughs [1] and will undoubtedly impact healthcare [2]. Over the recent years, there was an exponential growth in the number of articles about AI in

radiology, with an increased rate, from 100–150 to 700–800 scientific publications per year during the last decade [3]. Machine learning-based algorithms have the potential to improve various steps in the radiology workflow, such as scheduling and patient triage [4], clinical decision support [5,6], detection and interpretation of pathological findings [7–9], post processing [10–12], dose estimation [13], quality control [14] or reporting [15].

Many experts have stated their point of view about the future of radiology after the rise of AI [16–18], and radiological societies have published white papers and encouraging opinions about it [19,20]. Studies demonstrated that medical students are not worried by AI and do not fear radiologist replacement [21], but the anxiety related to a "displacement" discouraged some students from considering the specialty [22]. Except for one survey, which was conducted in a single radiology residency training program [23], no studies so far have focused on the feelings and thoughts of a large population of radiologists and their concerns about the impact of AI in their future practice.

The purpose of this study was to assess the perception, knowledge, wishes and expectations of a sample of French radiologists towards the rise of artificial intelligence (AI) in radiology.

Material and methods

Survey

We designed a general data protection regulation-compliant electronic survey using the Google forms web-based application. The questionnaire included 42 questions with a total response time estimated between 5 and 10 minutes. An explicit consent was required. The questionnaire was first sent on January 16th, 2019, with three subsequent reminders within the two following weeks. Anonymous responses were collected between January 16th and January 31st, 2019. The answers were analyzed together by a senior radiologist (T.J.) and a radiology resident (Q.W.).

Population

The survey was sent by e-mail to the 617 radiologists registered in two French departments, *via* pre-established mailing lists, including 93 radiology residents and 524 senior radiologists from both public and private institutions. One Department was the

Nord (2.6 million inhabitants) and the other was the Pas-De-Calais (1.5 million inhabitants). First, generic questions were asked such as age, gender, workplace and mode of exercise (residency, public hospital, private practice) (Figure 1) as well as subspecialty or involvement in interventional radiology.

Level of information on AI

We assessed the radiologists' level of information on AI in radiology by asking for their personal experience with AI-based solutions, as well as the number of scientific publications on AI they had studied over the last 12 months, and whether or not they received a specific training or attended dedicated seminars focusing on this topic.

We considered that a respondent had basic knowledge on AI in radiology if he/she met one of the following criteria: i) he/she received a specific training or attended at least one dedicated seminar on AI; ii) he/she used an AI-based tool on his/her daily practice; iii) he/she attended more than one industrial demonstration on an AI-based tool; iiii) he/she had studied more than 10 scientific articles on this topic over the last 12 months. We also assessed their willingness to receive further generic or technically advanced instruction (programming, neural network training) in this field.

Expectations on daily practice

Radiologists were asked to select which technical features they would expect the most from an AI-based tool (among 15 items, with up to 7 choices) (Figure 2A) and which positive consequences they would expect the most on their practice (among 7 items, with up to 3 choices) (Figure 2B). Respondents were also asked to give their personal opinion about the implementation of AI in their radiology division (public or private; residents were not included since they change division every 6 months), as well as for a predicted time interval until a broad diffusion of AI in radiology, their position towards partnership with AI industry, and regarding the regulatory framework and legal aspects of AI solutions (Figure 3).

Agreement to statements

To understand their position on some of the most frequently asked questions regarding AI in radiology, radiologists were asked to give their degree of agreement or disagreement on 11 specific statements (Figure 4A), with a Likert response-scale ranging from 1 to 8 (1:

total disagreement; 2: strong disagreement; 3: moderate disagreement; 4: mild disagreement; 5: mild agreement; 6: moderate agreement; 7: strong agreement; 8: total agreement).

Predicted impact of AI on subspecialties and imaging modalities

Radiologists were asked to indicate which radiological subspecialties were, in their opinion, prone to be the most impacted (up to three responses, ranked by likelihood) or the less impacted (up to three responses, ranked by likelihood) by the rise of AI in radiology. Individual responses were assessed, and a positive score was given whenever a subspecialty was listed as low risk to be impacted (+3 in first position, +2 in second and +1 in third) and a negative score was given when listed as high risk to be impacted (-3 in first position, -2 in second and -1 in third). Positive and negative scores were calculated as sums of individual values, and the total score for each subspecialty was defined as the mean between both.

Radiologists were also asked to rank the 6 main imaging modalities (computed tomography [CT], magnetic resonance imaging [MRI], ultrasound, mammography, X-rays and interventional radiology [IR]) depending of the likelihood to be impacted by AI. For each respondent, the first modality (higher risk) was given a score of 6, up to the last modality (lower risk) which was given a score of 1. The total score for each modality (Σ) was the sum of all individual values. Hence, the minimal theoretical score for this question was $\Sigma = 270$ points (270 respondents × 1 point) up to a theoretical maximal score of $\Sigma = 1620$ points (270 × 6 points).

Statistical analysis

Statistical analyses and graphical plotting were performed using GraphPad Prism software version 8.0.1 (GraphPad Software). Quantitative variables were expressed as mean, standard deviation (SD) and ranges. Qualitative variables were expressed as raw numbers, proportions and percentages. Comparison between subgroups of responders (*i. e.*, residents, private practice, public practice) were performed using two-tailed Mann-Whitney test, and comparisons between the three subgroups were performed using Kruskall-Wallis test followed by post-hoc Dunn's test for multiple comparisons. Statistical significance was set at $P < 0.05$.

Results

Population

A total of 270 individual responses were collected, representing a response rate of 43.8% (270/617). The response rate reached 75.3% (70/93) among residents and 38.2% (200/524) among senior radiologists. There were 183 men (183/270; 67.8%) and 87 women (87/270; 32.2%) with a mean age of 39.7 ± 12.3 (SD) years (range: 24 – 71 years). Radiology residents represented 70 respondents (70/270; 25.9% of the population), public hospital radiologists were 91 to respond (91/270; 33.7% of the population) and private practice radiologists were the largest group in the study population, with 109 participants (109/270; 40.4% of the population) (Figure 1A). Among all participants, 19/270 (7.0%) stated having a daily use of an AI-based tool, whereas 66/270 (24.4%) would consider using one within the following year, and 185/270 (68.5%) did not use any AI software in their daily practice nor foresee any change in the following year.

Level of information on AI

One hundred ninety-eight radiologists (198/270; 73.3%) estimated they had received insufficient previous information on AI, and 37/270 (13.7%) declared having received no previous specific information at all. Thirty-seven (37/270; 13.7%) attended a dedicated teaching on AI, and respectively 73/270 (27.0%) and 33/270 (12.2%) had taken part in one or more demonstrations of AI-based solutions. Two hundred thirty-one respondents (231/270, 85.6%) admitted they had read no (89/270; 33.0%) or less than five (142/270; 52.6%) scientific publications about AI over the last 12 months (Figure 1B). Based on the aforementioned criteria, we estimated that 62/270 respondents (23.0%) had basic knowledge on AI in radiology.

Two hundred fifty-five (255/270; 94.4%) respondents indicated that they would be interested in receiving a generic training on AI (Figure 1C) and 187/270 (69.3%) would be interested in receiving a technically advanced training on this subject (Figure 1D). Moreover, 229/270 radiologists (84.8%) would be interested in receiving a regular e-mail newsletter with follow-up of scientific publications and bibliographic reviews on this topic.

Expectations for daily practice

Regarding the technical characteristics expected by the respondents from an AI-based solution, the three most important features were automatic detection of lesions (197/270; 72.9%), automatic measurement of lesions with validation by the radiologist (197/270; 72.9%), followed by improvement in image post-processing (174/270; 64.4%) (Figure 2A). On the contrary, automatic interpretation without validation by the radiologist (2/270; 1.1%), automatic measurement of lesions without validation by the radiologist (15/270; 5.5%) and direct access to the source code of the algorithm (27/270; 10.0%) were the least requested features (Figure 2A).

Regarding practical consequences on daily practice, the most anticipated impact was the lowering of the risk of imaging-related medical errors (219/270; 81.1%), followed by the lowering of the interpretation time of each examination (201/270; 74.4%) and the increase in the time spent with patients (141/270; 52.2%) (Figure 2B).

Overall, 214/270 respondents (79.3%) thought that AI will have a positive impact on their future practice (Figure 3A).

In term of timeline, the most common expectation was that AI will be broadly used in clinical practice in 5 to 10 years (133/270; 49.3%) (Figure 3B).

Concerning the legal framework, 162/270 respondents (60.0%) thought that the radiologist should remain fully responsible in case of error, while 95/270 (35.2%) thought that responsibility had to be equally shared between the radiologist and the industrial company (Figure 3C).

One hundred sixty-five respondents (165/270; 61.1%) estimated that the need for radiologists in ten years will be the same. Thirty-four (34/270; 12.6%) thought the need for radiologists will be higher, whereas 71/270 (26.3%) estimated it will be lower (Figure 3D).

Regarding relations towards the industry, 139/270 radiologists (51.5%) would be interested in developing a research partnership, 88/270 (32.6%) would be interested in investing personal funds in an AI company or start-up, and 13/270 (4.8%) would consider launching their own start-up in this field.

Agreement to statements

Radiologists described themselves as interested in informatics and new technologies (mean Likert scale score: 6.4 ± 1.4 [SD]; range: 2-8) and in favor of the deployment of AI solutions in their hospital division or private practice (6.2 ± 1.6 [SD]; range: 1-8) (Figure 4B). The subgroup of radiologists that had previous knowledge on AI was more prone to be interested in new technologies (7.0 ± 1.3 [SD]; range: 2-8] *vs.* 6.3 ± 1.4 [SD]; range: 2-8) (P<0.001) and to agree on the deployment of AI-based solutions in their workplace (7.0 ± 1.4 [SD]; range: 1-8 *vs.* 6.0 ± 1.6 [SD]; range: 2-8) (P<0.001) (Figure 5B). Radiologists had a tendency to mildly agree that certain current AI algorithms can reliably detect pathological condition (5.3 ± 1.9 [SD]; range: 1-8) and had mixed opinion towards the fact that certain current AI algorithms can reliably reach a reliable diagnosis without the intervention of a radiologist, with a tendency towards a mild disagreement (4.2 ± 2.1 [SD]; range: 1-8). On the contrary, the subgroup with prior knowledge on AI had a superior agreement to this point (4.8 ± 2.0 [SD]; range: 1-8 *vs.* 4.1 ± 2.1 [SD]; range: 1-8) (P<0.05).

Respondents agreed upon the fact that AI will revolutionize radiology (6.0 ± 1.5 [SD]; range: 1-8), affect every field in medicine (6.6 ± 1.6 [SD]; range: 1-8) and improve their daily work (6.2 ± 1.3 [SD]: range: 1-8]), even more in the subgroup that had prior knowledge on AI (6.7 ±1.1 range:3-8] vs. 6.0 ±1.3 range:1-8], P<0.001). Respondents disagreed that AI will replace radiologists (3.1 ± 1.8 [SD]; range: 1-8) and had mixed opinions towards the fact that AI was going to shift their activity from diagnostic to interventional radiology (4.7 ± 1.8 [SD]; range: 1-8). Respondents agreed that the fundamentals of AI should be taught in medical school (6.1 ± 1.5 [SD]; range: 1-8) and that they would choose radiology as a medical specialty again today (6.8 ± 1.8 [SD]; range: 1-8). Radiology residents had a stronger agreement to this last statement (7.3 ± 1.1 [SD]; range: 3-8] than private practice radiologists (6.5 ± 2.1 [SD]; range: 1-8) (P<0.05). There were no significant differences for this statement between public hospital radiologists (6.7 ± 1.8 [SD]; range:1-8) neither with private practice radiologists (6.5 ± 2.1 [SD]; range: 1-8) (P=0.99) nor with radiology residents (7.3 ± 1.1 [SD]; range: 3-8) (P=0.19).

Predicted impact by subspecialty and modality

Based on the aforementioned composite score, oncologic imaging had highest likelihood of being impacted by AI (-160.5), followed by chest imaging (-152.5) and breast imaging (-136). On the contrary, interventional radiology (+218.0), antenatal (+139.5) and pediatric (+62.0) imaging had lowest likelihood of being impacted by AI (Figure 6.)

In parallel, based on the weighted sum of all responses (Σ), radiologists thought mammography (Σ=1296) would be the modality with the highest likelihood of being affected by AI, just ahead of CT (Σ=1224), X-rays (Σ=1126) and MRI (Σ=1035), and clearly ahead of ultrasound (Σ=529) and interventional radiology (Σ=460) (Figure 7).

Discussion

Our study reports the first survey on perception of AI involving a large group of French radiologists. To our knowledge, it is the first publication of this kind to include all modes of exercise (residents, public and private radiologists). The good response rate (43.8%) over a short period of time proves the dynamism and enthusiasm around this topic. The low proportion of radiologists using an AI solution in their daily practice proves that we are still at the dawn of AI [24]. A recent American publication [23] reported a higher rate of use, possibly due to its monocentric and academic nature. The response rate among residents in our study was twice the rate of senior radiologists and is coherent with a population slightly younger (39.7 year-old) than the mean age of the local population of radiologists (estimated around 46.1 year-old) (25).

Our results clearly show that there is an ongoing lack of training and information about AI among French radiologists, despite the tremendous increase in scientific publications. The overflow of information and the fast evolution in this field could paradoxically be discouraging individual radiologists, especially those who think that a strong technical background is required. We found that nearly all respondents would attend a dedicated training on AI should it be available, and a majority would even consider attending a technically advanced one (programming, neural network training). These results show once again the radiologists' interest towards new technologies and their wish to evolve with their time. Instruction is undoubtedly the most crucial point for radiologists as well as for medical students [26]. Respondents underlined that the basics of AI should be taught in medical school, which concurs with recent publications [21,26].

There was previously no academic teaching on AI dedicated to radiologists in France, but 2019 will be a crucial year since mandatory workshops have been set for all radiology residents, for the first time [27].

The two most expected features from AI-based tools were automatic lesion detection and measurement, with validation by a radiologist. As of today, many AI tools using deep learning algorithms have already been designed to detect specific lesions and perform measurements, which is especially true in the field of cancer imaging [28]. In parallel, the respondents in our study thought that cancer imaging, chest imaging, breast imaging and neuroradiology were the subspecialties that would be the most impacted by AI. The opinion of respondents on which subspecialties and modalities could be the most impacted is interestingly close to the trends in the literature, as reflected by the number of publications in each field of radiology [3]. Although considered less likely to be impacted, possibly because they are more operator-dependent, recent publications show that modalities such as ultrasound [29–31], interventional radiology [32] or antenatal imaging [33] could as well be impacted by AI.

In this survey, radiologists reported an overall positive opinion on AI and an optimistic view on the future of their specialty, with high expectations on the positive improvement of their daily work in the future. It is interesting to note that these statements were even truer in the subgroup of respondents that had previous knowledge on AI. Interestingly, the reduction in interpretation time came in second position of all positive expectations, after the reduction of medical error and immediately followed by the increase of time spent with patients, instead of the increase in the volume of examinations which came last. If it were to be proven again, these results confirm that the main concern of radiologists remains the patients.

Our study has several limitations. Even if the overall response rate was satisfying, radiologists who answered may have been those with a particular interest for this topic, as this could be suggested by a higher participation among residents and young radiologists. Moreover, radiologists had to express their opinion on specific questions on AI, while the majority of them declared they had received insufficient information on this topic. This could have led to a bias in their answers, being influenced by surrounding positive and/or negative opinions heard or read on AI. The fact that the number of answers for each question was limited and not open could have led to a restriction in the choice of responses but is inherent to the use of a survey. Furthermore, the use of a survey enables

only to understand trends in our population, but the wide range of answers to each question shows that individual opinions on this topic remain diverse.

In conclusion, most radiologists have received insufficient previous information on AI, but are clearly willing to attend further courses to improve their knowledge and technical skills on this field. The vast majority shares an optimistic view and thinks that AI will have a positive impact on their future practice. Their main expectations are about improvement of the quality of care they will provide to their patients and the time spent with them.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding this study.

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Figure legends

Figure 1. Pie charts show A: distribution of respondents to the survey by mode of exercise; B**:** number of scientific publications on artificial intelligence (AI) in radiology studied by respondents during the last 12 months; C: interest of respondents in attending a generic training on AI in radiology; D: interest of respondents in attending a technically advanced training on AI in radiology.

Figure 2. Column bars show A: Ranking of expected technical features of artificial intelligence (AI)-based tools, depending on the number of positive responses; B: Ranking of expected practical impacts of AI-based tools on daily practice, depending on the number of positive responses. CT: Computed tomography; MRI: Magnetic resonance imaging.

Figure 3. Pie charts show A: Expectations of the respondents on the global impact of artificial intelligence (AI) on their personal practice; B: Estimated time until a broad diffusion of AI-based tools on daily practice; C: Respondents' opinion towards the responsibility in case of medical error linked to an AI-based tool; D: Expected change in the number of radiologists needed in 10 years.

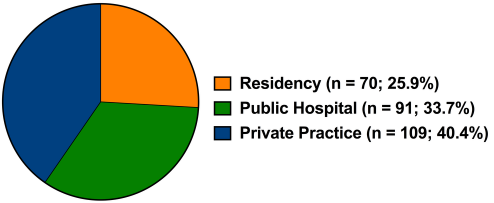
Figure 4. A: figure shows the 11 statements that were submitted to radiologists; B: box plots and whisker plots show distribution of responses using a Likert scale ranging from 1 to 8. The vertical bar represents the median value; 10^{th} and 90^{th} percentiles are set as whiskers limits and 25^{th} and 75^{th} as box limits; the mean value is plotted as a "+"

Figure 5. Box plots and whisker plots show results of subgroups analysis of responses to the 11 statements, according to the mode of exercise (A) and depending on the level of knowledge on AI (B). The vertical bar represents the median value; 10^{th} and 90^{th} percentiles are set as whiskers limits and 25^{th} and 75^{th} as box limits; the mean value is plotted as a "+".

Figure 6. Diagram shows estimated impact of artificial intelligence on radiology subspecialties, according to the respondents; the mean score is the mean between positive and negative individual scores given by radiologists.

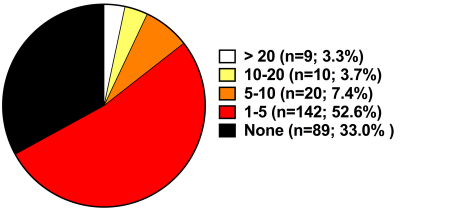
Figure 7. Diagram shows estimated impact of artificial intelligence on imaging modalities, according to the respondents (weighted sum of all responses). CT = computed tomography; MRI = magnetic resonance imaging; IR = interventional radiology.

A.



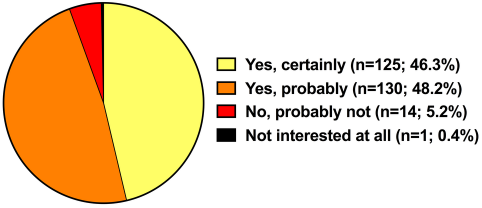
Distribution of respondents by mode of exercice

B.



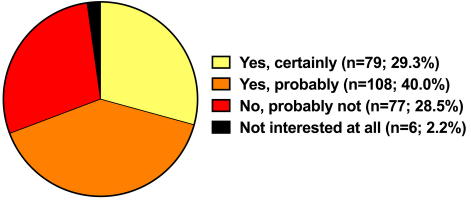
Number of scientific publications on AI in radiology studied by the respondents over the last 12 months

C.

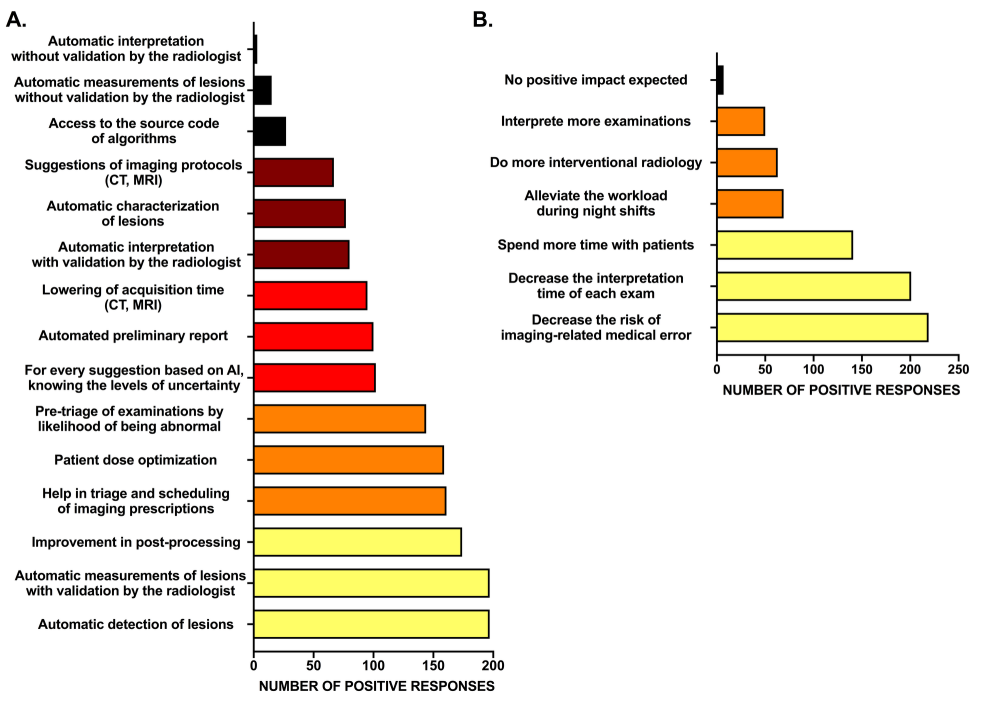


Interest in receiving a generic training on AI

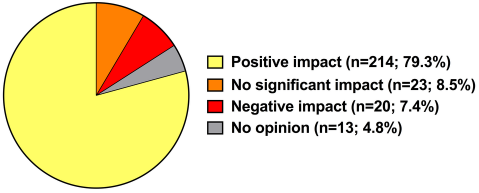
D.



Interest in receiving a technically advanced training on AI

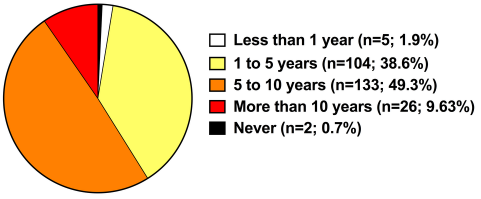

A.
Automatic interpretation without validation by the radiologist
Automatic measurements of lesions without validation by the radiologist
Access to the source code of algorithms
Suggestions of imaging protocols (CT, MRI)
Automatic characterization of lesions
Automatic interpretation with validation by the radiologist
Lowering of acquisition time (CT, MRI)
Automated preliminary report
For every suggestion based on AI, knowing the levels of uncertainty
Pre-triage of examinations by likelihood of being abnormal
Patient dose optimization
Help in triage and scheduling of imaging prescriptions
Improvement in post-processing
Automatic measurements of lesions with validation by the radiologist
Automatic detection of lesions
0
50
100
150
200
NUMBER OF POSITIVE RESPONSES
B.
No positive impact expected
Interprete more examinations
Do more interventional radiology
Alleviate the workload during night shifts
Spend more time with patients
Decrease the interpretation time of each exam
Decrease the risk of imaging-related medical error
0
50
100
150
200
250
NUMBER OF POSITIVE RESPONSES

A.



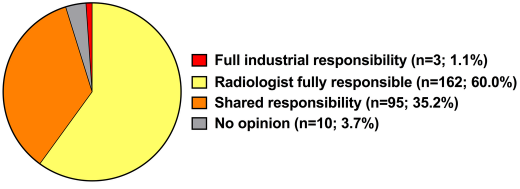
Expected impact of AI on personal practice

B.



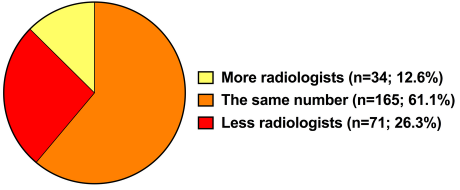
Estimated time until a broad diffusion of AI in daily practice

C.



Evolution of responsibility in case of medical error

D.



Expected changes in the number of radiologists needed

A.

S1: I would describe myself as interested in informatics and new technologies.

S2: I am in favor of the deployment of AI solutions in my division or private practice.

S3: I think that certain AI algorithms can reliably detect pathological conditions

S4: I think that certain AI algorithms can reliably reach a reliable diagnosis without the intervention of a radiologist.

S5: I think that AI is going to revolutionize Radiology.

S6: I think that AI is going to affect every field in Medicine.

S7: I think that AI is going to improve the daily work of radiologists.

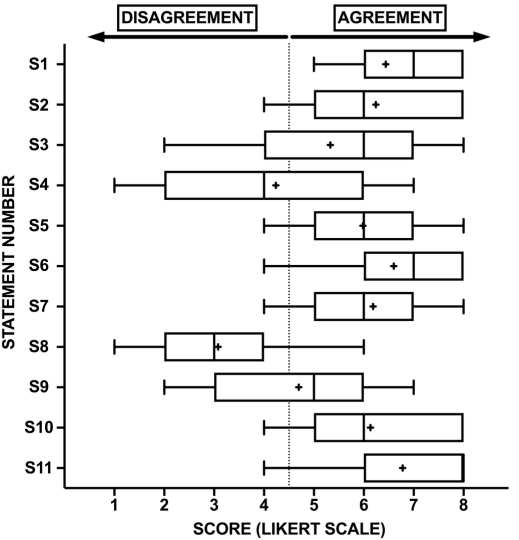
S8: I think that AI is going to replace radiologists.

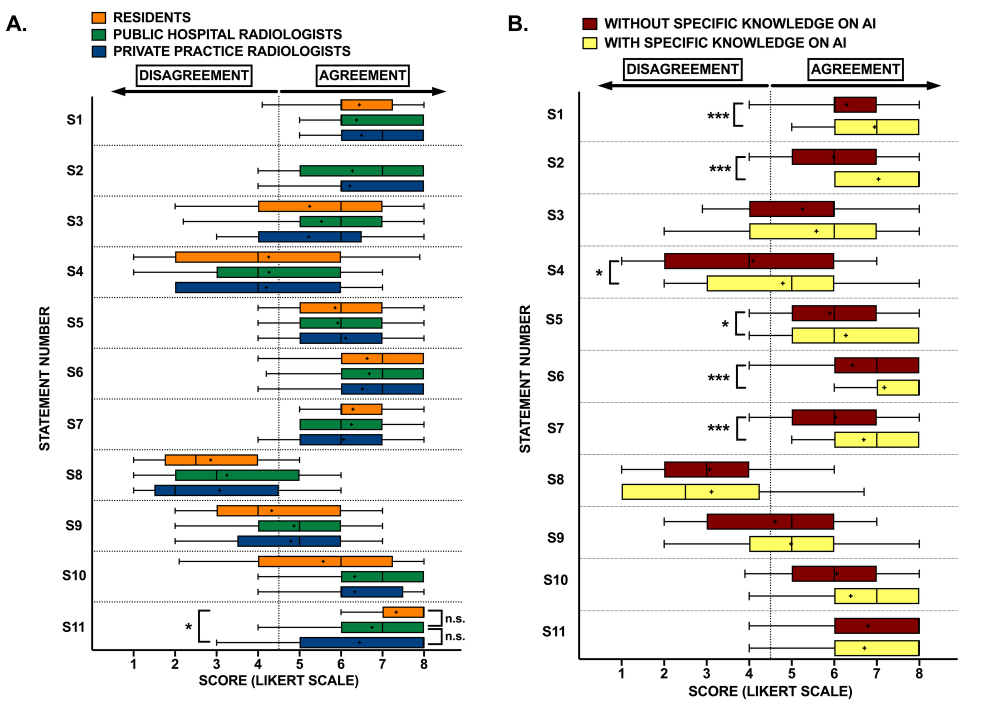
S9: I think that AI is going to shift our activity from diagnostic to interventional Radiology.

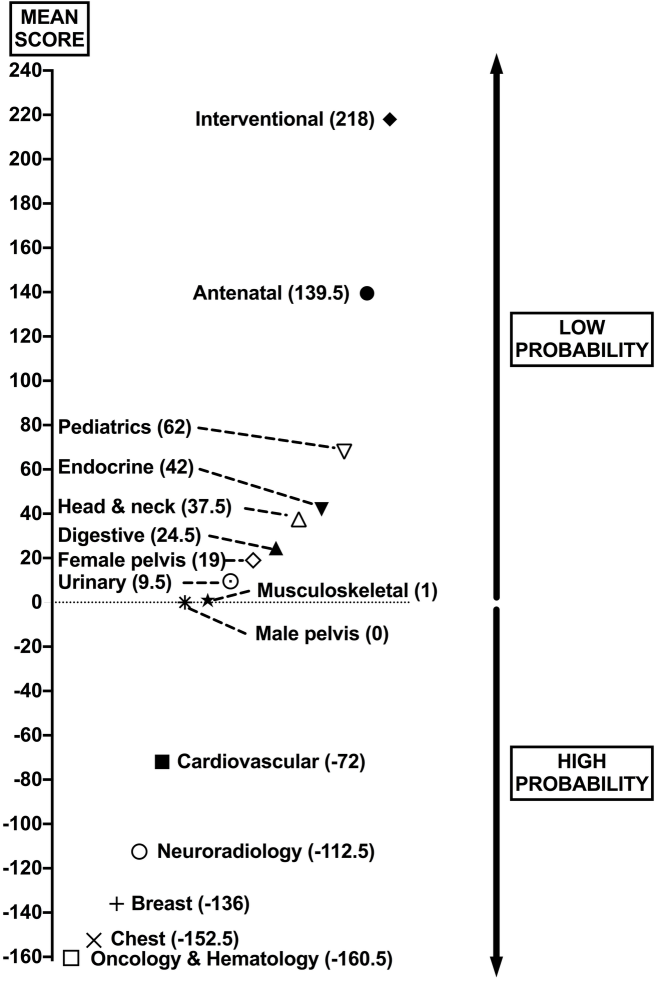
S10: I think that the fundamentals of AI should be taught in medical school.

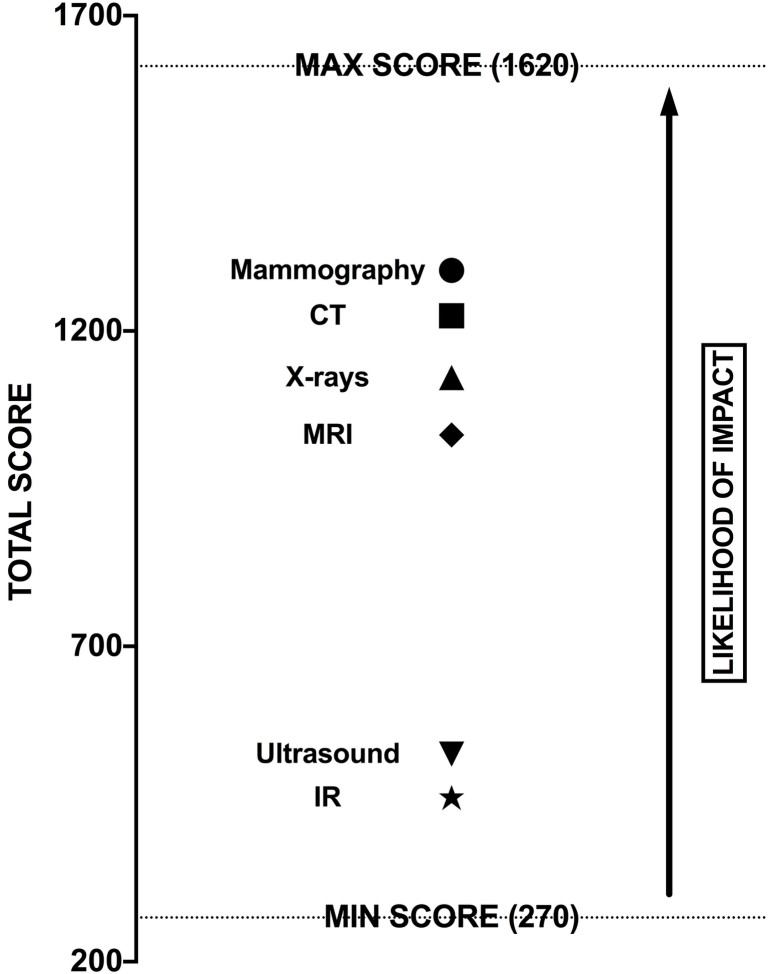
S11: If I were to choose my specialty today, I would choose Radiology again.

B.




A.
RESIDENTS
PUBLIC HOSPITAL RADIOLOGISTS
PRIVATE PRACTICE RADIOLOGISTS
DISAGREEMENT
AGREEMENT
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
STATEMENT NUMBER
*
n.s.
n.s.
1
2
3
4
5
6
7
8
SCORE (LIKERT SCALE)
B.
WITHOUT SPECIFIC KNOWLEDGE ON AI
WITH SPECIFIC KNOWLEDGE ON AI
DISAGREEMENT
AGREEMENT
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
STATEMENT NUMBER
***
***
*
*
***
***
1
2
3
4
5
6
7
8
SCORE (LIKERT SCALE)


MEAN SCORE
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
Interventional (218)
Antenatal (139.5)
Pediatrics (62)
Endocrine (42)
Head & neck (37.5)
Digestive (24.5)
Female pelvis (19)
Urinary (9.5)
Musculoskeletal (1)
Male pelvis (0)
Cardiovascular (-72)
Neuroradiology (-112.5)
Breast (-136)
Chest (-152.5)
Oncology & Hematology (-160.5)
LOW PROBABILITY
HIGH PROBABILITY


1700
MAX SCORE (1620)
1200
700
200
MIN SCORE (270)
TOTAL SCORE
Mammography
CT
X-rays
MRI
Ultrasound
IR
LIKELIHOOD OF IMPACT