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Anticipating artificial intelligence in mammography screening: views of Swedish breast radiologists

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ABSTRACT

Objectives Artificial intelligence (AI) is increasingly tested and integrated into breast cancer screening. Still, there are unresolved issues regarding its possible ethical, social and legal impacts. Furthermore, the perspectives of different actors are lacking. This study investigates the views of breast radiologists on AI-supported mammography screening, with a focus on attitudes, perceived benefits and risks, accountability of AI use, and potential impact on the profession.

Methods We conducted an online survey of Swedish breast radiologists. As early adopter of breast cancer screening, and digital technologies, Sweden is a particularly interesting case to study. The survey had different themes, including: attitudes and responsibilities pertaining to AI, and AI's impact on the profession. Responses were analysed using descriptive statistics and correlation analyses. Free texts and comments were analysed using an inductive approach.

Results Overall, respondents (47/105, response rate 44.8%) were highly experienced in breast imaging and had a mixed knowledge of AI. A majority (n=38, 80.8%) were positive/somewhat positive towards integrating AI in mammography screening. Still, many considered there to be potential risks to a high/somewhat high degree (n=16, 34.1%) or were uncertain (n=16, 34.0%). Several important uncertainties were identified, such as defining liable actor(s) when AI is integrated into medical decision-making.

Conclusions Swedish breast radiologists are largely positive towards integrating AI in mammography screening, but there are significant uncertainties that need to be addressed, especially regarding risks and responsibilities. The results stress the importance of understanding actor-specific and context-specific challenges to responsible implementation of AI in healthcare.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Radiologists believe that artificial intelligence (AI) will have a major impact in their field, and clinical retrospective studies of AI in mammography screening show promising results.

WHAT THIS STUDY ADDS

⇒ The social, ethical and legal aspects of integrating AI in mammography screening are underexplored, and by investigating the views of breast radiologists, this study provides important insights for a responsible approach to AI in mammography screening.

⇒ The study shows that most Swedish breast radiologists are positive about integrating AI in mammography screening, especially those with a heavy screen-reading workload. However, there is no unified vision of how AI should be used in the screening-work flow, and there is high uncertainty, and diverse views, on important aspects such as potential risks involved, and which actor(s) are liable for medical decision-making, particularly when AI is used as stand-alone reader.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study adds to the emerging body of research on AI in medical decision-making, taking into account contextual and actor-specific factors, and emphasises the social, ethical and legal unclarities of integrating AI into mammography screening, that must be addressed.

INTRODUCTION

In radiology, the use of artificial intelligence (AI) is rapidly evolving. One area targeted as especially promising is mammography screening.[1–3] The benefit of population-based screening is early breast cancer detection, reducing mortality and morbidity. This is a benefit balanced by the harm of false positives, overdiagnosis and false negatives.[4 5] The vast majority of individuals who are screened do not have breast cancer, however, screen examinations are, in European guidelines, recommended to be double-read to ensure a high sensitivity.[6] The hope is that integrating AI will result in a more efficient screening with reduced workload and a potentially higher accuracy. By adapting single-reading and double-reading to AI risk scores, or combining it with automated reading of low-risk examinations, it is suggested that the workload may be reduced by up to 63%.[7] In theory, reducing the number of exams that are double-read will lead to fewer false positives.[8] Retrospective studies have also shown that AI could potentially lower the

false-negative rate,[9 10] but prospective studies are still needed to understand the real impact of AI.[11]

Beyond clinical aspects, there are unresolved issues regarding the ethical, social and legal consequences of integrating AI into healthcare.[12 13] These include how to safeguard values of medical ethics such as fairness, accountability and transparency.[14 15] These matters are perceived as some of the greatest hurdles of implementing AI in radiology.[16–19] In response, standards for AI in radiology are stressed, including the equal distribution of benefits and harms between stakeholders, transparency of AI-systems, curtailing bias in decision-making, and that accountability should remain with humans.[12]

The expectation that AI will change the field of radiology in the near future is highly prevalent among radiologists, trainees and medical students.[16–18] Still, different stakeholders' notions of the challenges are in need of more exploration.[20–22] Prior studies show high willingness to use AI in clinical practice, but this could differ depending on subfield. While included in studies as one subdiscipline of many, not much focus has been dedicated specifically to breast radiologists, a group likely to be involved in AI-implementation on a large scale, and with experience of the particular conditions of the screening process.[16 23] In addition, mammography screening is a major medical intervention that affects a large part of the population, and social and ethical implications of integrating AI in this context are underexplored.[19 22] Therefore, we are examining the views of breast radiologists. Moreover, Sweden is an especially relevant case, as it is one of the most digitalised countries in the European Union,[24] as well an early adopter of population-based breast cancer screening and with ongoing pioneering prospective trials on AI in screening.[25]

This study investigated Swedish breast radiologists' views on the use of AI in mammography screening and their perceptions of the risks, benefits and responsibilities of actors involved, and its impact on the profession.

METHOD

An online survey (using Sunet Survey) was distributed to the Swedish Society of Breast Imaging (SSBI), in which the vast majority of Swedish breast radiologists are members. The survey was conducted over the course of 1 month in the late fall of 2021. Informed consent was obtained before answering the survey, by click-response. The questionnaire contained 45 questions falling under different themes. Besides background questions used to establish respondent characteristics, questions were chosen due to their relevance for the social, ethical and legal issues of AI implementation. This included (but was not limited to): attitudes about AI-supported mammography screening, responsibility of AI-use and the future professional impact of AI integration (see online supplemental appendix A). Background questions had categorical response options. Two questions only had free-text response option. The remaining questions had Likert-scale response options, representing degrees (to a low degree, to a somewhat low degree, uncertain, to a somewhat high degree, to a high degree) or attitudes (negative, somewhat negative, uncertain, somewhat positive, positive). In addition, the respondents had the opportunity to provide free-text comments.

Results were analysed using descriptive statistics and are presented in percentages and frequencies. Correlation analyses were performed by Spearman's r, with 95% CI and p values of <0.05 considered statistically significant. In addition, cross-tabulations were used to cover more correlations. Statistical analyses were performed using IBM SPSS Statistics for Mac (V.28.0, IBM). All free-text responses and comments were analysed using an inductive approach and used as method triangulation complementing the quantitative results. Since comments and the two free-text questions were optional, not all respondents' views are accounted for; still, they provide valuable means for obtaining a deeper understanding.

RESULTS

Out of the 105 members of the SSBI, 47 answered the survey (response rate: 44.8%). Of these, 25 were females (53.2%), and the majority of the respondents were older (66.5%>50 years of age), most had long experience in breast imaging (70.2%>11 years of experience) and a high reading-volume was fairly common (38.3% performed >10 000 screen-readings per year). A majority (n=33, 73.3%) of the respondents reported that they sometimes, often or always had difficulties finding time to do screen-readings. More respondents estimated to have higher literacy of technology in everyday life and at work in general, than of AI. Most (n=18, 38.3%) estimated their AI literacy to be neither high nor low, and 25.5% that it was somewhat high or high. Correspondingly, 21.3% had extensive or somewhat extensive experience of using AI in their work, while nearly half (n=22, 46.8%) had no experience (table 1).

Attitudes, benefits and risks of AI in mammography screening

Positive views and potential benefits

The breast radiologists were, to a large extent, positive towards AI-supported mammography screening; 80.8% (n=38) being somewhat positive or positive (table 2, figure 1A). Comments suggest that AI is perceived as a good complement and solution to the scarcity of breast radiologists. Furthermore, having difficulties finding the time to perform screen-readings correlated with a positive attitude towards AI-supported screening (Spearman's r=0.367, 95% CI, p=0.013, figure 2). A correlation between self-estimated literacy of AI and attitude could not be established (p=0.825).

A majority (n=37, 78.7%) of the respondents believed that there were potential benefits in using AI-supported screening, to a somewhat high or high degree (figure 1B). Benefits specified in the comments were improved detection and consistency in screen-reading. The respondents

Table 1 Background characteristics of participating breast radiologists

Characteristics of respondents	N (%)
Age (Q1)	(N=47)
<30	0 (0)
31–40	3 (6.4)
41–50	13 (27.7)
51–60	13 (27.7)
>60 years	18 (38.3)
Gender (Q2)	(N=47)
Female	25 (53.2)
Male	22 (46.8)
Experience of breast radiology (Q3)	(N=47)
<5 years	5 (10.6)
5–10 years	9 (19.1)
11–20 years	10 (21.3)
21–30 years	11 (23.4)
>30 years	12 (25.5)
Screen readings approx. performed per year (Q4)	(N=47)
None	2 (4.3)
<2000	4 (8.5)
2000–5 000 000	5 (10.6)
5000–10 000 000	18 (38.3)
>10 000	18 (38.3)
Difficulties finding time to perform screen-readings (Q5)	(N=45)
Never	4 (8.9)
Seldom	8 (17.8)
Sometimes	19 (42.2)
Often	8 (17.8)
Always	6 (13.3)
Self-estimated technology literacy, everyday life (Q6)	(N=47)
Low	0 (0)
Somewhat low	1 (2.1)
Neither high nor low	20 (42.6)
Somewhat high	19 (40.4)
High	7 (14.9)
Self-estimated technology literacy, work (Q7)	(N=47)
Low	0 (0)
Somewhat low	1 (2.1)
Neither high nor low	17 (36.2)
Somewhat high	21 (44.7)
High	8 (17.0)
Self-estimated AI literacy (Q8)	(N=47)
Low	4 (8.5)
Somewhat low	13 (27.7)
Neither high nor low	18 (38.3)
Somewhat high	8 (17.0)
High	4 (8.5)
Experience of using AI in breast radiology (Q12)	(N=47)
None	22 (46.8)
Little	9 (19.1)
Somewhat little	6 (12.8)
Somewhat large	6 (12.8)
Large	4 (8.5)

AI, artificial intelligence.

favoured using AI as a replacement of 1 reader in double-reading (n=21, 44.7%) or in addition to 2 human readers (n=14, 29.8%) (table 2). A wish to combine triage, reader replacement and detection support were also mentioned in the comments.

Negative views and potential risks

Nearly one-fifth of respondents (n=9, 19.2%) were negative/somewhat negative or uncertain about AI-supported screening (table 2). In the comments, negative attitudes refer to experiencing AI as linked to large numbers of false positives (due to a high sensitivity for calcifications), difficulty in interpreting AI-assessments and the risk of an increased workload, as expressed by one respondent:

> *It was annoying to have to go back and assess different AI findings of benign things all the time […] that I would normally not have had to put any energy into assessing. It made the work slower and disrupted the work pace, leading to more exhaustion* [P12].

The views concerning potential risks of integrating AI were diverse (figure 1B). Comments revealed that, besides medical risks, some feared AI would lead to a deterioration of working conditions, an increase in false positives and interpretation load, and loss of competence due to a lack of continuous training on healthy mammograms:

> *Consultation hours with ultrasounds and biopsies are often heavily booked with worried patients. Working whole days like that would be hard.* [P12]

> *There is a risk that AI detects findings that are obviously benign, which will take time and effort to investigate and prove. Some changes that are unquestionable to a radiologist, AI can't see* [P23].

Other comments stressed legal and ethical risks. One case mentioned, was if a physician disregards an AI finding that later turns out to be a cancer. The respondent suggested radiologists will be put in that situation 'all the time' since AI detects so many findings.

Table 2 General attitudes and perceived potential benefits and risks of AI-supported mammography screening

Attitudes, perceived benefits and risks	N (%)
Attitude towards AI-supported mammography screening (Q9)	(N=47)
Positive	11 (23.4)
Somewhat positive	27 (57.4)
Uncertain	6 (12.8)
Somewhat negative	1 (2.1)
Negative	2 (4.3)
Preferred use of AI in mammography screening (Q13)	(N=47)
AI as triage tool	6 (12.8)
AI as stand-alone reader	2 (4.3)
AI as replacement of one in double reading	21 (44.7)
AI as addition to double reading	14 (29.8)
Not at all	4 (8.5)
Potential benefits of AI-supported screening (Q10)	(N=47)
To a high degree	13 (27.7)
To a somewhat high degree	24 (51.1)
Uncertain	6 (12.8)
To a somewhat low degree	2 (4.3)
To a low degree	2 (4.3)
Potential risks of AI-supported screening (Q11)	(N=47)
To a high degree	6 (12.8)
To a somewhat high degree	10 (21.3)
Uncertain	16 (34.0)
To a somewhat low degree	14 (29.8)
To a low degree	1 (2.1)
Perceived risk of overconfidence in AI assessments (Q15)	(N=47)
To a high degree	4 (8.5)
To a somewhat high degree	9 (19.1)
Uncertain	20 (42.6)
To a somewhat low degree	13 (27.7)
To a low degree	1 (2.1)
Perceived risk of non-representative training data (Q38)	(N=47)
To a high degree	2 (4.3)
To a somewhat high degree	9 (19.1)
Uncertain	24 (51.1)
To a somewhat low degree	9 (19.1)
To a low degree	3 (6.4)
Perceived risk of inferior AI performance on certain risk groups or specific type of cases (Q39)	(N=47)
To a high degree	6 (12.8)
To a somewhat high degree	13 (27.7)
Uncertain	22 (46.8)
To a somewhat low degree	5 (10.6)
To a low degree	1 (2.1)

AI, artificial intelligence.

About half of the respondents (n=24, 51.1%) were uncertain as to whether there are risks in AI-models being trained on data that are not representative of the population to which they are applied. Many were also uncertain as to whether AI-models perform poorly on risk groups or certain types of cases (n=22, 46.8%) (table 2). Cases perceived as possibly more difficult for AI to assess included; dense breasts, atypical soft tissue masses without calcification, architectural distortion, developing asymmetric density, postoperative changes or young individuals with hereditary risk.

Accountability of AI-use

When AI is used in addition to radiologists in screen reading, most the respondents (n=31, 65.9%) considered the radiologist to be responsible for the assessments to a high/somewhat high degree, but 21.3% (n=10) were uncertain (figure 3A). When AI is used as a stand-alone reader, the radiologist (eg, in terms of oversight) was considered responsible to a high/somewhat high degree only by 12.8% (n=6) (figure 3B). The healthcare provider was, to a larger extent, considered responsible when AI is stand-alone reader, compared with when it is used in addition to radiologist(s). This was also the case regarding the responsibility of developers of AI-systems (figure 3).

To answer whether agency was ascribed to the AI-system, as is common in everyday discussions about AI, we included it as an option among liable actors. When used in addition to radiologist(s), 38.3% (n=18) of the respondents considered the AI-system to be responsible to a high/somewhat high degree. When used as stand-alone reader, the number was larger (n=23, 48.9%) and about one-third of the respondents were uncertain (n=14, 29.8%) (figure 3). Perceived shared responsibility was less prevalent when AI is used as a stand-alone reader. Uncertainty and urgency on the issue of responsibility emerged in the comments: *This is the most difficult part. Who takes responsibility? Healthcare should do it, probably, but it is actually the AI-system and the AI-developer who should be accountable for the result* [P24].

Impact on the profession

Nearly half of the breast radiologists in the sample (n=21, 44.7%) believed that integrating AI in mammography screening would encompass substantial differences in comparison to other previously introduced technologies (such as digital mammography and tomosynthesis), to a high/somewhat high degree. A comment suggested the reason for this was that previous technologies aimed to

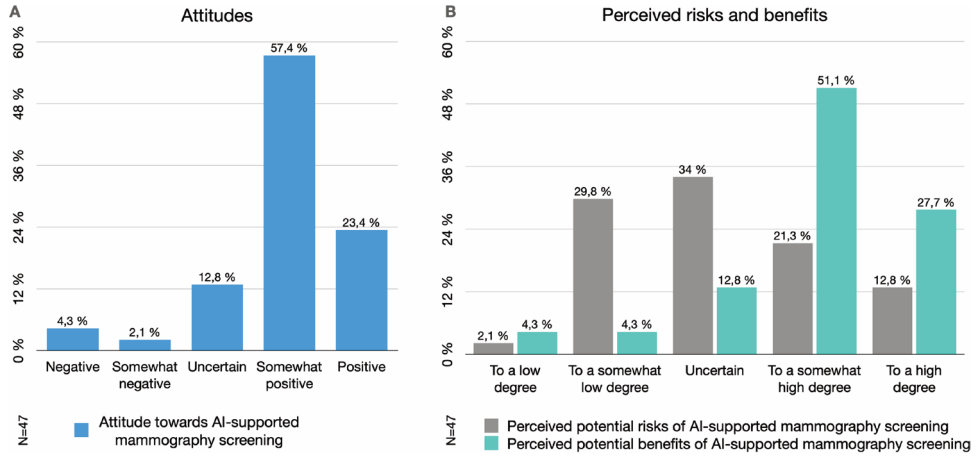

Figure 1 Attitudes. (A) The Swedish breast radiologists' attitude towards AI-supported mammography screening (Q9). (B) The perceived degree of benefits and risks of AI-supported mammography screening (Q10 and Q11). AI, artificial intelligence.

improve image quality, while AI is about delegating assessments to the technology. However, more than one-third of the respondents (n=17, 36.2%) were uncertain as to whether there were any substantial differences of introducing AI.

Moreover, there was a mix of viewpoints regarding how integrating AI might impact the role of the breast radiologist. Most commonly (n=20, 42.6%) AI was believed to have no impact, while nearly a third of respondents (n=15, 31.9%) thought it would strengthen/somewhat strengthen the role of breast radiologists and 25.5% (n=12) that it would weaken/somewhat weaken it. Only 21.3% (n=10) believed the use of AI would make it easier to recruit new breast radiologists to a high/somewhat high degree.

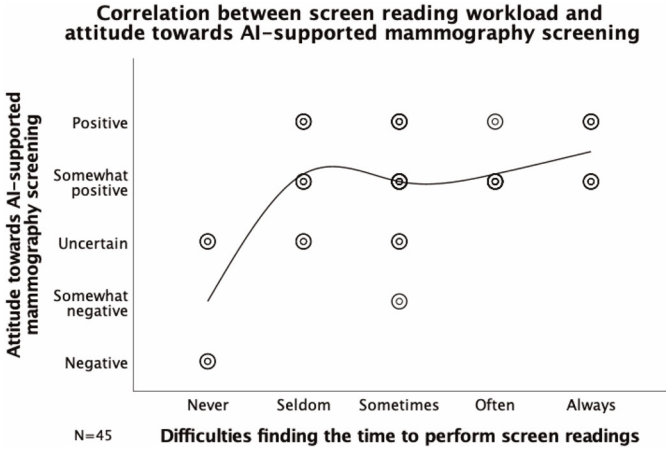

Figure 2 Correlation between the Swedish breast radiologists' attitude towards AI supported mammography screening (Q9) and their difficulties to find the time to perform screen-readings (Q5) (Spearman's r=0.367, 95% CI, p=0.013). The results suggest that the Swedish breast radiologists' experienced screen-reading workload correlates with their attitude towards AI-supported mammography screening. AI, artificial intelligence.

Relation to screening participants

The question about whether implementing AI-supported mammography screening would impact the relationship with screening participants was answered using free-text responses. Out of the total sample, 32 respondents answered, and both positive and negative outlooks were articulated. Some stated that the use of AI would increase the participants' trust, and improve working conditions and thereby also the relationship with caretakers. Other respondents suggested that trust would decrease and introducing AI would 'lead to chaos' and 'waste everyone's time'. Several highlighted the importance of AI systems being valid and trustworthy, and to be able to convey that trustworthiness to relevant actors. Some respondents also emphasised the significance of having radiologists in charge of AI implementation, management and quality control.

Technological development

How the profession will evolve, in light of current technological development, provided a mix of viewpoints. Some pointed to socioeconomic factors, such as: *[I] think that AI will be implemented in screening considering the economic benefits it could have for the employers* [P33]. Several respondents voiced insecurities and expressed reservations:

> *It probably cannot be avoided in the long run and should be able to provide more time for what needs to be investigated or acted upon. I am a bit worried about the loss of knowledge of the "normal breast as background"* [P2].

Still, others emphasised that they considered AI as not yet reaching an acceptable performance level: *until AI becomes good enough, it will be a long way* [P14]. However, other responses expressed hopes of what AI-integration could bring; easing screen-reading workload, improving diagnostics and healthcare quality, with statements like: *AI will be able to sort out the easier cases, decrease workload, and help to find more cancers* [P36]. Moreover, some comments emphasised AI's supporting qualities:

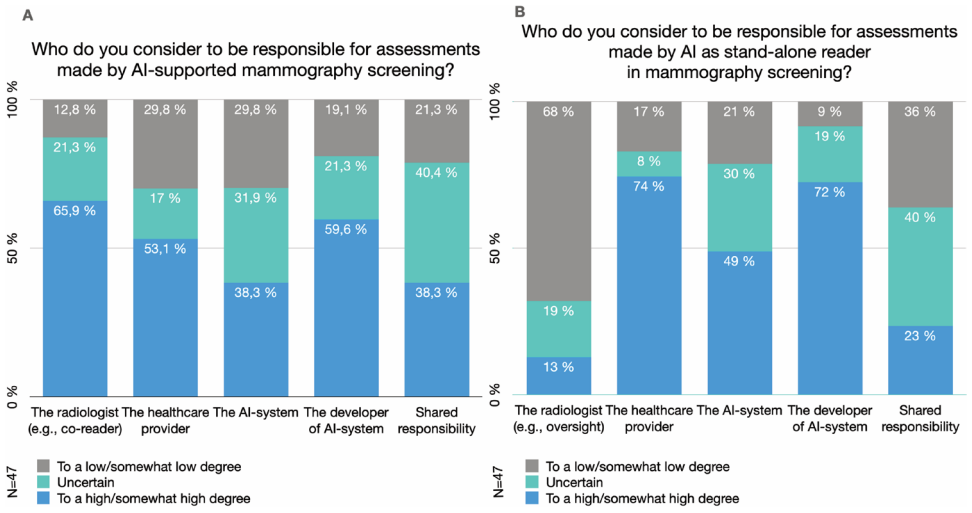

Figure 3 Accountability. (A) The Swedish breast radiologists' perceived levels of accountability of different actors for assessments made by AI-supported mammography screening (Q17–Q21). (B) The Swedish breast radiologists' perceived levels of accountability of different actors for assessments made by AI as stand-alone reader in mammography screening (Q22–Q26). AI, artificial intelligence.

> *It feels good to be able to be supported by AI in the screening, it could be nice to have a second reader (AI) whom never loses concentration. Considering the screening volumes and the scarcity of breast radiologists it feels good that AI can complement us.* [P16]

DISCUSSION

In this study, we have investigated Swedish breast radiologists' views on the use of AI in mammography screening. The respondents were, to a large extent, positive towards the integration of AI in screen reading, especially those having difficulties finding the time to perform screen-reading. This could explain the slightly more positive attitude, compared with general studies on radiologists' attitudes towards AI.[23 26 27] We could not establish a correlation between attitude and AI-literacy, prevalent in previous general studies.[23] However, it needs to be taken into account that our sample represents a relatively small number of individuals. Those more opinionated about AI could also be more inclined to answer the survey, possibly inducing bias in the results. The specific context, of mammography screening and the profession of breast radiologists, in a digitally advanced welfare state, however, showcases the importance of considering technological implementations in relation to organisational and socio-economic structures.

Furthermore, we did identify important reservations, factors associated with high uncertainties, and diverse viewpoints, such as regarding liability of AI use. The question is whether established practices need to be adjusted when medical decisions are increasingly supported by automated technologies or AI-systems. Our results point to a somewhat higher perceived responsibility of radiologists in AI-supported radiological practice, compared with previous studies.[20 27] Furthermore, the results show the complexity of accountability when AI enters radiology, how it is contextual, dependent on how AI is used and which actors are included. This further emerges in the insecurities regarding liability for missed cancers, when AI is used as a co-reader or as stand-alone reader, or when radiologists disregard AI findings. The results indicate a perceived shift of responsibility away from the radiologist as automation increases. Additionally, uncertainties regarding the responsibilities of AI-developers (and AI-systems) suggest a need for clarification.[28]

We could not identify one unified vision of a preferred way to use AI in mammography screening. Previously, AI has been expected to be used as second reader and for optimising workflows.[16–18] While using AI as replacement for one reader in double-reading was the most preferred option in our study, many favoured using it as an addition to double-reading or in a combination of uses, suggesting perceived qualities other than workload reduction. Furthermore, the perceived risk of AI deteriorating working conditions might be due to several reasons. Besides a risk of eroded knowledge of the normal breast, reduced screen reading workload might not improve working conditions. While more time for patient-centred care is portrayed as a positive outcome of AI,[27] some perceived screen reading as a welcomed interruption from emotionally burdensome work, which might be lost due to automation. Working with AI-systems also adds layers of interpretation,[29] which could be exhausting. This seems to be perceived as a medical risk, but also as an ethical burden with legal uncertainties.

Additionally, AI in mammography screening needs to be considered in light of previous innovations. Some aspects are not unique for AI, such as contested expertise.[30] However, radiologists, trainees and medical students strongly expect AI to change the field and impact job opportunities, tasks and relationships with

patients.[16–18 20] Our study shows that breast radiologists believed that AI will impact the profession, both positively and negatively. However, most did not believe it would impact the role of the breast radiologist. Few thought it would improve recruitment, possibly due to the idea of AI negatively affecting the professional reputation.[26] Many considered, or were uncertain whether, implementing AI represents a substantial difference in comparison to previous technologies. While new imaging methods aim to improve cancer visibility, AI differs since it involves medical decision-making. This implies that social, ethical and legal aspects have to be addressed, which in turn depends on how AI is incorporated into the clinical workflow. Greater unclarity about accountability seems to be prevalent regarding AI as a stand-alone technique, which was also the least favoured approach. This suggests that physicians are not willing to renounce their responsibility in medical decision-making. In total, our results echo the need for more research on social, ethical and legal matters of integrating AI into radiology and screening.

Strengths and limitations

The main limitations of the study are the specific conditions of the Swedish setting and the small number of respondents. The response rate was satisfactory, but the target population was limited since there are few Swedish breast radiologists. The study's strengths were that the respondents were highly experienced in breast imaging and that half of the group had experience of using AI in breast imaging.

CONCLUSIONS

Breast radiologists in Sweden were largely positive about integrating AI in mammography screening, especially those with a heavy screen-reading workload, citing reduced workload and increased sensitivity as benefits. Still, we identified several concerns and uncertainties that need to be addressed, foremost regarding potential risks – pertaining to medical outcomes, working conditions and the question of liability in medical decision-making when using AI. Furthermore, there is a lack of consensus on the optimal use of AI in the screening workflow. The results emphasise the need to understand actor-specific and context-specific challenges for responsible implementation of AI.

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Competing interests KL is on an advisory board for Siemens Healthineers.

Patient consent for publication Not applicable.

Ethics approval This study did not need an ethics approval, in accordance with local regulations, as no sensitive personal information about study participants (the radiologists) was collected. Informed consent was obtained prior to participation.

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Data availability statement No data are available. Data cannot be openly shared, due to respondent anonymity.

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REFERENCES

1 Dembrower K, Wåhlin E, Liu Y, *et al*. Effect of artificial intelligence-based Triaging of breast cancer screening mammograms on cancer detection and Radiologist workload: A retrospective simulation study. *Lancet Digit Health* 2020;2:S2589-7500(20)30185-0:e468–74.:.
2 Rodriguez-Ruiz A, Lång K, Gubern-Merida A, *et al*. Stand-Alone artificial intelligence for breast cancer detection in mammography: comparison with 101 radiologists. *JNCI* 2019;111:916–22.
3 McKinney SM, Sieniek M, Godbole V, *et al*. International evaluation of an AI system for breast cancer screening. *Nature* 2020;577:89–94.
4 Houssami N, Irwig L, Ciatto S. Radiological surveillance of interval breast cancers in screening programmes. *Lancet Oncol* 2006;7:259–65.
5 Loving VA, Aminololama-Shakeri S, Leung JWT. Anxiety and its association with screening mammography. *Journal of Breast Imaging* 2021;3:266–72.
6 Perry N, Broeders M, de Wolf C, *et al*. European guidelines for quality assurance in breast cancer screening and diagnosis. fourth edition -- summary document. *Ann Oncol* 2008;19:614–22.
7 Lauritzen AD, Rodríguez-Ruiz A, von Euler-Chelpin MC, *et al*. An artificial intelligence-based mammography screening protocol for breast cancer: outcome and radiologist workload. *Radiology* 2022;304:210948:41–9.:.
8 Taylor-Phillips S, Stinton C. Double reading in breast cancer screening: considerations for policy-making. *Br J Radiol* 2020;93:20190610:20190610.:.
9 Byng D, Strauch B, Gnas L, *et al*. AI-based prevention of interval cancers in a national Mammography screening program. *Eur J Radiol* 2022;152:S0720-048X(22)00171-1:110321.:.
10 Lång K, Hofvind S, Rodríguez-Ruiz A, *et al*. Can artificial intelligence reduce the interval cancer rate in mammography screening? *Eur Radiol* 2021;31:5940–7.
11 Freeman K, Geppert J, Stinton C, *et al*. Use of artificial intelligence for image analysis in breast cancer screening programmes: systematic review of test accuracy. *BMJ* 2021;374:n1872:1872.:.
12 Geis JR, Brady AP, Wu CC, *et al*. Ethics of artificial intelligence in radiology: summary of the joint European and North American multisociety statement. *Radiology* 2019;293:436–40.
13 Blasimme A, Vayena E. The ethics of AI in biomedical research, patient care, and public health. In: Das S, Pasquale F, Dubber MD, eds. *The Oxford Handbook of Ethics of AI*. New York, NY: Oxford University Press, 2020: 703–18.

14 Rajpurkar P, Chen E, Banerjee O, *et al*. Ai in health and medicine. *Nat Med* 2022;28:31–8.
15 Obermeyer Z, Lee TH. Lost in thought - the limits of the human mind and the future of medicine. *N Engl J Med* 2017;377:1209–11.
16 Huisman M, Ranschaert E, Parker W, *et al*. An international survey on AI in radiology in 1041 radiologists and radiology residents Part 2: expectations, hurdles to implementation, and education. *Eur Radiol* 2021;31:8797–806.
17 Gong B, Nugent JP, Guest W, *et al*. Influence of artificial intelligence on Canadian medical students' preference for radiology specialty: anational survey study. *Academic Radiology* 2019;26:566–77.
18 Collado-Mesa F, Alvarez E, Arheart K. The role of artificial intelligence in diagnostic radiology: a survey at a single radiology residency training program. *J Am Coll Radiol* 2018;15:S1546-1440(17)31666-6:1753–7.:.
19 Houssami N, Lee CI, Buist DSM, *et al*. Artificial intelligence for breast cancer screening: opportunity or hype? *The Breast* 2017;36:31–3.
20 Codari M, Melazzini L, Morozov SP, *et al*. Impact of artificial intelligence on radiology: a euroaim survey among members of the European Society of radiology. *Insights Imaging* 2019;10.
21 Scott IA, Carter SM, Coiera E. Exploring stakeholder attitudes towards AI in clinical practice. *BMJ Health Care Inform* 2021;28:e100450.
22 Carter SM, Rogers W, Win KT, *et al*. The ethical, legal and social implications of using artificial intelligence systems in breast cancer care. *Breast* 2020;49:S0960-9776(19)30564-8:25–32.:.
23 Huisman M, Ranschaert E, Parker W, *et al*. An international survey on AI in radiology in 1,041 radiologists and radiology residents Part 1: fear of replacement, knowledge, and attitude. *Eur Radiol* 2021;31:7058–66.
24 DESI. The Digital economy and society index. European Commission; 2022. Available: https://digital-strategy.ec.europa.eu/en/policies/desi
25 Duffy SW. Mammography screening and research evidence: the Swedish contribution. *Journal of Breast Imaging* 2021;3:637–44.
26 Coppola F, Faggioni L, Regge D, *et al*. Artificial intelligence: radiologists' expectations and opinions gleaned from a nationwide online survey. *Radiol Med* 2021;126:63–71.
27 Waymel Q, Badr S, Demondion X, *et al*. Impact of the rise of artificial intelligence in Radiology: What do Radiologists think. *Diagn Interv Imaging* 2019;100:S2211-5684(19)30090-7:327–36.:.
28 Pesapane F, Volonté C, Codari M, *et al*. Artificial intelligence as a medical device in Radiology: Ethical and regulatory issues in Europe and the United States. *Insights Imaging* 2018;9:745–53.
29 Lebovitz S, Lifshitz-Assaf H, Levina N. To engage or not to engage with AI for critical judgments: how professionals deal with opacity when using AI for medical diagnosis. *Organization Science* 2022;33:126–48.
30 Barley SR. Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of Radiology departments. *Adm Sci Q* 1986;31:78–108.

Enkät: Bröstradiologers syn på användning av artificiell intelligens i mammografiscreening

1. Ålder

Under 31 år | 31-40 år | 41-50 år | 51-60 år | Över 60 år

2. Kön

Kvinna | Man | Annat

3. Hur lång erfarenhet har du av bröstradiologi?

Under 5 år | 5-10 år | 11-20 år | 21-30 år | Över 30 år

Kommentar

4. Hur många mammografiscreeningundersökningar granskar du uppskattningsvis per år?

Inga | Färre än 2 000 | 2 000 - 5 000 | 5 000 - 10 000 | Fler än 10 000

Kommentar

5. Upplever du att det är svårt att hinna granska screeningundersökningarna?

Aldrig | Sällan | Ibland | Ofta | Alltid

Kommentar

6. Hur bedömer du din egen teknikkunnighet generellt i vardagen?

- Låg
- Ganska låg
- Varken hög eller låg
- Ganska hög
- Hög

Kommentar

7. Hur bedömer du din egen teknikkunnighet generellt i arbetet?

- Låg
- Ganska låg
- Varken hög eller låg
- Ganska hög
- Hög

Kommentar

8. Hur bedömer du din egen kunskap om AI, artificiell intelligens?

- Låg
- Ganska låg
- Varken hög eller låg
- Ganska hög
- Hög

Kommentar

Inställning till artificiell intelligens i arbetet

9. Vilken är din inställning till användning av AI-stödd mammografiscreening?

Negativ | Ganska negativ | Tveksam | Ganska positiv | Positiv

Kommentar

10. Anser du att det finns potentiella vinster med AI-stödd mammografiscreening?

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

Kommentar

11. Anser du att det finns potentiella risker med AI-stödd mammografiscreening?

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

Kommentar

12. Vilken erfarenhet har du av att använda AI i ditt arbete som mammografiläkare?

Ingen Liten Ganska liten Ganska stor Stor

Kommentar

13. Hur skulle du vilja använda AI i mammografiscreening?

AI som verktyg för triage
AI som enda granskare
AI ersätter en granskare vid dubbelgranskning
AI används i tillägg till dubbelgranskning
Inte alls

Det finns flera olika möjligheter att använda AI i screeningen. Skriv gärna egna förslag eller kommentarer till ovan nämnda förslag, t.ex. hur du skulle vilja kombinera alternativen.

14. I vilken grad skulle du lita på AI-verktygs bedömningar?

I låg grad I ganska låg grad Tveksam I ganska hög grad I hög grad

Kommentar

15. Tror du att det finns en risk att radiologer har en övertro till AI-verktygs bedömningar?

I låg grad I ganska låg grad Tveksam I ganska hög grad I hög grad

Kommentar

16. Skulle din tillit till AI-verktyget vara större ifall radiologernas bedömningar bidrog till fortsatt träning av AI-verktyget efter klinisk implementering?

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

Kommentar

Vem anser du bär ansvaret för bedömningar gjorda vid AI-stödd mammografiscreening?

17. Den enskilda radiologen (ex. i egenskap av medgranskare)

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

18. Vårdgivaren

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

19. AI-verktyget

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

20. Utvecklare av AI-verktyget

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

21. Delat ansvar

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Om du anser att det är delat ansvar, specificera mellan vilka aktörer och varför:

Vem anser du bär ansvar för bedömningar gjorda vid mammografiscreening med enbart AI-granskning?

22. Den enskilda radiologen (ex. i egenskap av översyn av screeningprocessen)

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

23. Vårdgivaren

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

24. AI-verktyget

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

25. Utvecklare av AI-verktyget

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

26. Delat ansvar

- ○ I låg grad
- ○ I ganska låg grad
- ○ Tveksam
- ○ I ganska hög grad
- ○ I hög grad

Om du anser att det är delat ansvar, specificera mellan vilka aktörer och varför:

Om du använder/har använt AI i ditt arbete, anser du att du har fått den information du behöver för att kunna bedöma riktigheten i AI-verktygets bedömning:

27. Vid användning av verktyget (information i användargränssnitt m.m.)?

- ○ I låg grad
- ○ I ganska låg grad
- ○ Tveksam
- ○ I ganska hög grad
- ○ I hög grad

Kommentar

28. Inför användning (information från utvecklare m.m.)?

- ○ I låg grad
- ○ I ganska låg grad
- ○ Tveksam
- ○ I ganska hög grad
- ○ I hög grad

Kommentar

29. Om du skulle använda AI-verktyg i mammografiscreening, önskar du få information om hur det har utvecklats (exempelvis vilken data som verktyget har tränats på)?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

Tror du att följande information hade underlättat för dig att kunna avgöra tilliten till ett AI-verktygs bedömning:

30. Information om vad i bilden som föranlett en viss riskgradering?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

31. Information om vad och hur mycket i bilden som hade behövt vara annorlunda för att den istället skulle ha graderats som en högre respektive lägre risknivå?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

32. Information om bakomliggande kod/algoritmer?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

33. Information om vilka kompetenser (ex. bröstradiolog, datavetare, statistiker) som varit delaktiga i utvecklingen av AI-verktyget?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

34. Information om vilken data AI-modellen har tränats på?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

35. Information om hur eventuell uppmärkning av träningsdata gått till (t.ex. hur mammografier med cancer har identifierats och annoterats inför träning av AI)?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

36. Information om verktygets fortsatta lärande efter klinisk implementering?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

37. Tror du att du skulle ha kompetens att avgöra om ett AI-verktygs bedömning vid mammografiscreening är korrekt?

- I låg grad
- I ganska låg grad
- Tveksam
- I ganska hög grad
- I hög grad

Kommentar

38. Tror du att det finns risk att de data som AI-verktyg har tränats på vid utveckling inte är representativ för den befolkningsgrupp som verktyget appliceras på?

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

Kommentar

39. Tror du att det finns en risk att AI-verktyg presterar sämre än radiologer vid mammografiscreening för vissa riskgrupper eller specifika typer av fall?

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

Beskriv i så fall vilka typer av riskgrupper/fall:

Professionens utveckling

40. Om du skulle använda AI-verktyg i ditt arbete med mammografiscreening, skulle du önska att din utvärdering av verktygets bedömning skulle användas för att fortsätta träna och förbättra verktygets precision?

I låg grad | I ganska låg grad | Tveksam | I ganska hög grad | I hög grad

Kommentar

41. Anser du att det finns betydande skillnader i att implementera AI-verktyg i mammografiscreening jämfört med annan tidigare teknikutveckling (t.ex. digital mammografi, tomosyntes)?

- ○ I låg grad
- ○ I ganska låg grad
- ○ Tveksam
- ○ I ganska hög grad
- ○ I hög grad

Kommentar

42. Hur tror du att mammografiläkarens roll skulle förändras om AI-stödd mammografiscreening införs?

- ○ Försvagas
- ○ Försvagas något
- ○ Inte alls
- ○ Stärkas något
- ○ Stärkas

Kommentar

43. Tror du att införande av AI-stödd mammografiscreening skulle göra det lättare att rekrytera nya bröstradiologer?

- ○ I låg grad
- ○ I ganska låg grad
- ○ Tveksam
- ○ I ganska hög grad
- ○ I hög grad

Kommentar

44. Tror du att införande av AI-stödd mammografiscreening skulle påverka relationen mellan läkare/sjukvård och individer som deltar i screening? I så fall, hur?

45. Hur tror du att professionen kommer att utvecklas, med tanke på rådande teknikutveckling med AI?

Survey: Breast Radiologists' Views on the use of Artificial Intelligence in Mammography Screening

1. Age

◯ <31 years ◯ 31-40 years ◯ 41-50 years ◯ 51-60 years ◯ >60 years

2. Gender

◯ Femal ◯ Male ◯ Other

3. How long experience do you have of working with breast radiology?

◯ <5 years ◯ 5-10 years ◯ 11-20 years ◯ 21-30 years ◯ >30 years

Comments

4. How many screening exams do you approximately review per year?

◯ None ◯ <2000 ◯ 2 000 - 5 000 ◯ 5 000 - 10 000 ◯ >10 000

Comments

5. Do you experience difficulties finding the time to perform the screen-reading?

◯ Never ◯ Seldom ◯ Some-times ◯ Often ◯ Always

Comments

6. What is your estimated level of literacy of technology in everyday life?

- ○ Low
- ○ Somewhat low
- ○ Neither high nor low
- ○ Somewhat high
- ○ High

Comments

7. What is your estimated general level of literacy of technology at work?

- ○ Low
- ○ Somewhat low
- ○ Neither high nor low
- ○ Somewhat high
- ○ High

Comments

8. What is you estimated level of literacy of AI, artificial intelligence?

- ○ Low
- ○ Somewhat low
- ○ Neither high nor low
- ○ Somewhat high
- ○ High

Comments

Attitudes towards artificial intelligence, AI, in the work

9. What is your attitude towards the use of AI-supported mammography screening?

- ○ Negative
- ○ Somewhat negative
- ○ Uncertain
- ○ Somewhat positive
- ○ Positive

Comments

10. Do you consider that there are potential benefits of using AI-supported mammography screening?

- ○ To low degree
- ○ To somewhat low degree
- ○ Uncertain
- ○ To somewhat high degree
- ○ To high degree

Comments

11. Do you consider that there are potential risks of using AI-supported mammography screening?

- ○ To low degree
- ○ To somewhat low degree
- ○ Uncertain
- ○ To somewhat high degree
- ○ To high degree

Comments

12. How much experience do you have of using AI in breast radiology?

- ○ None
- ○ Little
- ○ Somewhat little
- ○ Somewhat large
- ○ Large

Comments

13. How would you like to use AI in mammography screening?

- ○ AI as triage tool
- ○ AI as stand-alone reader
- ○ AI as replacement of one radiologist in double screen-reading
- ○ AI as addition to double screen-reading
- ○ Not at all

There are several possibilities of how to use AI in screening, please, write your suggestion or comments to the options mentioned above, for example how you would like to combine different options.

14. To what degree would you trust the assessments made by an AI-system?

- ○ To low degree
- ○ To somewhat low degree
- ○ Uncertain
- ○ To somewhat high degree
- ○ To high degree

Comments

15. Do you think there is a risk of radiologists over-relying on assessments made by AI-systems?

- ○ To low degree
- ○ To somewhat low degree
- ○ Uncertain
- ○ To somewhat high degree
- ○ To high degree

Comments

16. Would your trust in the AI-system be increased if your assessment contributed to train the AI-system after clinical implementation?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

Whom do you consider being responsible for assessments made by AI-supported mammography screening?

17. The radiologist (e.g., as co-reader)

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

18. The health care provider

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

19. The AI-system

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

20. Developers of the AI-system

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

21. Shared responsibility

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

If you consider there to be shared responsibility, specify between which actors and why:

Whom do you consider being responsible for assessments made by AI-supported mammography screening with AI as single reader?

22. The radiologist (e.g., in terms of oversight)

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

23. The health care provider

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

24. The AI-tool

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

25. The developer of the AI-system

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

26. Shared responsibility

- ○ To low degree
- ○ To somewhat low degree
- ○ Uncertain
- ○ To somewhat high degree
- ○ To high degree

If you consider there to be shared responsibility, specify between which actors and why:

If you are using/have been using AI in your work, do you consider that you have recieved the information you need, to be able to evaluate the accuracy of the AI-system's assessment:

27. When using the system (information in user interface etc.)?

- ○ To low degree
- ○ To somewhat low degree
- ○ Uncertain
- ○ To somewhat high degree
- ○ To high degree

Comments

28. Prior to use of AI-system (information from developer etc.):

- ○ To low degree
- ○ To somewhat low degree
- ○ Uncertain
- ○ To somewhat high degree
- ○ To high degree

Comments

29. If you were to use an AI system in mammography screening, would you wish to receive information about how it was developed (for example, regarding what data were used for training)?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

Do you think that the following information would have supported your trust evaluation of the assessments made by an AI-system:

30. Information about what in the image that caused the given risk score?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

31. Information about what, and how much, in the image that would have had to be different for it to receive a lower versus higher risk score?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

32. Information about the underlying code/algorithms?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

33. Information about competences involved in the development of the AI-system (e.g., breast radiologist, computer scientist, statisticians)?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

34. Information about training data?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

35. Information the labelling of the training data (e.g., how exams with cancer have been identified and annotated for the training of the AI-system)?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

36. Information about continuous training of the AI-system after clinical implementation?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

37. Do you consider that you would have competency enough to evaluate the accuracy of an AI-system's assessment of screening exams?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

38. Do you think there is a risk of the training data for AI-system not being representative enough for the demographics of the target population?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

39. Do you think there is a risk that the performance of AI-systems is lower than radiologists' regarding exams of certain risk groups or cases?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

If so, describe which risk groups/cases:

Development of the profession

40. If you would be using AI in your work with mammography screening, would you wish for your evaluation of the AI assessment to be included in the continuous training of the system for improving its precision?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

41. Do you consider there to be significant differences in implementing AI in mammography screening, in comparison to previous technologies (e.g., digital mammography, tomosynthesis)?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

42. How do you think the role of the breast radiologist would change if AI-supported mammography screening was implemented?

- Weakened
- Somewhat weakened
- Not at all
- Somewhat strengthened
- Strengthened

Comments

43. Do you think implementing AI-supported mammography screening would make recruitment of breast radiologists easier?

- To low degree
- To somewhat low degree
- Uncertain
- To somewhat high degree
- To high degree

Comments

44. Do you think that implementing AI-supported mammography screening would impact the relation between doctors/healthcare and screening participants? If so, how?

45. How do you think the profession will evolve, with regards to current technological development of AI?