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ARTIFICIAL INTELLIGENCE AND INFORMATICS

REVIEW

Systematic review of artificial intelligence competitions in radiology: a focus on design, evaluation, and trends

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ABSTRACT

This article explores the characteristics and scope of artificial intelligence (AI) competitions in medical imaging. A retrospective evaluation of AI competitions related to medical imaging was conducted between 2017 and 2023. Relevant terms associated with AI and competitions were searched using the PubMed database and the grand-challenge website, and applicable studies were included in the review. The 26 AI competitions included in the review covered a wide range of topics, from brain imaging to extremities and from stroke detection to bone age estimation, with many organized through international collaborations between engineering and medical professionals. Various national screening and teleradiology databases, as well as university databases, were used. Teams from different regions worldwide participated in these competitions. These initiatives contribute to the global adoption of AI technologies in healthcare. Moreover, they help raise awareness among high school students, medical students, radiology trainees, and young radiologists of the intersection between AI and medical imaging. AI competitions play a crucial role in fostering collaboration between the medical field and AI, driving innovation, and increasing societal awareness of AI applications in healthcare.

KEYWORDS

Artificial intelligence, radiology, imaging, healthcare, competition

Artificial intelligence (AI) in healthcare is evolving through human–machine collaboration, with innovation driven by partnerships between academic healthcare institutions and industry. The proper validation of AI algorithms, effective data sharing, and training for radiologists is essential.[1] Fundamental requirements and quality standards applicable to all AI-related organizations have begun to be established.[2]

A study examining the impact of AI on radiology and medical imaging through web searches revealed a prevailing positive outlook, highlighting the leading role of radiologists in this discourse.[3] Radiology department chairs tend to be optimistic, believing that AI will be beneficial in areas such as quality, efficiency, healthcare costs, and interpretation workflow.[4] Although radiologists support the idea that AI will streamline workflow, medical students and surgeons approach it more cautiously.[5]

Despite potential biases and pitfalls in the use of AI technologies in medical imaging, their development and advancement are achievable through grand challenges. The expected benefits include creating code and trained datasets, openly sharing them, generating new work areas, and directly involving AI in patient care.[6]

With the widespread use of AI in the medical field, this systematic review aims to investigate the effectiveness of recently organized and popular radiological imaging competitions worldwide.

Methods

Ethical committee approval and patient consent are not required for this type of article. A search was conducted on the PubMed database using the terms "competition" or "contest"

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added to the phrase "AI." The focus was on articles containing result reports of imaging-related competitions between 2019 and 2023. Completed competitions were identified using the "completed" filter on the grand-challenge website. Versions of identified competitions held in previous or subsequent years were also considered. A total of 26 competitions that provided sufficient information and had a substantial impact were included in the review (Figure 1).

Information recorded for each competition included the competition's name, year held, imaging modality, target region, search field, dataset source, dataset sample size, dataset accessibility, diversity of contributing institutions, derived academic publications (as of January 2024), citation count according to the Web of Science criteria (as of January 2024), competition location, evaluation criteria, and the number of participating individuals or teams.

Results

This review presents the characteristics of 26 AI and medical imaging-related competitions and datasets between 2017 and 2023 (Tables 1 and 2). These competitions were hosted by organizations such as the Annual Aviation, Space, and Technology Festival (TEKNOFEST), the Radiological Society of North America (RSNA), and the International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI), either individually or collectively. Final competitions or winner announcements were held either onsite or online.

Various imaging modalities, including magnetic resonance imaging, computed tomography, ultrasound, mammography, and digital breast tomosynthesis, were utilized. Competition themes covered different body regions, ranging from the head to the lower limb, with a focus on segmentation, cancer detection, and disease diagnosis. Most competitions used datasets from universities, but some also incorporated data from national teleradiology systems or screening programs. Although the majority of competition datasets were openly accessible, some required approval for access. One competition was conducted exclusively online, whereas others took place both online and onsite.

In the TEKNOFEST competitions, high school students competed in a separate category, distinguishing them from other competitions. Studies derived from these competition datasets were predominantly published in high-impact journals.

Main points

- In recent years, artificial intelligence (AI) competitions have become widespread in the field of medical imaging.
- Datasets are commonly shared openly, and competition results are published in prestigious journals, receiving substantial citations.
- AI competitions help shape perspectives on AI in radiology education and among aspiring radiologists.

Discussion

The current review aims to evaluate AI applications in medical imaging competitions, which are rapidly increasing in today's medical imaging landscape. High-participation competitions are organized online or onsite in different parts of the world. Collaboration in dataset preparation involves radiologists, clinicians, engineers, and data scientists from different countries and institutions. Studies produced after competitions are published in high-quality journals, and their citation potential is relatively high. Competitions play an effective role in increasing the positive impact and benefits of AI in medical imaging and in generating greater interest in this field.

Organizations such as RSNA, MICCAI, and TEKNOFEST, or online platforms such as the grand-challenge website, host these competitions.[7-35] Dataset organization teams have sometimes come together as multinational teams and are generally multi-institutional. AI competitions in medical imaging lead to the establishment of collaborations not only between interdisciplinary teams but also between institutions and countries, both for competition teams and data preparation teams. The robust infrastructure of national teleradiology systems and the strict preservation of imaging data enable the preparation of competition datasets and the generation of results closest to real-world data.

A study examining 2,517 clinical trials related to AI-associated medical devices revealed that research is generally conducted in specific countries at the national level, with studied populations limited to certain regions. In the last few decades, the development of AI technologies in the medical field has turned into a global competition led by China and the United States.[36] Allowing free participation from around the world in AI competitions in the health sector is increasing the momentum of innovation. The expansion of competitions to low-income countries will diversify the data population and facilitate the availability of developed software for the benefit of these countries.

In 2023, a competition format involving young radiologists and radiology trainees was first organized at the European Society of Medical Imaging Informatics Annual Meeting in Pisa, Italy; this marked a milestone in radiologists' orientation toward AI.[37] Participating in such competitions during the radiology training period can contribute to radiology education in the current era of strong momentum in AI and radiology collaboration.

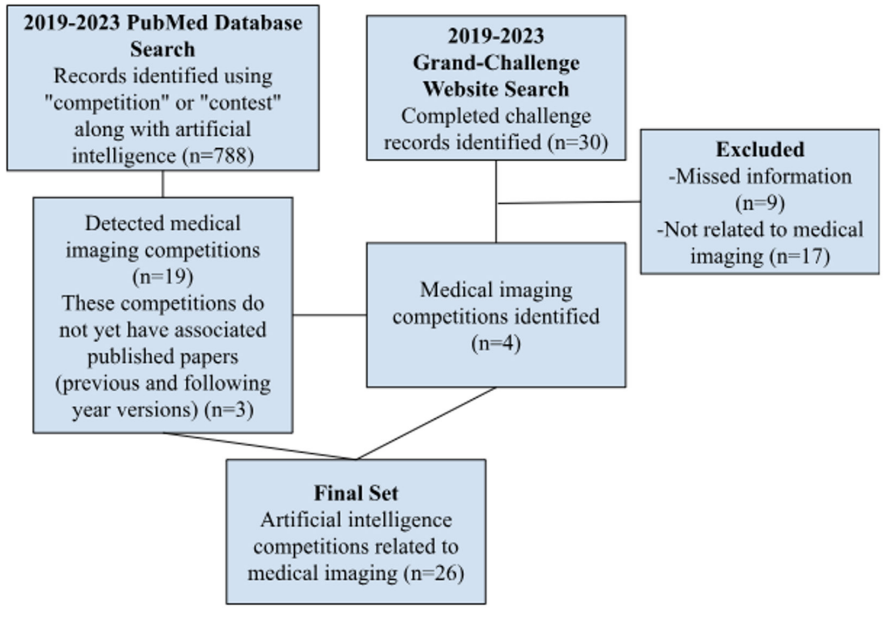

Figure 1. Flowchart of the selection process for AI competitions in medical imaging. AI, artificial intelligence.

Table 1. Features of the competitions and datasets

Competition	Date	Modality	Target structure	Search field	Dataset source	Sample size	Dataset access
TEKNOFEST 2021 artificial intelligence in health competition (stroke dataset)[7]	2021	CT	Brain	Stroke	National Teleradiology System, Türkiye	877 CT	Open
TEKNOFEST 2022 artificial intelligence in health competition[8]	2022	CT	Abdomen	Abdominal emergencies	National Teleradiology System, Türkiye	1,517 CT	Open
TEKNOFEST 2023 artificial intelligence in health competition[9]	2023	MG	Breast	Breast cancer	National Teleradiology System, Türkiye	N/A	Restricted
RSNA pediatric bone age challenge[10-12]	2017	X-ray	Hand	Bone age	Stanford University and University of Colorado	14,236 hand radiographs	Open
RSNA pneumonia detection challenge[13,14]	2018	X-ray	Lung	Pneumonia	Public NIH	26,684 radiographs	Open
RSNA intracranial hemorrhage detection challenge[15,16]	2019	CT	Head	Intracranial hemorrhage	Stanford University, Thomas Jefferson University, Unity Health Toronto, Universidade Federal de São Paulo, The American Society of Neuroradiology	27,861 unique CT	Open
RSNA pulmonary embolism challenge[17,18]	2020	CT	Lung	Pulmonary embolism	Multi-institutional	12,195 CT	Open
RSNA brain tumor AI challenge[19]	2021	MRI	Brain	Brain tumor segmentation/ radiogenomic classification	Multinational	8,000 MRI	Restricted
RSNA COVID-19 AI detection challenge (SIIM conference on machine intelligence in medical imaging)[20]	2021	X-ray	Lung	COVID-19 pneumonia	Multi-database	10,178 chest radiographs	Open
RSNA cervical spine fracture AI challenge[21]	2022	CT	Neck	Cervical spine fracture	Multinational	3,112 CT	Open
RSNA screening mammography breast cancer detection AI challenge[22]	2023	MG	Breast	Breast cancer	Mammography screening programs in Australia and the U.S.	8,000 MG	Open
RSNA abdominal trauma detection AI challenge[22]	2023	CT	Abdomen	Abdominal traumas	Multinational	>4,000 CT	Open
CHAOS - Combined (CT-MR) healthy abdominal organ segmentation[23]	2019	CT/MRI	Abdomen	Abdominal organ segmentation	Dokuz Eylül University	40 MRI and 40 CT	Open
Tumor detection, segmentation, and classification challenge on automated 3D breast ultrasound[24]	2023	Ultrasound	Breast	Breast cancer	Harbin Medical University Cancer Hospital	200 ultrasound	Upon request
KNee OsteoArthritis Prediction Challenge [25]	2020	X-ray/MRI	Knee	Knee osteoarthritis	Previous study data	423 X-ray/MRI	Open
Surface learning for clinical neuroimaging (MLCN workshop challenge, MICCAI)[24]	2022	MRI	Brain	Cortical development	Previous study data	514 MRI	Upon request
K2S: from undersampled k-space to automatic segmentation (MICCAI)[26]	2022	MRI	Knee	Knee joint degeneration	University of California	816 MRI	Upon request
1st Boston neonatal brain injury dataset for hypoxic ischemic encephalopathy lesion segmentation challenge (MICCAI)[27]	2023	MRI	Brain	Hypoxic ischemic encephalopathy	Massachusetts General Hospital	133 MRI	Open
DBTex Challenge[28]	2021	Digital breast tomosynthesis	Breast	Breast cancer	Duke University	22,032 digital breast tomosynthesis	Open

Table 1. Continued

Competition	Date	Modality	Target structure	Search field	Dataset source	Sample size	Dataset access
COVID-19 lung CT lesion segmentation challenge[29]	2020	CT	Lung	COVID-19 pneumonia	Previous study data from the Cancer Imaging Archive	295 CT	Partial
Kidney tumor segmentation challenge (MICCAI)[30]	2019	CT	Kidney	Kidney tumor	University of Minnesota Medical Center	300 CT	Partial
Kidney tumor segmentation challenge (MICCAI)[24]	2021	CT	Kidney	Kidney tumor/ cyst	M Health Fairview or Cleveland Clinic Medical Center	300 CT	Open
Kidney tumor segmentation challenge (MICCAI)[24]	2023	CT	Kidney	Kidney tumor/ cyst	M Health Fairview Medical Center	599 CT	Open
French Society of Radiology data challenge[31-33]	2018	MRI/CT/ Ultrasound	Knee/ Kidney/ Liver/ Breast	Meniscal tear, renal cortex segmentation, lesions of the liver, breast, and thyroid cartilage	Multi-institutional	5,170 images	N/A
French Society of Radiology data challenge[34]	2019	MRI/CT	Lung/ Brain/ Muscles	Pulmonary nodule, multiple sclerosis, sarcopenia	Multi-institutional	4,347 examinations	N/A
French Society of Radiology data challenge[35]	2020	CT/Ultrasound	Breast/ Neck/ Heart	Breast nodule, neck lymph node, coronary calcium score	Multi-institutional	2,076 examinations	N/A

TEKNOFEST, Annual Aviation, Space and Technology Festival; CT, computed tomography; MG, mammography; RSNA, Radiological Society of North America; NIH, National Institutes of Health; AI, artificial intelligence; MRI, magnetic resonance imaging; COVID-19, coronavirus disease 2019; MLCN, Machine Learning in Clinical Neuroimaging; MICCAI, International Conference on Medical Image Computing and Computer-Assisted Intervention.

In a survey conducted among medical students in Canada, it was observed that although radiology specialization was among the top choices, there were widespread concerns about the negative effects of AI on radiologists. Information meetings are suggested to address these concerns.[38] The negative effects of AI on radiology career development have also been noted among US medical students.[39] Public competitions involving medical students will contribute to a more realistic understanding of the relationship between AI and radiology expertise. Encouraging high school students to participate in some competitions strategically promotes AI development and raises social awareness among young individuals who have not yet made career choices. Technology teachers at the high school and even middle school levels can take the lead in encouraging participation in such activities during their training.

Additionally, such competitions can lead to the generation of new study topics on emerging issues and the establishment of new networks, facilitating the creation of start-ups. AI summer schools in medicine for high school students have begun to be established at universities.[40] Ethical dilemmas such as bias risk and data security, along with AI's potential to assist medical professionals, cannot be overlooked in the realm of AI in healthcare.[41] AI training programs should comprehensively address all these aspects.

The impact of AI-related medical imaging competitions on scientific publication conversion, citation potential, and integration into the literature was investigated. However, another crucial aspect—their clinical application and commercial utilization—lacks sufficient and effective information based on available datasets and publications. To bridge the gap between scientific innovation and clinical practice, it may be beneficial to increase awareness of these competitions among healthcare institutions, AI-related public organizations, and commercial entities while also expanding networking opportunities for competition participants.

Efforts have been made to standardize and enhance transparency in the evaluation of medical imaging competitions, from defining the competition's mission to dataset preparation methodologies and participant ranking metrics and criteria. However, substantial variations have been observed across these stages.[42] Proper competition design and interpretation can facilitate the validation of AI algorithms and promote their translation into clinical applications.[43] Several factors influence the outcomes of AI-related medical imaging competitions, including the dataset used, the reference annotations determined by annotators, and the scoring system applied for ranking.[44] Quality control at all stages of a competition enhances the validity and reliability of its results. In our review, a comprehensive framework has been established, detailing the design, execution, and outcomes of current AI-related medical imaging competitions.

This review has some limitations. Not all the databases where competitions could be included were examined for all dates. However, by focusing on recent competitions in the most well-known databases and platforms, an attempt was made to minimize selection bias. There are only a few studies in the literature examining competitions related to AI and radiology.[6,45] However, our review is the first to address the dataset, organization teams, and competition features.

In conclusion, as AI continues to play an increasing role in radiology, competitions related to AI and medical imaging contribute to quality dataset sharing, collaboration among experts, and increased awareness in this field.

Table 2. Characteristics of the competitions and publications

Competition	Studies derived from dataset	Citations	Dataset experts	Country	Number of individual participants or teams in the first application	Evaluation criteria
TEKNOFEST 2021 artificial intelligence in health competition	1	1	Multi-institutional radiologists and engineers	Türkiye	570 participants	F1 score, IoU
TEKNOFEST 2022 artificial intelligence in health competition	1	None	Multi-institutional radiologists and engineers	Türkiye	213 teams	Mean F1 scores computed across distinct threshold values for IoU
TEKNOFEST 2023 artificial intelligence in health competition	None	None	Multi-institutional radiologists and engineers	Türkiye	409 teams	F1 score
RSNA pediatric bone age challenge	3	271	Multi-institutional radiologists	U.S.	260 participants	Mean absolute distance in months
RSNA pneumonia detection challenge	2	39	Society for Thoracic radiology members and software	U.S.	1,400 teams	Mean average precision at different IoU thresholds
RSNA intracranial hemorrhage detection challenge	2	110	Multinational via commercial software	U.S.	1,345 teams	Weighted multi-label logarithmic loss
RSNA pulmonary embolism detection challenge	2	32	Society of Thoracic Radiology members	U.S.	784 teams	Weighted log loss
RSNA brain tumor AI challenge	1	1	Multinational	U.S.	1,555 teams	Dice similarity coefficient, Hausdorff distance (95%), AUC, accuracy, FScore (Beta), and Matthew's correlation coefficient
RSNA COVID-19 AI detection challenge	1	6	Multinational	U.S.	1,305 teams	Standard PASCAL VOC 2010 mean average precision at IoU >0.5
RSNA cervical spine fracture AI challenge	1	None	Spine radiology specialists from the American Society of Neuroradiology and the American Society of Spine Radiology	U.S.	883 teams	Weighted multi-label logarithmic loss
RSNA screening mammography breast cancer detection AI challenge	None	None	Via commercial software tools	U.S.	1,687 teams	Probabilistic F1 score
RSNA abdominal trauma detection AI challenge	None	None	Society of Abdominal Radiology and the American Society of Emergency Radiology members	U.S.	1,123 teams	Average of the sample weighted log losses from each injury type and an any-injury prediction generated by the metric
CHAOS - Combined (CT-MR) healthy abdominal organ segmentation	1	195	Engineers, radiologists, and PhD/MSc/BSc students from Türkiye	Italy	1,500 participants	Intra- and inter-annotator scores
Tumor detection, segmentation, and classification challenge on automated 3D breast ultrasound	None	None	Engineer/radiologist from China	Canada (MICCAI 2023)	503 participants	Dice similarity coefficient, Hausdorff distance, accuracy, AUC, free-response ROC
KNee OsteoArthritis Prediction Challenge	1	6	N/A	Netherlands/ Online	20 participants	ROC AUC and balanced accuracy
Surface learning for clinical neuroimaging (MLCN workshop challenge, MICCAI)	None	None	Engineers and radiologists from the U.K.	Singapore	91 participants	Mean absolute error

Table 2. Continued

Competition	Studies derived from dataset	Citations	Dataset experts	Country	Number of individual participants or teams in the first application	Evaluation criteria
K2S: from undersampled k-space to automatic segmentation (MICCAI)	1	2	Multinational engineers and radiologists	Singapore	87 teams	Dice similarity coefficient
1st Boston neonatal brain injury dataset for hypoxic ischemic encephalopathy lesion segmentation challenge (MICCAI 2023)	1	None	Single-center PhD and MD	Canada	131 participants	Dice, mean average surface distance, normalized surface distance
DBTex challenge	1	1	Multinational engineers and radiologists	U.S.	8 teams	Free-response ROC
COVID-19 lung CT lesion segmentation challenge	1	6	Automated segmentation and confirmation by single-center radiologists	Online	1,096 teams	Dice coefficient, normalized surface Dice, normalized absolute volume error
Kidney tumor segmentation challenge (MICCAI 2019)	3	173	Single radiologist and supervised students	China	106 teams	Sørensen–Dice coefficient
Kidney tumor segmentation challenge (MICCAI 2021)	None	None	Multi-institutional radiologists, urologists, and supervised students	France	N/A	Sørensen–Dice, surface Dice
Kidney tumor segmentation challenge (MICCAI 2023)	None	None	Multi-institutional radiologists, urologists, urologic oncologists, and supervised students	Canada	N/A	Sørensen–Dice, surface Dice
French Society of Radiology Data Challenge 2018	1	31	Multi-institutional radiologists and data scientists	France	323 participants	Dice score, binary AUC
French Society of Radiology Data Challenge 2019	1	18	Multi-institutional radiologists and data scientists	France	143 participants	Dice coefficient, AUC, mean square error
French Society of Radiology Data Challenge 2020	1	10	Multi-institutional radiologists and data scientists	France	39 participants	Concordance index, Dice score, AUROC

IoU, Intersection over Union; TEKNOFEST, Annual Aviation, Space and Technology Festival; RSNA, Radiological Society of North America; AI, artificial intelligence; AUC, area under the curve; COVID-19, coronavirus disease 2019; VOC, visual object classes; CT, computed tomography; MRI, magnetic resonance imaging; PhD, Doctor of Philosophy; MSc, master of science; BSc, bachelor of science; MICCAI, International Conference on Medical Image Computing and Computer-Assisted Intervention; ROC, receiver operating characteristic; MLCN, Machine Learning in Clinical Neuroimaging; MD, doctor of medicine; AUROC, area under the receiver operating characteristics.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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