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IMAGING INFORMATICS AND ARTIFICIAL INTELLIGENCE

Stakeholders' perspectives on the future of artificial intelligence in radiology: a scoping review

Ling Yang[1] · Ioana Cezara Ene[1] · Reza Arabi Belaghi[2] · David Koff[3] · Nina Stein[4] · Pasqualina (Lina) Santaguida[1]

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Abstract

Objectives Artificial intelligence (AI) has the potential to impact clinical practice and healthcare delivery. AI is of particular significance in radiology due to its use in automatic analysis of image characteristics. This scoping review examines stakeholder perspectives on AI use in radiology, the benefits, risks, and challenges to its integration.

Methods A search was conducted from 1960 to November 2019 in EMBASE, PubMed/MEDLINE, Web of Science, Cochrane Library, CINAHL, and grey literature. Publications reflecting stakeholder attitudes toward AI were included with no restrictions.

Results Commentaries (n = 32), surveys (n = 13), presentation abstracts (n = 8), narrative reviews (n = 8), and a social media study (n = 1) were included from 62 eligible publications. These represent the views of radiologists, surgeons, medical students, patients, computer scientists, and the general public. Seven themes were identified (predicted impact, potential replacement, trust in AI, knowledge of AI, education, economic considerations, and medicolegal implications). Stakeholders anticipate a significant impact on radiology, though replacement of radiologists is unlikely in the near future. Knowledge of AI is limited for non-computer scientists and further education is desired. Many expressed the need for collaboration between radiologists and AI specialists to successfully improve patient care.

Conclusions Stakeholder views generally suggest that AI can improve the practice of radiology and consider the replacement of radiologists unlikely. Most stakeholders identified the need for education and training on AI, as well as collaborative efforts to improve AI implementation. Further research is needed to gain perspectives from non-Western countries, non-radiologist stakeholders, on economic considerations, and medicolegal implications.

Key Points

- *Stakeholders generally expressed that AI alone cannot be used to replace radiologists. The scope of practice is expected to shift with AI use affecting areas from image interpretation to patient care.*
- *Patients and the general public do not know how to address potential errors made by AI systems while radiologists believe that they should be "in-the-loop" in terms of responsibility. Ethical accountability strategies must be developed across governance levels.*
- *Students, residents, and radiologists believe that there is a lack in AI education during medical school and residency. The radiology community should work with IT specialists to ensure that AI technology benefits their work and centres patients.*

Keywords Radiology · Artificial intelligence · Attitude · Education · Ethics

Ling Yang and Ioana Cezara Ene are co-first authors.

✉ Pasqualina (Lina) Santaguida
santag@mcmaster.ca

[1] McMaster University, 1280 Main St W, Hamilton, ON L8S 4L8, Canada

[2] University of Tabriz, 29 Bahman Boulevard, Tabriz, East Azerbaijan Province, Iran

[3] Department of Radiology, McMaster University, 1280 Main St W, Hamilton, ON L8S 4L8, Canada

[4] McMaster Children's Hospital, McMaster University, 1280 Main St W, Hamilton, ON L8N 3Z5, Canada

Abbreviations

AI	Artificial intelligence
ANN	Artificial neural networks
CADTH	Canadian Agency for Drugs and Technologies in Health
CINAHL	Cumulative Index to Nursing and Allied Health Literature
DL	Deep learning
ML	Machine learning
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Introduction

Artificial intelligence (AI) has seen increased public attention and industrial application in recent years [1–7]. Its ability in analysing complex data particularly suits it to automated interpretation in diagnostic imaging. Several collaborative programmes between medical institutions and data companies exist to establish reliable AI-based diagnostic algorithms [8–10].

Reception of such programmes has been mixed. While most believe that AI enhances the accuracy, efficiency, and accessibility of medical imaging, the role of the radiologist in this future remains uncertain [11, 12]. Attitudes of physicians are variable, ranging from envisioning an AI-dominated practice to optimism in broadening their scope of practice [13, 14].

AI refers to systems designed to execute tasks that traditionally require a human agent [15, 16]. *Machine learning* (ML) refers to computer algorithms applied in AI capable of automatic learning and data extrapolation [17–19]. ML can incorporate different learning algorithms, of which *artificial neural networks* (ANN) and deep learning (DL) are most well-known. ANN are collections of artificial neurons that analyse inputs and assign suitable weights to predict an outcome [18–21]. DL uses multilevel ANN for nonlinear data processing [22]. Experts predict that the coming decades will see DL grow into mainstream medical imaging [23, 24]. Although these definitions are understood by AI researchers, how clinicians or patients understand these terms and their implications remains unclear.

There is an increasing body of publications regarding attitudes toward the impact of AI in diagnostic imaging. A comprehensive review of stakeholders' perspectives has yet to be performed. We undertook a scoping review to systematically search the literature, identify relevant stakeholders, and categorise their views on the use of AI in radiology.

Methods

Study design The protocol was registered (DOI: 10.17605/OSF.IO/AXDPE). Based on the methodology outlined by Arksey and O'Malley (2005) and Levac et al (2010), this scoping review consisted of six stages [25, 26].

Stage 1: Formulating the research question

Following a preliminary exploration of published literature, the following research questions were identified:

- To what extent is AI expected to influence radiology practice?
- What are stakeholders' views on the use of AI in radiology?
- What challenges and advantages arise with AI use in radiology?

Stage 2: Identifying relevant studies

Database selection Publications were identified from EMBASE, PubMed/MEDLINE, Web of Science, Cochrane Library, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). Grey literature was searched using the Canadian Agency for Drugs and Technologies in Health (CADTH) Grey Literature Checklist, OpenGrey, and Google Scholar [27].

Search strategy The search strategy was drafted with consultation of a research librarian and a timeframe of 1960, when "artificial intelligence" first appeared in the literature, to November 2019 (Supplement S1).

Eligibility criteria Published studies and grey literature of any design, language, region, and timeframe including commentaries, abstracts, and reviews were eligible.

Stage 3: Study selection

Two levels of screening were conducted: (1) title and abstract review, and (2) full-text review. For level one screening, two reviewers (C.E., L.Y.) independently screened titles and abstracts for full-text review based on the inclusion criteria. In level two screening, full-text studies underwent independent review, including reference list searches. Relevant studies were included if perspectives on AI use in radiology were described. The PRISMA flow diagram tracking progress is shown in Figure 1 [28].

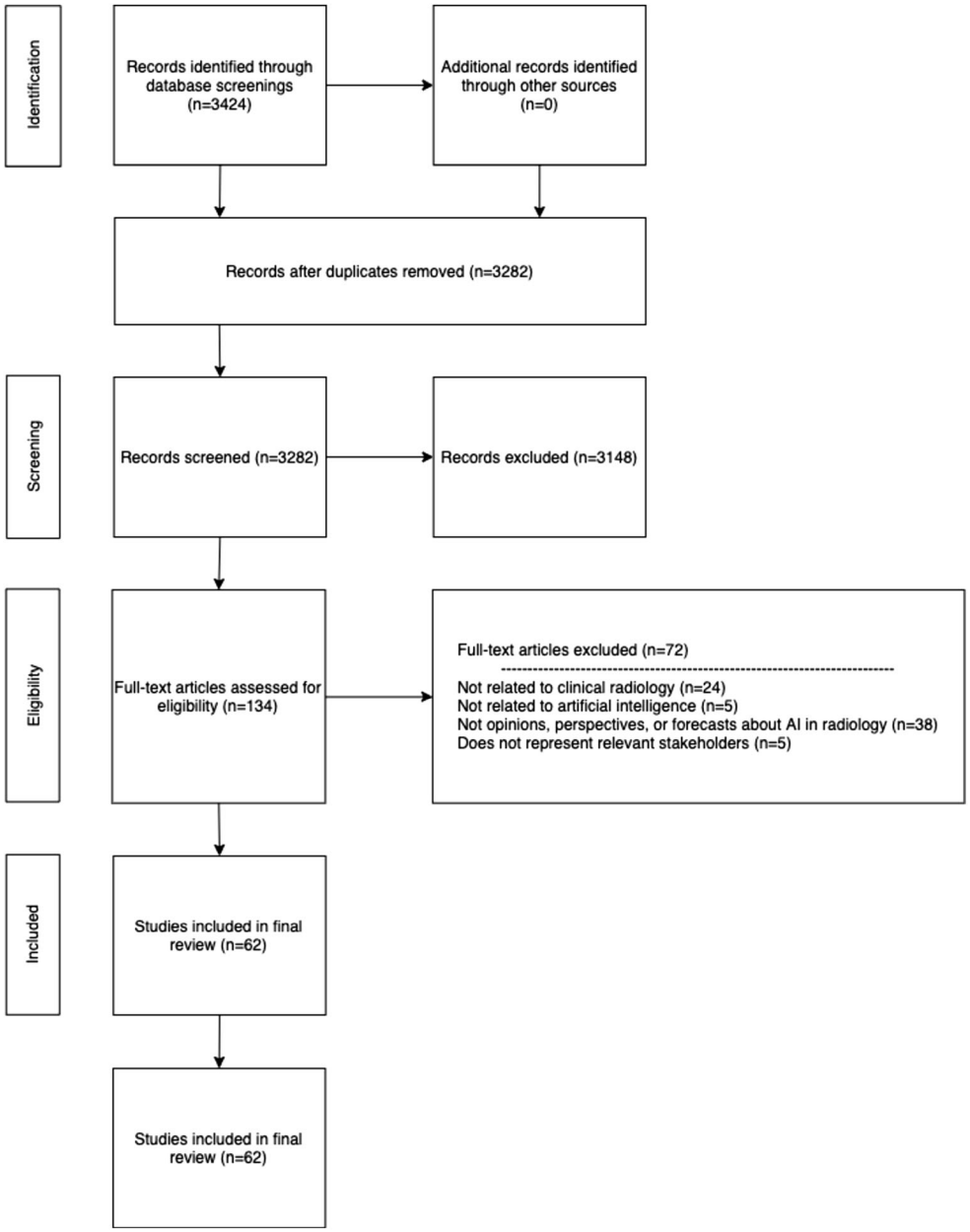

Fig. 1 PRISMA flow diagram

Stage 4: Charting the data

All included articles were independently extracted using a standardised form. Characteristics organised included bibliographical information (i.e. authors, titles, dates, and journals), objective, study type, participant demographic, AI definitions, and attitudes toward AI.

Stages 5 and 6: Collection, summary, and consultation

The PRISMA-ScR guided the collection, interpretation, and communication of results [28]. Following the recommendations by Levac et al (2010), thematic analysis consisted of (1) analysing the data, (2) reporting results, and (3) applying meaning to the results [25]. A spreadsheet was generated with article characteristics and conclusions. Extracted text was grouped by stakeholder, issues discussed, and expressed views. Themes were subsequently identified. Following the initial groupings by C.E. and L.Y., methodological experts (R.A., P.S.) and radiologists (D.K., N.S.) reviewed the data to provide additional input and confirm interpretations. Several iterations were undertaken to ensure accuracy and consistency.

Results

Characteristics of all included publications

Sixty-two publications were included from the 3282 screened (Figure 1). These represented radiologists

Table 1 General characteristics of survey studies (n = 13) grouped by stakeholders

Author (year), country	Perspectives expressed	Aim*	Methodology*	Key findings
Radiologists				
van Hoek et al (2019), Switzerland [62]	Radiologists (n = 40 diagnostic, 2 interventional, 17 both)	Evaluate the opinion and assessment of radiologists, surgeons and medical students on a number of important topics regarding the future of radiology.	Online questionnaire (#Qs=17)	Radiologists significantly favoured the use of AI in radiology, more so than surgeons. Views were less positive on AI being used alone for image interpretation despite high diagnostic accuracy. Radiologists do not fear the loss of their jobs with technological advancement. The majority expect an acceleration of their work using AI, and would choose radiology as a speciality again. Turf losses are possible.
Ooi et al (2019), Singapore [29]	Radiologists (n = 70 residents, 55 faculty)	Assess the attitudes and learner needs of radiology residents and faculty radiologists regarding artificial intelligence (AI) and machine learning (ML) in radiology.	Online questionnaire (#Qs=20)	Participants felt positively about AI, saying they would still choose radiology as a speciality, plan to learn more about AI/ML, and disagree with the possibility of AI replacing human radiologists. Faculty felt that their residency programmes lacked AI/ML training, more so than residents.
Eltorai et al (2019), largely US [30]	Chest radiologists (n = 95)	(1) Assess thoracic radiologists' perspectives on the role and expected impact of AI in radiology, and (2) Compare radiologists' perspectives with those of computer science (CS) experts working in the AI development.	Online survey (#Qs=unclear)	All radiologists had heard of AI/ML, and its impact on radiology is expected to be high. 0% expected radiology to become obsolete in the next 5–10 years. 3.2% expect obsolescence in 10–20 years, which is significantly less than computer scientists predict. Radiologists are optimistic about future job satisfaction and salary, and the majority plan to engage with AI/ML development. Oversight of AI/ML by radiologists is expected.
Koh (2019), International (40 countries) [61]	Radiologists (n = 664)	Understand the current attitudes and perceptions of radiologists to AI and machine learning in cancer imaging.	Online survey (#Qs=unclear)	The majority of responders found the benefits of AI to be much bigger or slightly bigger than the risks in cancer imaging, and anticipate benefit to the field in the next 5 years. Perspectives on whether AI would replace or devalue radiologists' work were highly varied.
Waymel et al (2019), France [60]	Radiologists at public and private institutions (n = 93 residents, 524 senior radiologists)	Assess the perception, knowledge, wishes and expectations of a sample of French radiologists toward the rise of artificial intelligence (AI) in radiology.	Electronic survey (#Qs=42)	Radiologists believed they were not adequately informed on AI and would appreciate educational materials on the subject. Anticipated impacts on daily practice were largely positive, and most disagreed that AI would replace radiologists. AI should be taught in medical school.
European Society of Radiology (2019), Europe and USA [32]	Members of the European Society of Radiology (n = 675)	Determine radiologists' position toward these new technological innovations which could strongly impact their specialty.	Online survey (#Qs=22)	The direction of how AI will affect radiologists' job opportunities, workload, and clinical profile is unclear. Radiologists will play a role in the development and validation of AI tools in medical imaging. Overall, there is a trend toward radiologists becoming more patient-oriented.
Collado-Mesa et al (2018), USA [59]	Radiologists (n = 35 attending radiologists, 34 trainees)	Establish a baseline upon which to build educational activities on artificial intelligence in diagnostic radiology.	Web-based questionnaire (#Qs=13)	AI/ML is unlikely to lead to the obsolescence of radiology. Trainees were more likely to doubt their pursuit of diagnostic radiology compared to attendings had they known about the potential impact of AI. No difference was found between groups for willingness to contribute to development of AI, nor

Table 1 (continued)

Author (year), country	Perspectives expressed	Aim*	Methodology*	Key findings
				for their expectations about its potential impact on daily practice.
Surgeons				
van Hoek et al (2019), Switzerland [62]	Surgeons (n = 56)	Evaluate the opinion and assessment of radiologists, surgeons and medical students on a number of important topics regarding the future of radiology.	Online questionnaire (#Qs=14)	Surgeons favoured AI in radiology less than radiologists and medical students, and were more skeptical on its use alone in interpreting images after achieving high diagnostic accuracy.
Medical students				
van Hoek et al (2019), Switzerland [62]	Medical students (n = 55)	Evaluate the opinion and assessment of radiologists, surgeons and medical students on a number of important topics regarding the future of radiology.	Online questionnaire (#Qs=13)	Students favoured AI in radiology, more so than surgeons. They were more pessimistic than radiologists regarding diagnostic radiology's prospects given technical advancements like AI. Fifteen percent of students answered they considered radiology as a possible future specialisation. Of the students who did not consider radiology as an option for specialisation, 26% cited the future use of AI as one of the reasons not to choose radiology. Students are significantly less pessimistic than radiologists in considering turf losses to other specialities.
Dbouk et al (2019), France [73]	First to sixth year medical students (n = 548)	Assess awareness and knowledge of Interventional Radiology (IR) in a large population of medical students in France in 2019.	Electronic survey (#Qs=2)	One third of students answered that AI is a threat to radiology, but the majority believe radiology has a future.
Gong et al (2019), Canada [31]	Canadian medical students (n = 322)	Investigate Canadian medical students' perceptions of the impact of AI on radiology, and their influence on the students' preference for radiology specialty.	Online survey (#Qs=17)	The impact of AI on radiology will be largely positive, though the impact of AI alone may reduce the number of radiologists needed. Anxiety exists regarding choosing radiology as a speciality, at least in part due to AI. Increased year level and significant exposure to AI decrease anxiety about radiology's prospects. Participants' self-assessments of competence in AI was significantly higher than their competence measured objectively. Sources of information for students varied widely—obtaining information from local radiologists, radiology conferences, and radiology journals was associated with optimism. Narratives showed mixed perceptions of AI in radiology overall.
Pinto dos Santos et al (2018), Germany [72]	Undergraduate medical students (n = 263)	Assess undergraduate medical students' attitudes toward artificial intelligence (AI) in radiology and medicine.	Web-based questionnaire (#Qs=13)	Half were aware that AI is a major topic in radiology, and a third had basic knowledge of the technology. AI will revolutionise radiology, but will not replace human physicians or radiologists, specifically. One-third were concerned about AI, and less than half found these developments made radiology more exciting. There is a need for training on AI in medical school. AI will improve radiology and medicine as a whole.

Table 1 (continued)

Author (year), country	Perspectives expressed	Aim*	Methodology*	Key findings
Patients				
Ongena et al (2020), Netherlands [74]	Patients scheduled for CT, MRI, and/or conventional radiography (n = 155)	Develop and validate a standardised patient questionnaire on the implementation of AI in radiology.	Standardized questionnaire (#Qs=39)	Patients are moderately negative in their trust of AI taking over for diagnostic radiologists, prefer personal interaction over AI-based communication, and predict a lack of emotional support from a computer delivering their diagnoses. However, patients are engaged in understanding how their imaging examinations are acquired, interpreted, and communicated, and would prefer AI perform holistic assessments that can inform them of future diseases they will experience. Ambiguity remained as to whether AI would improve diagnostic workflow.
Haan et al (2019), Netherlands [58]	Patients at a tertiary care radiological academic institution (n = 20)	Develop an understanding of the patient's level of knowledge of AI and to explore the meanings patients ascribe to key topics, such as radiology and AI.	Semi-structured face-to-face interview (#Qs=5 broad domains)	Given equal ability, patients prefer human physicians over computers and fear depersonalisation of medicine. If evidence shows that computers are superior, patients prefer computers. Patients have uncertain procedural knowledge and do not know how AI would affect workflow. They are unsure about computers' skills, and believe them to be a useful checking tool that should not function alone. AI will positively affect efficiency. Patients' overall knowledge of AI and radiology is limited.
Computer scientists				
Eltorai et al (2019), largely US [30]	Computer science experts (n = 45)	(1) Assess thoracic radiologists' perspectives on the role and expected impact of AI in radiology, and (2) Compare radiologists' perspectives with those of computer science (CS) experts working in the AI development.	Online survey (#Qs=unclear)	CS experts expect the impact of AI on radiology to be higher compared to radiologists: 15.6% of CS experts expect radiology to be obsolete in 10–20 years, compared to 3.2% of radiologists. CS experts are optimistic about future job satisfaction and salary.
General public				
Rosenkrantz and Hawkins (2017), Twitter [76]	Twitter users (n = 41)	Evaluate the feasibility of using Twitter polls to assess public opinion regarding session content at a national specialty society meeting.	Twitter polls (#Qs=2)	The majority of respondents disagreed that a supercomputer could entirely replace radiologists.

*Aims and methodology as stated by the authors where available.

Table 2 Included themes in survey studies (n = 13)

Group	Predicted impact (a)	Knowledge of AI (b)	Potential for replacement (c)	Trust (d)	Medicolegal implications (e)	Education (f)	Economic considerations (g)
Radiologists							
van Hoek et al (2019) [62]	X		X				
Ooi et al (2019) [29]	X	X	X			X	
Eltorai et al (2019) [30]	X	X	X	X		X	
Koh (2019) [61]	X			X			
Waymel et al (2019) [60]	X		X	X	X	X	
Collado-Mesa et al (2018) [59]	X	X	X			X	
European Society of Radiology (2019) [32]	X	X	X	X	X	X	
Surgeons							
van Hoek et al (2019) [62]			X	X			
Medical students							
van Hoek et al (2019) [62]	X		X				
Dbouk et al (2019) [73]	X		X				
Pinto dos Santos et al (2018) [72]	X	X	X	X		X	
Gong et al (2019) [31]	X	X	X	X		X	
Patients							
Ongena et al (2020) [74]	X			X	X		
Haan et al (2019) [58]	X	X	X	X			
Computer scientists							
Eltorai et al (2019) [30]	X	X	X				
General public							
Rosenkrantz and Hawkins (2017) [76]			X				

Note: X indicates a theme that is discussed

a. The magnitude and/or direction of the predicted impact of artificial intelligence on the field of radiology

b. Awareness, understanding, training, knowledge and/or competency in AI, and its application on radiology

c. The potential of artificial intelligence to replace the current work of radiologists

d. Level of comfort, acceptance, and trust toward using artificial intelligence in radiology

e. Legal and ethical implications of AI use

f. Current and desired state of education regarding using artificial intelligence and its use in radiology

g. Financial considerations and cost-effectiveness

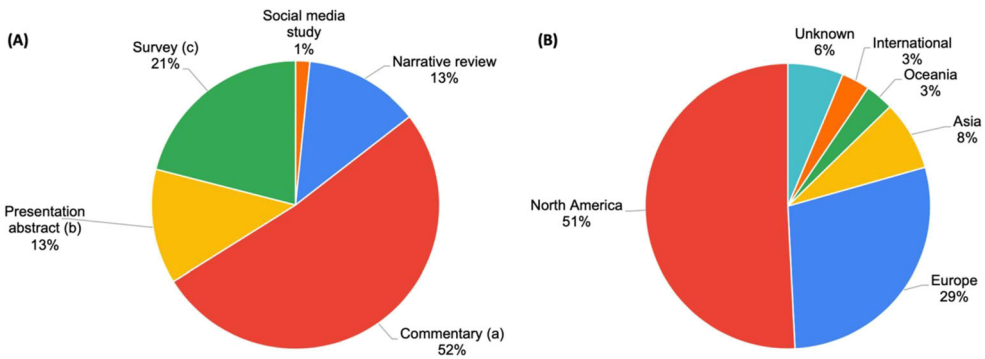

Fig. 2 **A** Study designs. (a) Includes perspective articles, editorials, commentaries, statements letters to the editor, and essays; (b) includes orations, presentations, lectures, forums, symposiums, and conferences summaries; (c) includes surveys, questionnaires, and interviews. **B** Geographic distribution

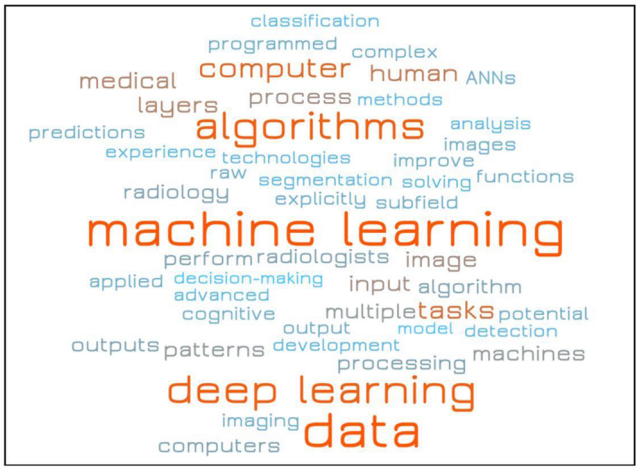

Fig. 3 Word cloud of most frequently used words in AI definitions, where size and colour is representative of frequency of use

(n = 52, 7 surveys), medical students (n = 7, 4 surveys), the general public (n = 4, 1 survey), patients (n = 3, 2 surveys), computer scientists (n = 3, 1 survey), and surgeons (n = 1, 1 survey); many studies assessed more than one stakeholder group. Table 1 shows characteristics for surveys and Table S3 (online supplement) shows characteristics of non-surveys. Most publications were commentaries and editorials (n = 39) and a minority (n = 13) were surveys. The majority of publications (n = 50) represented North American and European views (Figure 2). The majority (81%) of eligible publications were dated after 2018, indicating a surge of interest in AI (Figure 4) (Table 2).

Definition of AI in all included publications

A working definition of AI was found in 52% (n = 33) of studies. These were grouped into one or more of three broad categories that defined AI: (1) into its sub-concepts, ML, DL, and ANN [14–16, 29–51]; (2) with a technical description of its mechanisms [14–16, 33, 35, 37, 38, 40–47, 49–58]; and (3) via its current and future applications [30–32, 34, 39, 59]. Figure 3 is a weighted word map showing the dominant vocabulary used. A greater percentage of commentaries, narrative reviews, and social media studies explicitly defined AI compared to surveys and presentation abstracts.

Generally, AI was understood as the use of pattern-identifying computational algorithms extrapolating from training sets to make predictions, i.e. machines performing problem-solving tasks typically delegated to humans [14, 24, 33, 35, 37, 38, 40, 42, 49, 50, 52, 54–56, 58]. Commonly cited applications in radiology included quantitative feature extraction, computer-aided classification and detection, image reconstruction, segmentation, and natural language processing [30, 32, 34, 52, 59].

Analysis of themes expressing views on AI in radiology

Following content analysis, seven themes were identified: (1) predicted impact of AI on radiology, (2) potential for radiologist replacement, (3) trust in AI, (4) knowledge of AI, (5) education on AI, (6) economic considerations, and (7) medicolegal implications. Results were consistent across publications (online Tables S4 and S5). 81–90 As the surveys represented include larger sample sizes, we have summarised these separately (Tables 3 and 4) and will be prioritising them in our results. Findings from non-survey studies will be explicitly identified. Themes captured in surveys are shown in Table 2.

(1) Predicted impact of AI on radiology

While this theme did not include surgeons' views, all remaining stakeholders—radiologists, medical students, patients, computer scientists, and the general public—were generally optimistic. Radiologists and residents consistently expressed that AI will have a significant, positive impact in daily practice [29, 59–61]. Most believe that practical changes will occur in the next 10–20 years [30, 60, 61]. The majority would still choose this specialty if revisiting the choice [29, 30, 59, 62], citing interests in advancing technology [29, 62]. Senior radiologists have greater confidence in the future of the specialty than trainees [59]. Radiologists emphasise that avoiding AI is not feasible, and most medical students agree that radiologists should embrace AI and work with the industry; this is reflected in both surveys [31, 72] and commentaries [39, 63]. Computer scientists had a higher estimate of AI's impact on radiology than radiologists, with half predicting dramatic changes in the next 5–10 years [30]. Medical students believe that the impact of AI will be largely positive [31, 72]. Positions with procedural training are seen as having greater job security compared to diagnostic radiology, as AI is expected to automate image interpretation [62, 73]. Patients believe that AI will positively affect efficiency [58], and no negative impacts were anticipated by the general public in a search of Twitter opinions [54].

(2) Potential for radiologist replacement and (3) Trust

None of the stakeholder groups foresees total replacement of radiologists, and do not trust AI to make decisions independently. Radiologists and medical students expect AI to act as a "co-pilot" [30–32, 60]. Surgeons also expressed skepticism that AI can make clinical decisions alone, and are ambivalent about the endangerment of diagnostic radiology [62]. Radiologists do not expect their diagnostic roles to be replaced due to AI's lack of general intelligence and human traits [29, 30, 59, 62]; they do expect that clinicians who embrace AI will replace those who do not. They anticipate that AI will

Table 3 Survey studies' results part 1

Author (year), country	Predicted impact (a)	Knowledge of AI (b)	Potential for replacement (c)	Trust (d)
Radiologists				
van Hoek et al (2019), Switzerland [62]	• Most in the current situation would choose radiology as a specialty again (91%), some due to interest in technology (79%). • A small proportion would not choose radiology again (9%).	Not assessed.	• Radiologists, surgeons, and students disagree diagnostic radiology will be endangered in the future, with no significant difference between groups ($p = 0.206$). • Students are significantly more negative than radiologists toward diagnostic radiology being jeopardised by technical innovations like AI ($p = 0.0401$). • Radiologists do not fear the loss of their job due to technological developments. • Radiologists see turf losses to be quite possible.	Not assessed.
Ooi et al (2019), Singapore [29]	• AI/ML practice would completely change radiology ($n = 111$, 88.8%). • Most would still specialise in radiology today ($n = 100$, 80.0%). • Few would choose interventional radiology ($n = 16$, 12.8%). • Most AI/ML makes radiology more exciting ($n = 95$, 76.0%), tech-savvy agreed more (54/65, 83.1%) vs non tech-savvy (41/60, 68.3%).	• Majority of respondents considered themselves novices ($n = 81$, 64.8%), some considered themselves competent/very competent/expert ($n = 19$, 15.2%). • Non-tech-savvy respondents are more likely to see themselves as novices compared to tech-savvy respondents (50/60, 83.3% vs 31/65, 47.7%). • Nearly all are aware of implementation of some form of AI in radiology practices ($n = 121$, 96.8%). • Majority interested to participate in AI/ML research ($n = 84$, 67.2%). • Tech-savvy group more likely to be involved in research (16/65, 24.6% vs 13/60, 21.7%). • Half had read 1–5 journal articles on AI/ML in radiology in the last 6 mos ($n = 70$, 56.0%), more tech-savvy have read more than ten articles (10/65, 15.4%), and more in the non-tech savvy group did not read any articles at all (23/60, 38.3%). • Most have not attended any course on AI/ML or data science in the last 5 years ($n = 101$, 80.8%), but tech-savvy group was more likely to have attended at least one course (17/65, 26.2%) vs non-tech savvy group (7/60, 11.7%). • All have heard of AI/ML (100%, $p = 0.9999$).	• AI/ML will not replace human radiologists ($n = 79$, 63.2%) vs will ($n = 15$, 12.0%).	Not assessed.

Table 3 (continued)

Author (year), country	Predicted impact (a)	Knowledge of AI (b)	Potential for replacement (c)	Trust (d)
Eltorai et al (2019), largely US [30]	• Job will be dramatically different in 5–10 years (31.6%), majority predict job will be dramatically different in 10–20 years (61.1%). • Job satisfaction will increase or stay the same (89.5%), salary will increase or stay the same (83.2%), role will improve or stay the same (88.4%). • A small minority would change their decision to pursue radiology (6/95, 6.3%).	• Some used AI/ML applications in daily work (23.2%). • Most would be willing to create or train ML algorithms (70/95, 73.7%).	• None predict replacement in 5 years (0%), few predict obsolescence in 10–20 years (3.2%).	• Most AI/ML applications would require radiologist oversight (70.8%).
Koh (2019), International (40 countries) [61]	• Most felt that AI tools could be used in at least some areas of work that would add value to cancer imaging within the next 5 years (86%).	Not assessed.	Not assessed.	• Benefits of AI/ML are much bigger or slightly bigger than risks for cancer imaging (66%).
Waymel et al (2019), France [60]	• AI will have a positive impact on future practice (214/270, 79.3%). • Estimated time till broad diffusion 5–10y (133/270, 49.3%), 1–5y (104/270, 38.6%). • Lowering risk of imaging-related medial errors (219/270, 81.1%). • Lowering interpretation time of each examination (201/276, 74.4%). • Increase time spent with patients (141/270, 52.2%). • (1–8) I think that AI is going to shift our activity from diagnostic to interventional radiology (4.7 +/− 1.8). • (1–8) If I were to choose my specialty today, I would choose radiology again (6.8+/− 1.8).	Not assessed.	• Number of radiologists needed: the same number (165/270, 61.1%), less (71/270, 26.3%), more (34/270, 12.6%). • (1–8) I think AI is going to replace radiologists (3.1 +/− 1.8).	• Moderately confident that certain AI algorithms can reliably detect pathological conditions. • Less confident that certain AI algorithms can reliably reach a reliable diagnosis without the intervention of the radiologist.
Collado-Mesa et al (2018), USA [59]	• No influence (12/69, 17.4%). • Field would be dramatically different (55/69, 79.7%). • Would not change their decision to pursue radiology given their current knowledge on AI/ML (55/69, 79.7%); would change (2/69, 2.9%); would maybe change (23/69, 33.3%).	• Over a third had not read scientific medical literature article on the topic of AI in radiology in the last 12 mos (25/69, 36%). • Few read 7+ articles (< 8%). • Some reported using AI during daily work: computer assisted detection and voice recognition (12/69, 29%). • Many would be willing to help create or train an ML algorithm so it can do some of the tasks of a radiologist (46/69, 66.7%).	• Few said their jobs would be obsolete (2/69, 2.9%).	Not assessed.
European Society of Radiology (2019), Europe and USA [32]	• There will be an impact on total workload (74.7%), either a reduction (50.8%) or increase (49.2%). • Half think that AI will make radiologists more clinical (53.9%), while some believe that it will become more technical (27.7%).	• Do not use AI in their clinical practice (47.6%), are currently using these systems (20.4%), or do not use them at present but are planning to do it (30.4%).	• Foresee an impact of AI on job opportunities (55.6%), increase (58.1%) or reduction (41.9%).	• Believe that patients will not accept a diagnosis made by AI alone (55.4%); few claim the opposite (11.4 %).

Table 3 (continued)

Author (year), country	Predicted impact (a)	Knowledge of AI (b)	Potential for replacement (c)	Trust (d)
	• Radiologists will be more subspecialty focused (27.7%), less subspecialty focused (17.9%), or unchanged (40.1%). • The use of AI systems will change the patient radiologist relationship (61.5%); more interactional (66.3%) or more impersonal (33.7%).			
Surgeons				
van Hoek et al (2019), Switzerland [62]	Not assessed.	Not assessed.	• Radiologists, surgeons, and students disagree diagnostic radiology will be endangered in the future, with no significant difference between groups ($p = 0.206$).	• Surgeons were more skeptical than radiologists and medical students toward radiology being used alone for image interpretation after achieving diagnostic accuracy ($p = 0.097$).
Medical students				
van Hoek et al (2019), Switzerland [62]	• Students' answers were more pessimistic than radiologists' regarding whether the profession of diagnostic radiology would be jeopardised in the future by technologies like AI ($p = 0.041$). • Some consider radiology as a possible future specialisation (15%); for some, the future of AI is a reason to not do so (26%).	Not assessed.	• Students are less negative than radiologists when it comes to the possibility of turf losses to other professions ($p < 0.001$). • Students are significantly more negative than radiologists toward diagnostic radiology being jeopardised by technical innovations like AI ($p = 0.0401$).	Not assessed.
Dbouk et al (2019), France [73]	• Radiology has a future (500/548, 91.2%).	Not assessed.	• AI is a threat for radiology (186/548, 33.9%).	Not assessed.
Pinto dos Santos et al (2018), Germany [72]	• AI will revolutionise radiology (77.2%). • These developments make radiology more exciting (30.8%). • The use of AI will improve radiology (85.8%).	• Aware that AI is a hot topic in radiology (52.5%). • Have basic knowledge of the underlying technologies (30.8%). • Heard about it from media (85.2%), social media (65.8%), university lectures (55.9%), and friends and family (61.2%).	• Human radiologists cannot be replaced in the foreseeable future (82.9%).	• AI cannot make an automated diagnosis from imaging examinations (56.7%).
Gong et al (2019), Canada [31]	• AI will augment radiologist's capability, and make radiology more efficient (94.7% of those ranking radiology in top 3). • If the potential impact of AI was not a consideration, 20% more respondents would choose it as their first specialty choice.	• Exposure to radiology led to a lower frequency of anxiety regarding AI (76.6% non-exposure vs 53.0% exposure, $p = 0.003$). • Respondents who did not agree with the anxiety statement demonstrated a higher level of confidence in their understanding of AI ($p = 0.044$). • 78.9% agreed that they had a good understanding of what AI is, but only 49.7%	• Disagree that AI will replace radiologists in their lifetime (58.6% of those ranking radiology in top 3). • The impact of AI alone will reduce the number of radiologists that are needed (67.7% of those ranking radiology in top 3).	• Agree that radiologists should embrace artificial intelligence and work with the IT industry for its application (90.2% of those ranking radiology in top 3). • The uncertain impact of AI makes them worried to choose radiology as a career (56.4%).

Table 3 (continued)

Author (year), country	Predicted impact (a)	Knowledge of AI (b)	Potential for replacement (c)	Trust (d)
		answered at least 3/5 knowledge questions correctly. • 30.7% did not answer any questions correctly.		
Patients				
Ongena et al (2020), Netherlands [74]	• Unclear as to whether AI will improve diagnostic workflow.	Not assessed.	Not assessed.	• Patients are moderately negative when it comes to their trust in AI taking over diagnostic interpretation tasks of the radiologist, in terms of accuracy, communication, and confidentiality. • Prefer personal interaction over AI-based communication. • Would feel a lack of emotional support when computers provide results.
Haan et al (2019), Netherlands [58]	No numerical results reported.	No numerical results reported.	No numerical results reported.	No numerical results reported.
Computer scientists				
Eltorai et al (2019), largely US [30]	• Job will be dramatically different in 5–10 years (57.8%) or in 10–20 years (73.3%). • Job satisfaction will increase or stay the same (86.7%), salary will increase or stay the same (73.4%), or role will improve or stay the same (86.7%).	• All have heard of AI/ML (100%, $p = 0.9999$). • Most use AI/ML applications in daily work (91.1%).	• None predict replacement in 5 years (0%), some predict obsolescence in 10–20 years (15.6%).	Not assessed.
General public				
Rosenkrantz and Hawkins (2017), Twitter [76]	Not assessed.	Not assessed.	• 85% disagree that Watson will entirely replace radiologists.	Not assessed.

a. The magnitude and/or direction of the predicted impact of artificial intelligence on the field of radiology

b. Awareness, understanding, training, knowledge and/or competency in AI, and its application on radiology

c. The potential of artificial intelligence to replace the current work of radiologists

d. Level of comfort, acceptance, and trust toward using artificial intelligence in radiology

Table 4 Survey studies' results part 2

Author (year), country	Education (e)	Economic considerations (f)	Medicolegal implications (g)
Radiologists			
van Hoek et al (2019), Switzerland [62]	Not assessed.	Not assessed.	Not assessed.
Ooi et al (2019), Singapore [29]	• 108 plan to advance knowledge in AI/ML to improve performance as radiologists (86.4%). • Residents agreed with the above statement more (63/70, 90%) vs faculty (45/55, 81.8%) (p = 0.207). • Most agree that AI/ML or data science should be introduced during residency (n = 106, 84.8%), (n = 59, 47.2%) think that it should start in junior resident years, and (n = 47, 37.6%) think that it should start in senior years. • Data science training is as important as clinical skills and knowledge (n = 91 72.8%) and imaging physics (n = 100, 80.0%) curricula. • Strongly agree/agree (n = 84, 67.2%) for adding training to a formal summative assessment within the residency programme. •74 said respective residency programmes have not adequately implemented AI/ML training into their curricula (59.2%), faculty (39/55, 70.9%) vs residents (35/70, 50.0%).	Not assessed.	Not assessed.
Eltorai et al (2019), largely US [30]	• 89/95 (93.7%) plan to learn about AI/ML as it pertains to their job.	Not assessed.	Not assessed.
Koh (2019), International (40 countries) [61]	Not assessed.	Not assessed.	Not assessed.
Waymel et al (2019), France [60]	• (1–8) I think that the fundamentals of AI should be taught in medical school (6.1+/− 1.5).	Not assessed.	• 60% of radiologists believed that radiologists should be responsible in case of medical errors. • 1.1% believed that industry should be responsible. • 35.2% believed in shared responsibility. • 3.7% expressed no opinion.
Collado-Mesa et al (2018), USA [59]	• 60/69 (86.9%) plan to learn about AI/ML as it pertains to their jobs.	Not assessed.	Not assessed.
European Society of Radiology (2019), Europe and USA [32]	• 100.0% believe that radiologists will play a role in the development and validation of AI applications to medical imaging. • 64.3% believe that radiologists should supervise all stages of AI development. • Specific roles: task definition 53.2%, providing labelled images 29.2%, and developing AI-based applications 27.9%. • 68.6% want to be educated on advantages and limitations of AI applications, 58.1% on its clinical use, 33.8% on how to get into the driver's seat in using AI, 17.6% on technical methods, 11.1% on how to survive to the AI revolution, and 0.9% on how to avoid the its use.	Results not stratified.	• 41.1% believed that radiologists should be legally responsible for AI system outcome. • 41.1% believed that it should be a shared responsibility. • 16.9% believed that it should be developers, insurance companies, and others.
Surgeons			
van Hoek et al (2019), Switzerland [62]	Not assessed.	Not assessed.	Not assessed.
Medical students			
van Hoek et al (2019), Switzerland [62]	Not assessed.	Not assessed.	Not assessed.
	Not assessed.	Not assessed.	Not assessed.

Table 4 (continued)

Author (year), country	Education (e)	Economic considerations (f)	Medicolegal implications (g)
Dbouk et al (2019), France [73]			
Pinto dos Santos et al (2018), Germany [72]	• 70.1% feel that AI should be included in medical training.	Not assessed.	Not assessed.
Gong et al (2019), Canada [31]	• 71.4% of respondents with radiology in top 3 choices suggested inviting experts to provide opinions on the impact of AI (vs 69.8% ranking radiology lower than 3rd choice). • 59.4% vs 73.5% suggested discussing AI in preclinical radiology lectures. • Publishing position statements of radiology organisations (31.6% vs 20.6%). • Offering courses on AI (29.3% vs 30.2%). * Explaining the perspectives of radiologists in general media (29.3% vs 29.6%).	Not assessed.	Not assessed.
Patients			
Ongena et al (2020), Netherlands [74]	Not assessed.	Not assessed.	• (Likert 1–5) Patient find it impossible to address computers on their errors (4.18). • (Likert 1–5) Patient find it unclear who is responsible when a computer makes an error in evaluating a scan (3.01).
Haan et al (2019), Netherlands [58]	No numerical results reported.	No numerical results reported.	No numerical results reported.
Computer scientists			
Eltorai et al (2019), largely US [30]	Not assessed.	Not assessed.	Not assessed.
General public			
Rosenkrantz and Hawkins (2017), Twitter [76]	Not assessed.	Not assessed.	Not assessed.

e. Current and desired state of education regarding using artificial intelligence and its use in radiology

f. Financial considerations and cost-effectiveness

g. Legal and ethical implications of AI use

shift their focus from repetitive tasks to activities involving research, teaching, and patient interaction [32]. Some radiologists expressed that the use of AI opens the possibility for other specialties to assume radiological tasks, and they anticipate a fall in job demand [32, 60, 62]. Medical students anticipate a similar reduction in radiologists needed, but most believe that such "turf losses" are unlikely [31]. Medical students also expressed worry about replacement and excitement about the use of AI in radiology [62, 72, 73]. Although uncertain about changes to workload, most radiologists are optimistic about job satisfaction and salary—a sentiment echoed by computer scientists [30, 32, 60]. Computer scientists did not predict replacement of radiologists in the next 5 years, and few predicted obsolescence in the next 10–20 years [30]. Notably, views presented at an international symposium indicated that computer scientists who worked in medical imaging are more skeptical about AI replacing radiologists [75].

Similarly, patients expressed a lack of trust in machine diagnoses, prefer personal interactions, and anticipate a lack of emotional support from AI [72]. Given equal ability, patients prefer human physicians [72]. However, if computers can perform better and more holistic assessments to predict future diseases, patients prefer AI [72]. An editorial suggests that the public is generally uncomfortable with technology without a human in command [68]. The majority surveyed felt that technology could not entirely replace radiologists [76], a view consistent with perspectives expressed in commentary [54].

(4) Knowledge of AI and (5) Education

Radiologists, medical students, and patients in surveys expressed a lack of knowledge on AI. Although most radiologists are aware of the prominence of AI in radiology, they report limited knowledge and training [29, 30, 32, 59]. They expressed interest in ongoing research and felt that AI should be taught in medical training [29, 30, 59, 60]. Radiologists pointed to their role in AI development for medical imaging, especially in task definition, providing labelled images, and developing applications [32]. Residents are especially enthusiastic to learn about technological advancement [29, 32]. Education can increase interest, as tech-savvy respondents are more likely to find AI and ML exciting for radiology [29].

Medical students surveyed overestimated their competency in AI [31]. Only half were aware that AI is a major topic in radiology and a third had basic knowledge [72]. Most agreed that there is a need for training in AI during medical school [31, 72]. Increased year level, exposure to AI, and obtaining knowledge from literature and radiologists decreased pessimism toward field prospects [31].

Although patients believe AI to be a useful checking tool, they report having limited knowledge and express uncertainty about how AI will affect workflow [74].

As expected, computer scientists have the most knowledge and exposure to AI [30]. Although this survey did not discuss education [30], one commentary emphasises on the collaboration between radiologists and AI experts to ensure clinical relevance of AI technologies [68].

There were no surgeon or public views on knowledge or education in the included articles.

(6) Economic considerations

While none of the surveys evaluated radiologists' views on economic implications, this theme was explored in commentaries with mixed opinions [35, 57, 64–66]. Some radiologists cited an increase in costs associated with computer-aided detection systems without an increase in productivity [57]. Conversely, others suggested that AI may reduce burnout and cost while increasing care quality [35, 64]. Another urged that although AI may be more cost effective, progress must be driven by patient impact instead of financial considerations [55]. A commentary anticipates that hospitals—especially in publicly funded systems—may hesitate to invest in technology lacking vigorous testing, and may lack the network infrastructure to run these programmes [50].

Surgeons', medical students', patients', and computer scientists' views on economic considerations were not addressed in any of the included publications.

(7) Medicolegal implications

Both surveys [32, 62] and commentaries indicated that regulation, accountability, and ethical issues present barriers to AI implementation [14–16, 38, 40, 41, 44, 46, 47, 50, 55, 57, 65, 67–71]. Most radiologists surveyed believed they would assume responsibility for medical errors made by AI [32, 60]. Included non-survey articles echo similar sentiments [37, 44, 64, 70, 71]. Commentaries emphasised that time is needed to set up regulatory bodies [36, 40]. They suggest that radiologists should help develop assessment processes for AI tools based on evidence, and advocate for patients' consent, privacy, and data security [14–16, 41, 46, 55, 66].

Patients surveyed suggest it is difficult to address computer errors and assigning accountability [58, 74]. Similarly, a social media analysis indicated that legal and regulatory concerns present a challenge to AI implementation; these issues are not frequently discussed [54].

Surgeons', medical students', and computer scientists' views on medicolegal implications were not addressed in the included publications.

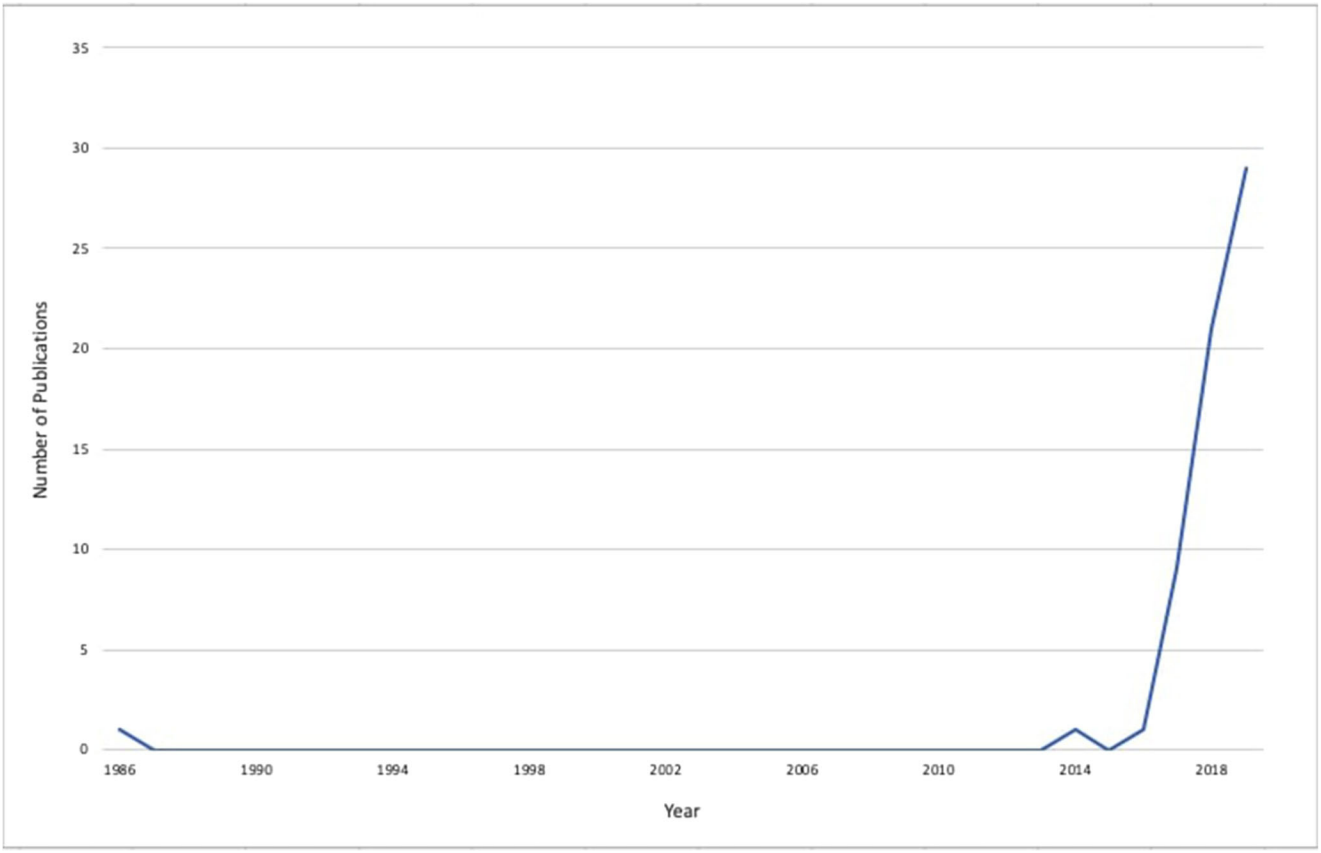

Fig. 4 Temporal distribution of included publications

Discussion

This scoping review is the first step in summarising views on AI in medical imaging. Seven themes were identified from the included articles, representing views from six stakeholders. Radiologists' views were predominantly represented. Inconsistencies existed within the half of the articles that provided definitions of AI. This may pose difficulties in future comparisons and syntheses. Overall, stakeholders do not trust AI in making independent diagnoses and do not believe that radiologists can be completely replaced. The general public and patients dislike AI due to a lack of "human touch". However, patients would accept its use if it can provide more insight than a human clinician.

Instead of replacement, stakeholders expect AI to function as a "co-pilot" in reducing error and repetitive tasks. Nevertheless, a decrease in the demand for diagnostic radiologists is anticipated. Radiologists' responsibilities are expected to shift from image interpretation to patient communication, policy development, and innovation. This is an important consideration for medical students when making residency choices. Radiologists, medical students, and patients indicated a need for education in the clinical use of AI.

There is opportunity for interdisciplinary collaboration between radiologists and AI experts to design technologies that advance the Quadruple Aim: patient outcome, cost-effectiveness, patient experience, and provider experience. The medical community must also work with legislative bodies to ensure that changes are driven by patient outcomes rather than economic considerations [55].

Economic considerations and medicolegal implications were not well addressed. No surveys consulted stakeholders in terms of economic considerations despite coverage in commentaries, indicating a need to outline this emerging technology's financial angle. A recent systematic review similarly found a need for economic analyses of AI implementation in healthcare [77]. The values and resources of health systems may constitute an additional consideration. Although the general public and patients do not know how to address potential errors made by computer systems, radiologists believe that they should be "in-the-loop" in terms of responsibility; ethical accountability strategies must be developed across governance levels. In comparison with existing literature, several commentaries discussed ways to restrict data transmission, protect patient privacy, and suggested review boards to prevent information compromise [64, 78, 79]. In addition to ethical and medicolegal barriers, adoption may be slow if radiology does not identify a need for automatic image interpretation. The European Society of Radiologists and Canadian Association of Radiologists have written ethical

statements on the subject, indicating the beginning of much-needed higher level regulation [15, 80]. These findings must be accounted for in large-scale decision-making.

Biases and limitations AI is under investigation in multiple areas of radiology, such as pre- and post-imaging workflow. Since this review focused on AI use in image interpretation, radiologists' perception of other applications fell outside our scope. Given the methodology of scoping reviews, risk of bias assessment was not performed, and would have been applicable only to the survey studies. Most of the publications represent Western radiologists' perspectives (Figure 2). This indicates a gap in knowledge from non-Western countries and other stakeholders (e.g. government, insurance providers, radiation technicians, radiographers, or radiation technologists) [91, 92]. Due to an exponential rise in scientific publications on AI (Figure 4), there are undoubtedly new publications on views of stakeholders considered in this study as well as others that were not represented. As AI may increase accessibility of radiological diagnoses in low- and middle-income countries, it is important to include global perspectives in future study and adapt such technologies to different international healthcare contexts. There were limited publications capturing the views of surgeons (n = 1), computer scientists (n = 3), patients (n = 3), and the general public (n = 4). Radiologists' views were more frequently published or evaluated in formal surveys, likely because of their proximity to these emerging technologies. However, it is important to incorporate other stakeholders' views into the design of such systems. As patient information will be used in the development of AI technology and patient care will undergo significant changes, patient perspectives need to be prioritized.

Future directions AI is innovative and highly applicable to radiology; barriers to entry and drivers of adoption must be considered. This scoping review can encourage a comprehensive plan in adapting current training and practice. There is a need for stakeholders to incorporate the growing body of evidence around AI in radiology in order to guide development, education, regulation, and deployment. Given that AI is currently an intervention of great interest in health contexts, it is beneficial to regularly update reviews capturing perspectives. More formal qualitative studies can further explore elements that facilitate or prevent AI implementation. The present scoping review serves as a first step toward future research and synthesis of such information.

Conclusion

The views of radiologists, medical students, patients, the general public, and computer scientists suggest that replacement of radiologists by AI is considered unlikely; most acknowledge its potential and remain optimistic. Stakeholders identified a need for education and training on AI, and specific efforts are needed to improve its practical integration. Further research is needed to gain perspectives from non-Western countries, non-radiologist stakeholders, economic considerations, and medicolegal implications.

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Methodology
• scoping review

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