Cross-sectional Study

ANNALS OF MEDICINE & SURGERY

OPEN

Knowledge, attitude, and practice of artificial intelligence among medical students in Sudan: a cross-sectional study

Mohammed Hammad Jaber Amin, MBBS[a], Musab Awadalla Mohamed Elhassan Elmahi, MBBS[a], Gasm Alseed Abdelmonim, MBBS[b], Gasm Alseed Fadlalmoula, MBBS[b], Jaber Hammad Jaber Amin, MBBS[a], Noon hatim Khalid Alrabee, MBBS[c], Mohammed haydar Awad, MBBS[d], Zuhal yahya mohamed omer, MBBS[a], Nuha Tayseer Ibrahim Abu Dayyeh, MBBS[f], Nada Abdalla Hassan Abdalkareem, MBBS[f], Esra Mohammed Osman Meisara Seed Ahmed, MBBS[a], Hadia Abdelrahman Hassan Osman, MBBS[g], Hiba A.O. Mohamed, MBBS[h], Aya Elshaikh Mohamedtoum Babiker, MBBS[f], Ammar Alemam Diab Alnour, MBBS[i], Estbrg alsafi Mohamed ahmed, MBBS[j], Eithar hussein elamin garban, MBBS[k], Noura Satti Ali Mohammed, MBBS[l], Khabab Abbasher Hussien Mohamed Ahmed, MBBS[c], Mirza Adil Beig, MBBS[m], Muhammad Ashir Shafique, MBBS[n], Mazar Gamal Mohamed Elhag, MBBS[f], Mojtaba Majdy Elfakey Omer, MBBS[a], Amna Alrasheed Abuzaid Ali, MBBS[e], Doaa Haider Mohamed Shatir, MBBS[f], Hiba Osman Ali MohamedElhassan, MBBS[f], Khlood Hamdi Ahmed Bin saleh, MBBS, Maria Badraldin Ali, MBBS[e], Sahar Suliman Elzber Abdalla, MBBS[o], Waleed Mohammed Alhaj, MBBS[a], Elaf Sabri Khalil Mergani, MBBS[e], Hazim Hassan Mohammed, MBBS[a]

Introduction: In this cross-sectional study, the authors explored the knowledge, attitudes, and practices related to artificial intelligence (AI) among medical students in Sudan. With AI increasingly impacting healthcare, understanding its integration into medical education is crucial. This study aimed to assess the current state of AI awareness, perceptions, and practical experiences among medical students in Sudan. The authors aimed to evaluate the extent of AI familiarity among Sudanese medical students by examining their attitudes toward its application in medicine. Additionally, this study seeks to identify the factors influencing knowledge levels and explore the practical implementation of AI in the medical field.

Method: A web-based survey was distributed to medical students in Sudan via social media platforms and e-mail during October 2023. The survey included questions on demographic information, knowledge of AI, attitudes toward its applications, and practical experiences. The descriptive statistics, χ^2 tests, logistic regression, and correlations were analyzed using SPSS version 26.0.

Results: Out of the 762 participants, the majority exhibited a basic understanding of AI, but detailed knowledge of its applications was limited. Positive attitudes toward the importance of AI in diagnosis, radiology, and pathology were prevalent. However, practical application of these methods was infrequent, with only a minority of the participants having hands-on experience. Factors influencing knowledge included the lack of a formal curriculum and gender disparities.

Conclusion: This study highlights the need for comprehensive AI education in medical training programs in Sudan. While participants displayed positive attitudes, there was a notable gap in practical experience. Addressing these gaps through targeted educational interventions is crucial for preparing future healthcare professionals to navigate the evolving landscape of AI in medicine.

Recommendations: Policy efforts should focus on integrating AI education into the medical curriculum to ensure readiness for the technological advancements shaping the future of healthcare.

Keywords: AI—artificial intelligence, attitude, DL—deep learning, knowledge, medical students, ML—machine learning, practice, Sudan

[a]Alzaiem Alazhari University Faculty of medicine,Khartoum-Sudan, [b]Shendi University Faculty of Medicine,Shendi, Sudan, [c]University of Khartoum faculty of medicine , Khartoum-Sudan, [d]Karary University, faculty of medicine, Omdurman, Sudan, [e]MBBS,Al-Neelain University Faculty of medicine,Khartoum-Sudan, [f]Ahfad University for women Faculty of medicine,Khartoum-Sudan, [g]Sinnar University Faculty of medicine,Sinnar-Sudan, [h]Nile University Faculty of medicine,Khartoum-Sudan, [i]Al Mughtaribeen University Faculty of Medicine ,Khartoum -Sudan, [j]West kordufan University Faculty of Medicine ,kordufan -Sudan, [k]University of bahri,Faculty of Medicine , Khartoum,Sudan, [l]University-Dehradun institute of technology ,Organisation- FIND INDIA, [m]Jinnah Sindh Medical University ,Pakistan, [n]Nile valley university ,Faculty of Medicine , Khartoum,Sudan and [o]International University Of Africa faculty of medicine ,,Khartoum -Sudan

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

**Corresponding author. Address: Medical Student, Faculty of medicine Alzaiem Alazhari University. Tel.: + 249 119 303 629. E-mail: mohammesjaber123@gmail.com (M. Hammad Jaber Amin).*

Annals of Medicine & Surgery (2024) 86:3917–3923

Received 26 January 2024; Accepted 5 April 2024

Published online 24 April 2024

http://dx.doi.org/10.1097/MS9.0000000000002070

Artificial intelligence (AI) is a software system designed to emulate human intelligence, utilizing data to make independent decisions or aid in decision-making. This broad term includes machine learning, representation learning, deep learning, and natural language processing, extending its influence beyond computer science into fields such as medicine, philosophy, psychology, linguistics, and statistics[1].

In the medical field, AI plays a pivotal role, notably in radiology but also in dermatology, ophthalmology, psychiatry, cardiology, oncology, neuroscience, pathology, and general medicine. These algorithms assist in identifying abnormal characteristics, classifying conditions, hypothesizing about underlying issues, determining appropriate procedures, and interpreting results.In pathology, AI enhances predictive and prognostic capabilities, improving tissue histology and molecular data analysis. Similarly, in dermatology and ophthalmology, AI aids in diagnostic imaging and assessment of various conditions[2].

While high-income countries invest significantly in AI research for healthcare, developing countries such as Sudan face challenges in education, research, and AI implementation. Limited resources, compounded by the pandemic, highlight the need for AI knowledge to reduce workload and diagnostic errors[2].

Despite these challenges, the outlook for AI in healthcare is promising. This approach has the potential to address shortcomings in traditional diagnostic and treatment methods, reduce errors, address diagnostic inaccuracies, and alleviate patient anxiety. However, there are misconceptions about AI's capabilities and impact on healthcare[1,3–7].

In Sudan, despite a presidential AI initiative, obstacles, including resistance to change, financial constraints, a shortage of qualified medical professionals, insufficient data, concerns about physician displacement, societal barriers, confidentiality issues, and medico-legal implications, hinder healthcare AI integration[2,8,9].

This research aimed to determine Sudanese medical students' knowledge and perceptions of AI by assessing current AI practices in Sudan. The hypothesis suggests that medical students may not be fully aware of the implications of AI.

Methodology

Study design and sample size

Between 1 October and 30 October 2023, we conducted a cross-sectional study in Sudan in which a web-based survey was distributed to medical students and physicians through social media applications (WhatsApp, Facebook, Messenger) and e-mail. The questionnaire, adapted from prior research (Ahmed *et al*., 2022), was confirmed to be accurate for Sudanese respondents. Anonymous responses were collected, and only the principal investigator had access to the survey. Using a convenience sampling technique, we surveyed 30 participants experimentally before a pilot study with 50 individuals to confirm validity and reliability. Sub-scale consistency was assessed using Cronbach's alpha values (knowledge = 0.795, practice = 0.702, attitude = 0.663). The tool allowed participants to modify replies and only completed, non-duplicate entries were considered. The inclusion criteria involved Sudanese medical students and doctors, while non-medical responders and incomplete surveys were excluded. The sample size was calculated with a calculator. Based on a 48 million population in 2023 (UN statistics), we aimed for 385 participants, accounting for a 50% design effect, 0.05 margin of error, and 95% confidence level. Participants were encouraged to complete the survey on the Google form. The work has been reported in line with the STROCSS criteria.

Ethical approval

All participants had the right to withdraw from the cross-sectional research at any point, and participation was entirely voluntary. Due to the absence of names or e-mails in the study, participants' identities remained confidential. Ethics committee provided approval, and the study adhered to the principles of the Helsinki Declaration. For statistical analysis, we employed SPSS version 26.0 and presented variable frequencies through frequency tables. Cronbach's α coefficient was used to assess the internal consistency of the scale. The χ^2 test was used to determine the statistical correlation among categorical variables, with a p value less than 0.05 indicating statistical significance. The Mann–Whitney and Kruskal–Wallis tests were chosen based on the normality of the data. Additionally, univariate logistic regression predicted outcomes related to artificial intelligence (knowledge, attitudes, practices) from baseline characteristics. Unadjusted odds ratios and their respective 95% CIs were used in the regression.

Measurements

Demographic information

The questionnaire consisted of age, sex, qualification level, rank, and university year for the undergraduate participants.

Knowledge of AI

This sub-scale has seven questions about the general knowledge of AI, including knowledge of artificial intelligence machine learning, AI in the medical field, AI in radiology, AI in pathology, and AI during the training of postgraduate doctors (for the statistical analysis, yes = 1, no = 0 and good knowledge is above 3 points). Attitude toward artificial intelligence: This sub-scale has ten questions about attitudes toward AI, including the necessity of AI in the medical field, training, assessment, diagnosis, radiology, pathology, and importance (for the statistical analysis, "don't know", "disagree" or "strongly disagree" = 0, agree or strongly agree = 0, and "good attitude" is more than 5 points).

Table 1

General characteristics (*N* = 762)

Characteristic	Value	Frequency	Percentage
Age (mean 22.4, SD 2.834)	< 20 years	129	16.9
	20–22 years	222	29.1
	23–25 years	352	46.2
	> 25 years	59	7.7
Sex	Male	147	19.3
	Female	615	80.7
Educational level	1st Grade	96	12.6
	2nd Grade	108	14.2
	3rd Grade	96	12.6
	4th Grade	171	22.4
	5th Grade	120	15.7
	6th Grade	171	22.4

Table 2

Knowledge, attitudes, and practices scores for medical students receiving AI

Characteristic	Value		N	Mean (Std. deviation)
Knowledge of artificial intelligence	Age	< 20 years	129	2.3721 (1.40351)
		20–22 years	222	1.7162 (1.40317)
		23–25 years	352	2.4886 (1.49449)
		> 25 years	59	2.4915 (1.91521)
		Total	762	2.2441 (1.52620)
	Sex	Male	147	2.4490 (1.63516)
		Female	615	2.1951 (1.49624)
		Total	762	2.2441 (1.52620)
	Educational level	1st Grade	96	2.1563 (1.42406)
		2nd Grade	108	1.9722 (1.26386)
		3rd Grade	96	2.0000 (1.50787)
		4th Grade	171	2.1053 (1.57947)
		5th Grade	120	2.2750 (1.55549)
		6th Grade	171	2.7193 (1.58026)
		Total	762	2.2441 (1.52620)
Attitude of artificial intelligence	Age	< 20 years	129	4.7209 (1.92831)
		20–22 years	222	4.0270 (2.42707)
		23–25 years	352	4.7869 (2.22202)
		> 25 years	59	5.3559 (2.11532)
		Total	762	4.5984 (2.26123)
	Sex	Male	147	5.1837 (2.00349)
		Female	615	4.4585 (2.29810)
		Total	762	4.5984 (2.26123)
	Educational level	1st Grade	96	4.9688 (2.10989)
		2nd Grade	108	4.3056 (2.15501)
		3rd Grade	96	4.7188 (2.41357)
		4th Grade	171	4.1579 (2.38221)
		5th Grade	120	4.3750 (2.11462)
		6th Grade	171	5.1053 (2.18835)
		Total	96	4.9688 (2.10989)
Practice of artificial intelligence	Age	< 20 years	129	3.2636 (1.37227)
		20–22 years	222	2.7793 (1.49234)
		23–25 years	352	3.1449 (1.44964)
		> 25 years	59	3.0847 (1.24966)
		Total	762	3.0538 (1.44400)
	Sex	Male	147	3.4966 (1.51420)
		Female	615	2.9480 (1.40748)
		Total	762	3.0538 (1.44400)
	Educational level	1st Grade	96	3.2396 (1.47073)
		2nd Grade	108	2.7778 (1.32081)
		3rd Grade	96	2.9896 (1.48320)
		4th Grade	171	2.7544 (1.56371)
		5th Grade	120	3.1250 (1.41755)
		6th Grade	171	3.4094 (1.28646)
		Total	762	3.0538 (1.44400)

AI, artificial intelligence.

Practice toward AI

This sub-scale has seven questions about the practice of AI, including whether the doctor has inserted the AI in the medical field and whether the patient was willing to use this technique during training (for the statistical analysis, yes = 1, no, never applied = 0 and good practice is greater than 2 points).

Table 3

Descriptive statistics for knowledge of artificial intelligence among medical students

Characteristic	Value, *n* (%)	
	Yes	No
Do you know what artificial intelligence is?	642 (84.3)	120 (15.7)
Do you know about machine learning and deep learning (subtypes of AI)?	249 (32.7)	513 (67.3)
Do you know about any application of AI in the medical field?	330 (43.3)	432 (56.7)
Have you ever been taught about Artificial intelligence in medical school?	138 (18.1)	624 (81.9)
Do you know about the application of AI in radiology?	186 (24.4)	576 (75.6)
Do you know about the application of AI in the pathology field?	165 (21.7)	597 (78.3)

AI, artificial intelligence.

Results

A total of 762 (100%) individuals responded to the survey. The participation rate was difficult to estimate due to potential redundancies across social media groups and mailing lists. The respondents' mean age was 22.4± SD 2.8346, and 80.7% of the respondents were females. In terms of academic experience, there were students with different professional statuses in different institutes in Sudan. The baseline characteristics of all the populations are given in Tables 1 and 2. Knowledge, attitudes, and practice scores for medical students receiving AI.

Knowledge of AI

With respect to knowledge of AI, individuals were questioned about the basic concept of AI; its subtypes, that is machine learning (ML), deep learning (ML) and DL (DL); and its applications. Overall, 642 (84.3%) had a basic understanding of AI, but only 249 (32.7%) had knowledge of ML and DL. Furthermore, only 330 (43.3%) participants demonstrated awareness of AI applications. Notably, 120 (15.7%) individuals lacked knowledge about the basic concept of AI, 513 (67.3%)

Table 4

Knowledge of AI based on age, sex, and qualification level among medical students

Characteristic	Knowledge of artificial intelligence, *n* (%)		*P*
	Good, 315 (41.3)	Poor, 447 (58.7)	
Age			
< 20 years	54 (7.1)	75 (9.8)	< 0.001
20–22 years	60 (7.9)	162 (21.3)	
23–25 years	175 (23.0)	177 (23.2)	
> 25 years	26 (3.4)	33 (4.3)	
Sex			
Male	72 (9.4)	75 (9.8)	0.023
Female	243 (31.9)	372 (48.8)	
Educational level			
1st Grade	36 (4.7)	60 (7.9)	< 0.001
2nd Grade	30 (3.9)	78 (10.2)	
3rd Grade	33 (4.3)	63 (8.3)	
4th Grade	72 (9.4)	99 (13.0)	
5th Grade	48 (12.6)	72 (9.4)	
6th Grade	96 (12.6)	75 (9.8)	

AI, artificial intelligence.

Table 5

Binary logistic regression between baseline characteristics of the study population and knowledge of artificial intelligence among medical students

Characteristic	Value	*P*	Odds ratio	Lower	Upper
Age	< 20 years	0.000	Reference	—	—
	20–22 years	0.000	4.074	1.932	8.590
	23–25 years	0.047	2.325	1.013	5.336
	> 25 years	0.011	3.376	1.318	8.648
Sex	Male	0.021	0.630	0.425	0.932
	Female	Reference	—	—	—
Educational level	1st Grade	0.007	Reference	—	—
	2nd Grade	0.901	1.041	0.551	1.966
	3rd Grade	0.054	0.422	0.175	1.014
	4th Grade	0.021	0.366	0.157	0.857
	5th Grade	0.072	0.440	0.180	1.077
	6th Grade	0.001	0.234	0.096	0.572
Constant	0.105	1.443	—	—	

Table 6

Binary logistic regression between baseline characteristics of the study population and artificial intelligence practices among medical students

Characteristic	Value	*P*	Odds ratio	Lower	Upper
Age	< 20 years	0.367	Reference	—	—
	20–22 years	0.111	1.670	0.889	3.135
	23–25 years	0.219	1.586	0.760	3.313
	> 25 years	0.133	1.944	0.817	4.626
Sex	Male	0.000	0.451	0.291	0.698
	Female	Reference	—	—	—
Educational level	1st Grade	0.002	Reference	—	—
	2nd Grade	0.287	1.403	0.752	2.616
	3rd Grade	0.311	1.488	0.689	3.214
	4th Grade	0.186	1.654	0.785	3.483
	5th Grade	0.652	0.831	0.371	1.859
	6th Grade	0.225	0.606	0.270	1.362
Constant	0.000	0.387	—	—	

had no knowledge about ML and DL, and 432 (56.7%) were unaware of any application of AI in the medical field. Only 186 (24.4%) individuals were aware of the application of AI in radiology, and only 165 (21.7%) knew about the application of AI in pathology. A few of the applications of AI known to individuals were in robotic surgery, diagnostic radiology, crisis technology, diagnostic imaging in ophthalmic pathologies, 3D anatomical studies, risk assessment in cardiac patients by imaging techniques, automated ventilators, radiological imaging modalities such as MRI, computed tomography (CT) scan, X-rays and ultrasound, stroke assessment, radiotherapy in cancer patients, histological imaging in pathology laboratories and electrocardiogram (ECG) assessment for cardiac anomalies.Table 3 shows descriptive statistics for knowledge of artificial intelligence among medical students. The correlation between knowledge of AI and different variables and odds ratios are given in Table 4. A lack of curriculum training during graduation and a lack of gender were significant factors affecting AI knowledge, with *P* values less than 0.05. Females were found to have more knowledge about AI than males. The qualification level and rank were not significant factors for knowledge of AI, with a *P* value greater than 0.05. Table 5 shows the binary logistic regression results for the baseline characteristics of the study population and the knowledge of artificial intelligence among medical students. Table 6 shows the binary logistic regression results for the baseline characteristics of the study population and the use of artificial intelligence among medical students.

Attitude toward AI

Concerning attitudes toward AI in the health sector, 237 (31.1%) individuals strongly agreed, and 366 (48.0%) agreed that AI is essential in the medical field. Approximately 108 (14.2%) had no opinion, with the majority being females. Additionally, 225 (29.5%) medical students strongly agreed, and 324 (42.5%) agreed that AI aids practitioners in early diagnosis and assessment of disease severity. Conversely, 162 (21.3%) individuals had no opinion. For pathology, 165 (21.7%) medical students strongly agreed, 303 (39.8%) doctors agreed that AI is essential for diagnostic techniques, and 234 (30.7%) individuals had no opinion. Table 7 presents descriptive statistics for attitudes toward artificial intelligence among medical students, covering AI applications in radiology, curriculum inclusion in residency training, AI as a practitioner's aid, and concerns about AI as a burden or replacement for physicians. While many believe that an appropriate budget should be allocated for promoting AI in the

Table 7

Descriptive statistics for attitudes toward artificial intelligence among medical students

	Value, *n* (%)				
Characteristic	Strongly agree	Agree	Don't know	Disagree	Strongly disagree
Do you believe AI is essential in the medical field?	237 (31.1)	366 (48.0)	108 (14.2)	42 (5.5)	9 (1.2)
Do you think AI should be included in the curriculum in medical school as well as specialist training?	234 (30.7)	339 (44.5)	117 (15.4)	48 (6.3)	24 (3.1)
Do you think that AI aids practitioners in early diagnosis and assessment of the severity of disease?	225 (29.5)	324 (42.5)	162 (21.3)	36 (4.7)	15 (2.0)
Do you believe that AI will replace physicians in the future?	102 (13.4)	138 (18.1)	204 (26.8)	180 (23.6)	138 (18.1)
Do you believe AI is very essential in the field of radiology?	204 (26.8)	306 (40.2)	195 (25.6)	48 (6.3)	9 (1.2)
Do You believe AI is essential in the field of Pathology?	165 (21.7)	303 (39.8)	234 (30.7)	51 (6.7)	9 (1.2)
.Do you believe AI would be a burden for practitioners?	84 (11.0)	192 (25.2)	327 (42.9)	111 (14.6)	48 (6.3)
Do you believe AI would increase the percentage of errors in diagnosis?	99 (13.0)	186 (24.4)	276 (36.2)	150 (19.7)	51 (6.7)

AI, artificial intelligence.

Table 8

The attitudes toward AI were based on age, sex, and qualification level among medical students

	Attitude of artificial intelligence, *n* (%)		
Characteristic	**Favourable, 543 (71.3)**	**Unfavourable, 219 (28.7)**	***P***
Age			
< 20 years	99 (13.0)	30 (3.9)	0.001
20–22 years	138 (18.1)	84 (11.0)	
23–25 years	256 (33.6)	96 (12.6)	
> 25 years	50 (6.6)	9 (1.2)	
Sex			
Male	117 (15.4)	30 (3.9)	0.007
Female	426 (55.9)	189 (24.8)	
Educational level			
1st Grade	78 (10.2)	18 (2.4)	0.032
2nd Grade	66 (8.7)	42 (5.5)	
3rd Grade	66 (8.7)	30 (3.9)	
4th Grade	120 (15.7)	51 (6.7)	
5th Grade	84 (11.0)	36 (4.7)	
6th Grade	129 (16.9)	42 (5.5)	

AI, artificial intelligence.

health sector, some disagree. The correlations of attitudes toward AI essentialness in the medical field with variables such as gender, lack of curriculum, and qualification level, along with the odds ratio, are presented in Table 8. These findings indicate that lack of curriculum is a significant factor ($p < 0.05$), while gender has no significant effect on attitudes. Table 9 displays the binary logistic regression results between the baseline characteristics of the study population and attitudes toward artificial intelligence among medical students.

Practices of AI

Table 10 provides descriptive statistics for the practice of artificial intelligence among medical students. Only 267 (35%) had ever practically applied AI, and all agreed that it facilitated their respective tasks. Conversely, 90 (11.8%) individuals had never applied AI in any task. Notably, many surgeons have practical experience with AI in radiology, utilizing X-ray, CT, and MRI

Table 9

Binary logistic regression between baseline characteristics of the study population and attitudes toward artificial intelligence among medical students

Characteristic	Value	*P*	Odds ratio	Lower	Upper
Age	< 20 years	0.034	Reference	—	—
	20–22 years	0.035	2.036	1.053	3.938
	23–25 years	0.425	1.376	0.629	3.013
	> 25 years	0.714	0.828	0.301	2.273
Sex	Male	0.048	0.630	0.399	0.996
	Female	Reference	—	—	—
Educational level	1st Grade	0.325	Reference		
	2nd Grade	0.037	2.054	1.043	4.045
	3rd Grade	0.607	1.246	0.539	2.876
	4th Grade	0.501	1.322	0.586	2.984
	5th Grade	0.422	1.426	0.599	3.394
	6th Grade	0.680	1.205	0.497	2.919
Constant	.000	0.225	—	—	

Table 10

Descriptive statistics for the practice of artificial intelligence among medical students

	Value, *n* (%)		
Characteristic	**Yes**	**No**	**Never applied**
Application AI technology in any field?	267 (35.0)	405 (53.2)	90 (11.8)
Did AI make your task easy?	441 (57.9)	42 (5.5)	279 (36.6)
Physician role is important in application and evaluation?	639 (83.9)	18 (2.4)	105 (13.8)
Would you like to work on AI in future?	543 (71.3)	60 (7.9)	159 (20.9)

AI, artificial intelligence.

modalities for diagnostic and research purposes. A significant majority, 543 (71.3%), of the individuals expressed readiness to practically apply AI in the future, while 159 (20.9%) did not provide a clear opinion on working with AI in the future. Table 11 outlines the correlation between current AI practices and different variables, including odds ratios (ORs), revealing that a lack of curriculum and gender are significant factors affecting AI practices, with p values less than 0.05. Table 6 presents binary logistic regression results relating to the baseline characteristics of the study population and the practice of artificial intelligence among medical students.

Discussion

AI has revolutionized healthcare delivery[10], as it allows tasks to be completed efficiently and accurately through the use of algorithms based on human intelligence[11–16]. Machine learning, a subtype of AI, relies on algorithms that require pre-calculated data and feature input, while deep learning is more advanced and skips the need for pre-designed classification and features[8,16].

During the recent armed conflict, healthcare facilities and workers faced a crisis due to the reallocation of resources. In developing countries such as Sudan, there is an urgent need for patient-centred AI tools to assist physicians in diagnosis and

Table 11

The practice of AI was based on age, sex, and qualification level among medical students

Characteristic	Practice of artificial intelligence, *n* (%)		*P*
	High; 489 (64.2)	Low; 273 (35.8)	
Age			
< 20 years	91 (11.9)	38 (5.0)	0.016
20–22 years	124 (16.3)	98 (12.9)	
23–25 years	233 (30.6)	119 (15.6)	
> 25 years	41 (5.4)	18 (2.4)	
Sex			
Male	111 (14.6)	36 (4.7)	0.001
Female	378 (49.6)	237 (31.1)	
Educational level			
1st Grade	69 (9.1)	27 (3.5)	< 0.001
2nd Grade	65 (8.5)	43 (5.6)	
3rd Grade	54 (7.1)	42 (5.5)	
4th Grade	91 (11.9)	80 (10.5)	
5th Grade	83 (10.9)	37 (4.9)	
6th Grade	127 (16.7)	44 (5.8)	

AI, artificial intelligence.

treatment[5,17]. Sudan is still in the initial phases of AI introduction and implementation, and little native data are available.

Our research focused on the population of medical students in Sudan and evaluated different aspects of the knowledge, attitudes, and practices of AI in the field of medicine. A total of 762 medical students participated in the study; 19.3% were males, and 80.7%were females, resulting in a male-to-female ratio of 0.23. Of the 762 participants, 642 (84.3%) had basic knowledge of AI subtypes, but only 249 (32.7%) had knowledge about the subtypes ML and DL.

Most of the individuals with knowledge of AI were males, and almost 432 (56.7%) participants were not aware of the practical application of AI in medicine. This suggests that Sudanese medical students, despite having basic AI knowledge, lack awareness of its practical implications. Three-fourths (74.4%) of the study population acknowledged the importance of AI in modern diagnostics and considered it essential in advanced medicine.

This aligns with a study conducted in the UK's medical institutes, where a three-fourths majority of students acknowledged the essential role of AI in healthcare, similar to our results[18]. In our study, 13.3% of participants agreed that implementing AI in medicine would reduce diagnostic errors, which is consistent with the findings of a study in India in which 89% of students expressed optimistic views about AI implementation[19].

Moreover, 192 (25.2%) medical students acknowledged that AI could soon serve as a practitioner's aid. Most of them do not consider AI a physician's replacement but rather a diagnostic aid. The majority (44.5%) also agreed on including an AI curriculum in medical schools, consistent with results from studies in the USA[20,21] and Sudan[1].

The major causes of AI implementation failure in Sudan, as expressed by participants, include lack of adequate knowledge and awareness, disinterest in the field, poor training, no curriculum, low financial resources, and lack of technological advancements in our country[22–25]. Furthermore, 219 (26.5%) students considered AI essential in advanced radiology, with many agreeing on its importance in the COVID-19 pandemic due to the reallocation of healthcare resources.

Conclusion

Our results show that most doctors and medical students have basic knowledge about AI but lack detailed knowledge about its applications in the medical field. Overall, the attitudes of doctors and medical students toward the need for AI in the medical field are satisfactory, and the majority consider AI essential in radiology, pathology, and other medical fields.

Most individuals agreed with the idea of including an AI curriculum in medical colleges and postgraduate residency training, considering it a physician's aid in early diagnosis and error reduction rather than a replacement. Only a minority (11.3%) of the participants had practical applications of AI in the medical field for diagnostic and research purposes, primarily in radiology (X-ray, CT, and MRI) and pathology (histopathological tests and culture and sensitivity testing).

Our research provides unique insights into the extent of knowledge, attitudes, and practices of students and doctors working in different institutes in Sudan and the factors affecting these attitudes. Since there is a need to address the willingness to adapt innovations and increase awareness of AI applications in current medicine, it is recommended that an appropriate AI curriculum be designed and implemented in the medical field in Sudan, as AI will play a progressively larger and more important role in the future of medicine and healthcare. Senior decision-makers should aim to develop policies to bring about innovations in the field.

Ethical approval

All participants could withdraw from the cross-sectional research at any time, and participation is completely voluntary. The participant could not be identified since the study did not provide names or e-mails. Each participant's identity is therefore wholly protected during the investigation. Alzaiem Alazhari University ethics committee granted its permission and gave the research the go-ahead, and the Helsinki Declaration carried out the study.

Consent

All participants could withdraw from the cross-sectional research at any time, and participation is completely voluntary. The participant could not be identified since the study did not provide names or e-mails. Each participant's identity is therefore wholly protected during the investigation. Alzaiem Alazhari University ethics committee granted its permission and gave the research the go-ahead, and the Helsinki Declaration carried out the study

Sources of funding

No funding.

Author contribution

The author contributed to this work.

Conflicts of interest disclosure

The author declares no conflicts of interest.

Research registration unique identifying number (UIN)

research study did not involving human subjects so we do not register it.

Guarantor

Mohammed Hammad Jaber Amin1.

Data availability statement

Data are available upon reasonable request.

Provenance and peer review

Not commissioned, externally peer-reviewed.

References

[1] Abid S, Awan B, Ismail T, *et al*. Artificial intelligence: medical student s attitude in the district of Peshawar, Pakistan, Pak. J Public Health 2019;9: 19–21.

[2] 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;100:327–36.

[3] Ooi SK, Makmur A, Soon AY, *et al*. Attitudes toward artificial intelligence in radiology with learner needs assessment within radiology residency programmes:a national multiprogramme survey. Singapore Med J 2021;62:126.

[4] Wahl B, Cossy-Gantner A, Germann S, *et al*. Artificial intelligence (AI) and global health: how can AI contribute to health in resource-poor settings? BMJ Glob Health 2018;3:e000798.

[5] Xiang Y, Zhao L, Liu Z, *et al*. Implementation of artificial intelligence in medicine: status analysis and development suggestions. Artif Intell Med 2020;102:101780.

[6] Shinners L, Aggar C, Grace S, *et al*. Exploring healthcare professionals' perceptions of artificial intelligence: validating a questionnaire using the e-Delphi method. Digit Health 2021;7:20552076211003433.

[7] Sarwar S, Dent A, Faust K, *et al*. Physician perspectives on the integration of artificial intelligence into diagnostic pathology. NPJ Digit Med 2019;2:1–7.

[8] Guo J, Li B. The application of medical artificial intelligence technology in rural areas of developing countries. Health Equity 2018;2:174–81.

[9] Sit C, Srinivasan R, Amlani A, *et al*. Attitudes and perceptions of UK medical students towardartificial intelligence and radiology: a multicenter survey. Insights, Imaging 2020;11:14.

[10] Yan Y, Zhang JW, Zang GY, *et al*. The primary use of artificial intelligence in cardiovascular diseases: what kind of potential role does artificial intelligence play in future medicine? J Geriatr Cardiol 2019;16:585.

[11] Shimizu H, Nakayama KI. Artificial intelligence in oncology. Cancer Sci 2020;111:1452.

[12] Hassabis D, Kumaran D, Summerfield C, *et al*. Neuroscience-inspired artificial intelligence. Neuron 2017;95:245–58.

[13] Hosny A, Parmar C, Quackenbush J, *et al*. Artificial intelligence in radiology. Nat Rev Cancer 2018;18:500–10.

[14] Kahn CE Jr. Artificial intelligence in radiology: decision support systems. Radiographics 1994;14:849–61.

[15] Li CX, Shen CB, Xue K, *et al*. Artificial intelligence in dermatology: past, present, and future. Chin Med J 2019;132:2017.

[16] Du-Harpur X, Watt FM, Luscombe NM, *et al*. What is AI? Applications of artificial intelligence to dermatology. Br J Dermatol 2020;183:423–30.

[17] Ting DS, Pasquale LR, Peng L, *et al*. Artificial intelligence and deep learning in ophthalmology. Br J Ophthalmol 2019;103:167–75.

[18] Moraru AD, Costin D, Moraru RL, *et al*. Artificial intelligence and deep learning in ophthalmology-present and future. Exp Ther Med 2020;20: 3469–73.

[19] Chan KS, Zary N. Applications and challenges of implementing artificial intelligence in medical education: integrative review. JMIR Med EdU 2019;5:e13930.

[20] Laï MC, Brian M, Mamzer MF. Perceptions of artificial intelligence in healthcare: findings from a qualitative survey study among actors in France. J Transl Med 2020;18:1–3.

[21] Rodela TT, Tasnim S, Mazumder H, *et al*. The Economic Impacts of Coronavirus Disease (COVID-19) in Developing Countries SocArXiv. Wygpk. Preprint, 2020. https://doi.org/10.31219/osf.io/wygpk

[22] Castagno S, Khalifa M. Perceptions of artificial intelligence among healthcare staff: a qualitative survey study. Front Artif Intell 2020;3:84.

[23] Jindal A, Bansal M. Knowledge and education about artificial intelligence among medical students from teaching institutions in India: a brief survey. MedEdPublish 2020;16:9.

[24] Wood EA, Ange BL, Miller DD. Are we ready to integrate artificial intelligence literacy into medical school curriculum: students and faculty survey. J Med Educ Curric Dev 2021;8:23821205211024078.

[25] Mathew G, Agha R. for the STROCSS Group. STROCSS 2021. Strengthening the Reporting of cohort, cross-sectional and case-control studies in Surgery. In: for the STROCSS Group. STROCSS 2021, editors. Int J Surg 2021;96:106165.