Machine Learning in Otorhinolaryngology, Head and Neck Surgery and its applications in diagnosis and management: Undergraduates Perception toward New Era

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Received: October 2021; Accepted: November 2021; Published: December 1, 2021.
Citation: Saleh Abdulmoneim Alomary et al. Machine Learning in Otorhinolaryngology, Head and Neck Surgery and its applications in diagnosis and management: Undergraduates Perception toward New Era. World Family Medicine. 2021; 19(12): 137-148 DOI: 10.5742/MEWFM.2021.94191

Abstract

Background & aim: Machine learning (ML) is a growing field concerned with predicting novel situations from previous observations. The aim of this study was to determine medical students' perceptions of ML in otorhinolaryngology, head, and neck surgery and its applications in diagnosis and management. Also, to assess medical students' awareness of current challenges facing the application of ML in medical practice in the Kingdom of Saudi Arabia (KSA).

Methods: A cross-sectional survey was conducted in February–May 2021 among medical students in Saudi Arabia. The participants were provided with questionnaires of the survey using electronic forms. Validation of the questionnaire was done using exploratory factor analysis and confirmatory factor analysis. There were 8 validated items on Attitude and 6 items on Knowledge.

Results: A total of 538 students completed the questionnaire. The majority of the students were familiar with machine learning in general 308 (57.3%). However, only a few of the participants were familiar with machine learning applications in the field of otorhinolaryngology, head, and neck surgery 184 (34.2%). There was a significant difference between knowledge and attitude with the current year of study and GPA score, however, gender had no difference, yet there was a significant association between attitude among male and female medical students.

Conclusion: Medical students in the KSA demonstrated a good knowledge of ML in general, although many were not familiar with machine learning applications in the field.

Key words: Machine learning, Otorhinolaryngology, Medical student, Kingdom of Saudi Arabia

Introduction

Machine learning (ML) is a subfield of artificial intelligence (AI) constituting vast resources to combine computer science and data by utilizing statistical algorithms to help solve various medical problems. It is a growing field that is concerned with predicting novel situations from previous observations. ML has a great potential to deal with large, complex, and disparate data commonly found in the medical field. Due to its vast potential, it is considered as the future of research in the biomedical field, personalized medicine, and computer-aided diagnosis (1). The common applications of ML across a range of specialties include enhanced cancer diagnosis, adaptive clinical trial designs, and prognosis prediction by integrating clinical and genomic data (2,3). The deployment of ML models in the healthcare domain can increase the speed and accuracy of diagnosis and improve treatment planning and patient care (4). Li W et al conducted a study for a more accurate diagnosis of COVID-19 based on symptoms and results of routine tests by applying ML to reanalyze COVID-19 data from 151 published studies and they found that it was able to distinguish COVID-19 patients from influenza patients with a specificity of 97.9% and a sensitivity of 92.5% (5). Deep learning is becoming the gold standard in ML and is gradually becoming the most commonly used computational approach in ML. It has the ability to learn a large amount of information with great results (6). But to improve the diagnostic performance, we cannot rely solely on ML as it is also important to understand the role of human decisions (7). AI has the potential to deliver more precise results in clinical diagnosis. A study conducted in China developed and utilized an AI system, Med3R which became the first AI system to successfully pass the written test of the National Medical Licensing Examination in China 2017 with a total score of 456, exceeding 96.3% of human examinees. Med3R with the help of real electronic medical records has been used to provide aided clinical diagnosis services (8).

Otolaryngology-head and neck surgery is the oldest branch in medicine that carries unique opportunities to show the potential of ML (9). Recently, there has been a steep increase in the literature volume describing the vast applications of ML in the field of otolaryngology–head and neck surgery that include automatic recognition of auditory brainstem response waveforms, genomic prediction of oral squamous cell carcinoma, and acoustic voice feature classification (10-12). ML with the use of deep learning algorithms can be helpful in improving accuracy and can also improve doctors' confidence in both diagnoses and decision-making with respect to this field. Fang SH et al (13) and Fujimura S et al (14) utilized the use of ML in diagnosing a plethora of diseases of the head and neck through detection of the pathological voice using cepstrum vectors and discrimination of "hot potato voice" using a support vector machine respectively. Halicek M et al conducted a study to detect tumours of the thyroid and salivary glands using hyperspectral imaging and deep learning (15,16). Bing D et al have reported its use in predicting hearing outcomes in sudden sensorineural hearing loss (17). Formeister EJ et al predicted the postoperative complications in head and neck microvascular free tissue transfer (18).

The medical schools should be aware of the perception of medical students about ML to enhance the students' knowledge about this science and its importance in diagnosing as well as treating diseases with accuracy along with fewer side effects. Therefore, knowing the perceptions of medical students in this field will be beneficial for medical schools and the students to develop their understanding of ML. Given the importance of computer science in medical practice and advancement in ML, otolaryngologists and head and neck surgeons are tasked with how ML can identify the statistical patterns of data generated by tens of thousands of physicians and billions of patients by training computers to perform specific tasks with sometimes superhuman ability (19). This study examines the medical students' perceptions of ML in otorhinolaryngology, head, and neck surgery, and its importance in the medical field.

Methods

A questionnaire-based cross-sectional survey was conducted in February 2021 among medical students in Saudi Arabia. The study was approved by the Institutional Review Board of the Medical Research Unit, College of medicine, Imam Mohammad Ibn Saud Islamic University. The study was conducted using questionnaires through an electronic form which was distributed among medical students. Validation of the questionnaire was done using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). There were 8 validated items on Attitude and 6 items on Knowledge. The questionnaire addressed demographic information, knowledge of ML in otorhinolaryngology, head and neck surgery, sources of information, and the level of awareness of its applications in diagnosis, and management. Students' consent to participate in the survey was done.

The questionnaire was completed by 538 respondents. Medical Students were asked about their gender, age, year of study, and their Grade Point Average (GPA) scores. Further questions addressed whether they were familiar with ML use in otorhinolaryngology, head and neck surgery to assess the extent to which the universities and college of medicine in Riyadh informed the students of ENT about ML and its importance in the diagnosis and treatment of a variety of diseases, as well as, its benefits in decreasing the time it takes to reach a diagnosis and offer treatment in some diseases in otorhinolaryngology, head, and neck surgery. The survey asked if medical students in Riyadh agreed that they knew the importance of ML or not or whether the ENT curriculum or even any curriculum in the colleges introduced ML. Students were asked if they thought this information would be offered in advanced-level courses in medical school and if the students preferred to know it during the residency in otorhinolaryngology, head, and neck surgery, for example.

Statistical analysis: Statistical analysis was performed using SPSS 28.0 (IBM, Armonk-USA. Counts and percentages were used to summarize categorical variables. The mean ± standard deviation was used to summarize the distribution of continuous variables. Chi-square test of independence was used to assess the association between categorical variables. The association of attitude and knowledge was analyzed using the Chi-square test. EFA and CFA were carried out to explore the factors associated with machine learning in otorhinolaryngology and also for validation of the instrument using SAS 9.4

Results

The questionnaire was completed by 538 respondents (70.6% males and 29.4% females). Respondents aged 18–20 years and 21–23 years represented 12.6% and 40.7% of the study sample, respectively, while respondents aged 24–26 years represented 44.6% of the study sample. Interns represented 13.1% of the study sample. Approximately half of the respondents were in the 5th year of study (48.3%). Respondents in the pre-clinical years (1st, 2nd, and 3rd years) and clinical years (4th year, 5th years, and interns) represented 27.1% and 72.8% of the study sample, respectively. Half of the respondents (45.7%) reported a GPA of 3.75–4.49, and one-third (30.3%) reported a GPA of 4.5–5 (Table 1).

Table 1: Descriptive statistics of the study sample (n=538)

Variables	n (%)
Gender	
Male	380(70.6)
Female	158(29.4)
Age in Years	
18-20	68(12.6)
21-23	219(40.7)
24-26	240(44.6)
>26	11(2.0)
Current year of Study	
First year	61(11.3)
Second year	37(6.9)
Third year	48(8.9)
Fourth year	62(11.5)
Fifth year	260(48.3)
Intern	70(13.0)
GPA	
2-2.74	18(3.3)
2.75-3.74	86(16.0)
3.75-4.49	246(45.7)
4.50-5	163(30.3)
Prefer not to answer	25(4.7)

Table 2 showed that three main challenges faced the application of ML: unfamiliarity with ML (35.1%), machine errors that compromise patient care (29.2%), and affordability (28.2%). One-third of the respondents thought applying ML in otorhinolaryngology was important due to the anatomical complexity (35.1%). Others (30.7%) thought that it was important to improve physician's decision-making skills and less than one-quarter (1.9%) thought that it was important to reduce diagnostic errors. Suggested options to overcome these challenges included: exposing medical students to the concept of ML in their curriculum (32.9%), advertising ML applications among physicians (26.0%), promoting research importance in ML (24.9%), and increasing the affordability of ML applications (14.3%).

Table 2: Challenges and suggestions for overcoming the application of ML

Variable	n (%)
Q10. In your opinion what is the most important challenge that faces the application of machine learning in medical practice	
Affordability	151(28.1)
Machine errors may compromise patient care	157(29.2)
Unfamiliarity with machine learning	189(35.1)
Data security	35(6.5)
I don't know	06 (1.1)
Q11. In your opinion why is the application of machine learning in otorhinolaryngology, Head and Neck surgery important?	
Not important	51(9.5)
The anatomical complexity	189(35.1)
Decrease diagnostic errors	118(21.9)
To improve physician's decision making skills	165(30.7)
I don't know	15(2.8)
Q12. In your opinion what can be done to overcome the challenges that face machine learning application in otorhinolaryngology, Head and Neck surgery	
Expose medical students to the concept of machine learning in their curriculum	177(32.9)
Advertise machine learning applications among physicians	140(26.0)
Promote research importance in machine learning	134(24.9)
Increase the affordability of machine learning applications	77(14.3)
I don't know	10 (1.9)

Table 3 depicts the percentage of attitude and knowledge in ML. The majority of the participants 308(57.3%) were familiar with ML. About 235(69.2%) considered that ML was important in health practice. But only 173(32.1%) had it covered in the ENT curriculum. Most of the students 343(54.8%) felt that there was a great future for ML in ENT in KSA. Only a few students felt that 162(30.1%) ML was not important to learn in the curriculum of ENT. The students were also open-minded in responding to the not necessary instrument in ML in the field of ENT 166(30.9%). Only 297(55.2%) felt that ML in ENT should be taught after graduation.

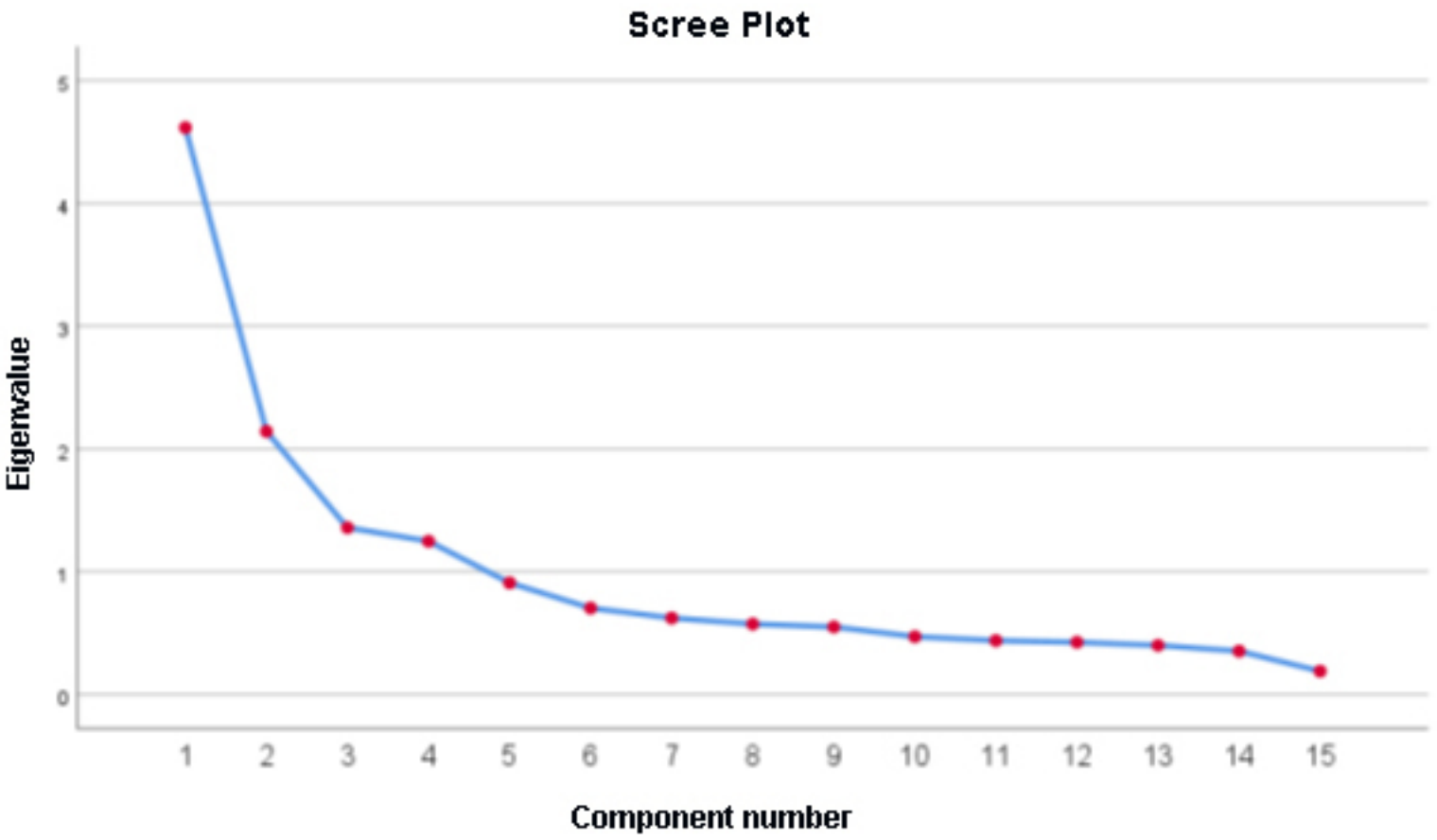
Table 3: Distribution of the Machine Learning questionnaire in Otolaryngology.

Items in Machine Learning Questionnaire	SA	A	U	D
Q6. Are you familiar with "machine learning"?	101 (18.8)	207 (38.5)	136 (25.3)	94 (17.5)
Q7. Are you familiar with "machine learning" applications in medical practice?	71 (13.2)	226 (42.0)	124 (23.0)	117 (21.7)
Q8. Are you familiar with "machine learning" applications in the field of Otolaryngology-Head and Neck surgery?	47 (8.7)	137 (25.5)	177 (32.9)	177 (32.9)
Q9. In your opinion is "machine learning" important in health practice:	152 (28.3)	220 (40.9)	140 (26.0)	26 (4.8)
Q13. Do you think that the ENT curriculum has been covered Machine Learning very well	42 (7.8)	131 (24.3)	218 (40.5)	147 (27.3)
Q14. Do you think that Machine Learning in ENT has a great future especially in the Kingdom of Saudi Arabia?	108 (20.1)	235 (43.7)	173 (32.2)	22 (4.1)
Q15. Do you think that the benefits and negatives of Machine Learning have been excellently demonstrated in ENT specialty?	63 (11.7)	165 (30.7)	237 (44.1)	73 (13.6)
Q16. Do you think that the Machine learning will be a reason for a qualitative shift in the ENT surgeries?	126 (23.4)	190 (35.3)	184 (34.2)	38 (7.1)
Q17. Do you prefer to go more deeply into Machine Learning in the ENT specialty, because it is considered a step forward in the development of the health system?	150 (27.9)	210 (39.0)	138 (25.7)	40 (7.4)
Q18. Do you think that Machine Learning in ENT surgeries will have a positive effect in terms of reducing the duration of operations?	135 (25.1)	246 (45.7)	130 (24.2)	27 (5.0)
Q19. Do you think that Machine Learning in ENT surgeries will have a positive effect in terms of reducing the complications of surgery?	106 (19.7)	257 (47.8)	142 (26.4)	33 (6.1)
Q20. Do you think that machine learning is not important to learn in ENT curriculum	41 (7.6)	121 (22.5)	152 (28.3)	224 (41.6)
Q21. Do you think that machine learning in ENT had an impact on you for considering this specialty in the future?	108 (20.1)	170 (31.6)	168 (31.2)	92 (17.1)
Q22. In ENT curriculum; there are certain instruments that I don't need to know?	57 (10.6)	109 (20.3)	197 (36.6)	175 (32.5)
Q23. I think that machine learning in ENT should be after graduation when choosing this specialty	142 (26.4)	155 (28.8)	136 (25.3)	105 (19.5)

*SA: Strongly Agree , A: Agree, U: Unsure , D: Disagree, SD: Strongly disagree- nobody strongly disagreed.

Figure 1 represents the Scree plot of the exploratory factor analysis with Eigenvalue in the y-axis and the component (Questions) in the x-axis. This is a pictorial representation of deciding the number of factors to enter into the final rotation. As per the previous literature, it is wise to fix our Eigenvalue at 1.5 which gives us two factors namely one with an Eigenvalue at 4.618 and another at 2.143 namely attitude and knowledge, respectively.

Figure 1: Showing Scree plot of the EFA with Eigen value in the y axis and the component (Questions) in the x axis



Exploratory Factor analysis (EFA) and Confirmatory factor analysis (CFA): An EFA was done on the ML-survey questionnaire with an Eigenvalue restricted at 1.5 or above which had given two factors with 30.78% and 14.29% variation explained respectively. The Kaiser Mayer-Olkin (KMO) (20) which is a measure of sampling adequacy was found to be 0.815. Bartlett's test of Sphericity was found to be highly significant with a P-value <0.001. The factor analysis was performed based on the Principal component analysis with including factor loading only 0.5 and above was considered further, which is indicated as bold and italic in Table 4. Factor loading less than the specification was not included in the further modeling. Table 4 explains the factor loading for each item. A Promax rotation with Kappa= 4 was chosen. This resulted in 10+6 items into two factors which were named as Attitude (first factor) with 10 items and Knowledge for the second domain with 6 items. Question 23 "I think that machine learning in ENT should be after graduation when choosing this specialty" was removed from the model as it had the least factor loading which was not included in either of the factors. Question 20 "Do you think that machine learning is not important to learn in ENT curriculum" had a negative factor loading for the factor Attitude but it had a higher and positive factor loading in Knowledge factor so it was considered into the second factor. Negative factor loadings indicated that the scoring has to be given in reverse order. CFA with the above 16 items was carried out where the Chi-square statistics had a P-value of <0.0001 with an RMSEA (21) of 0.14, despite a Bentler's CFI of 0.67 (21,22) which was considered to be low. However, the fitted factor's Cronbach's alpha (23) was considerably higher with 0.827 for Attitude and 0.737 for Knowledge.

Table 4: Factor loading after Promax rotation with Kappa=4 in exploratory factor analysis:

Items in Machine Learning Questionnaire	Attitude Eigen values=4.618 Cronbach's α=0.827	Knowledge Eigen values=2.143 Cronbach's α=0.737
17. Do you prefer to go deeper in the Machine Learning in ENT specialty, because it is a considered step forward in the development of the health system?	*0.746*	0.068
19. Do you think that the Machine Learning in ENT surgeries will have a positive effect in terms of reducing the complications of surgery?	*0.732*	0.169
18. Do you think that the Machine Learning in ENT surgeries will have a positive effect in terms of reducing the duration of operations?	*0.694*	0.094
16. Do you think that the Machine learning will be a reason for a qualitative shift in the ENT surgeries?	*0.684*	0.086
6. Are you familiar with "machine learning"?	*0.657*	0.505
9. In your opinion is "machine learning" important in health practice:	*0.631*	0.218
14. Do you think that Machine Learning in ENT has a great future especially in the Kingdom Of Saudi Arabia?	*0.612*	0.257
21. Do you think that machine learning in ENT had an impact on you for considering this specialty in the future?	*0.572*	0.225
23. I think that machine learning in ENT should be after graduation when choosing this specialty	0.347*	*0.251*
20. Do you think that machine learning is not important to learn in ENT curriculum	-0.47	*0.672*
22. In ENT curriculum; there are certain instruments that I don't need to know.	0.032	*0.669*
13. Do you think that the ENT curriculum has covered Machine Learning very well	0.189	*0.664*
8. Are you familiar with "machine learning" applications in the field of Otolaryngology-Head and Neck surgery?	0.383	*0.635*
15. Do you think that the benefits and negatives of Machine Learning have been excellently demonstrated in ENT specialty?	0.334	*0.634*
7. Are you familiar with "machine learning" applications in medical practice?	0.587	**0.621**

Bold values indicate item retained in the scale. *q23 I think that machine learning in ENT should be after graduation when choosing this specialty had a least factor loading.

A path diagram in Figure 2 based on the principal component analysis was drawn which is displayed with the respective factor loading according to the factors and items within the subscales.

Figure 2: Path diagram showing the respective factor loading according to the factors and items within the sub scales

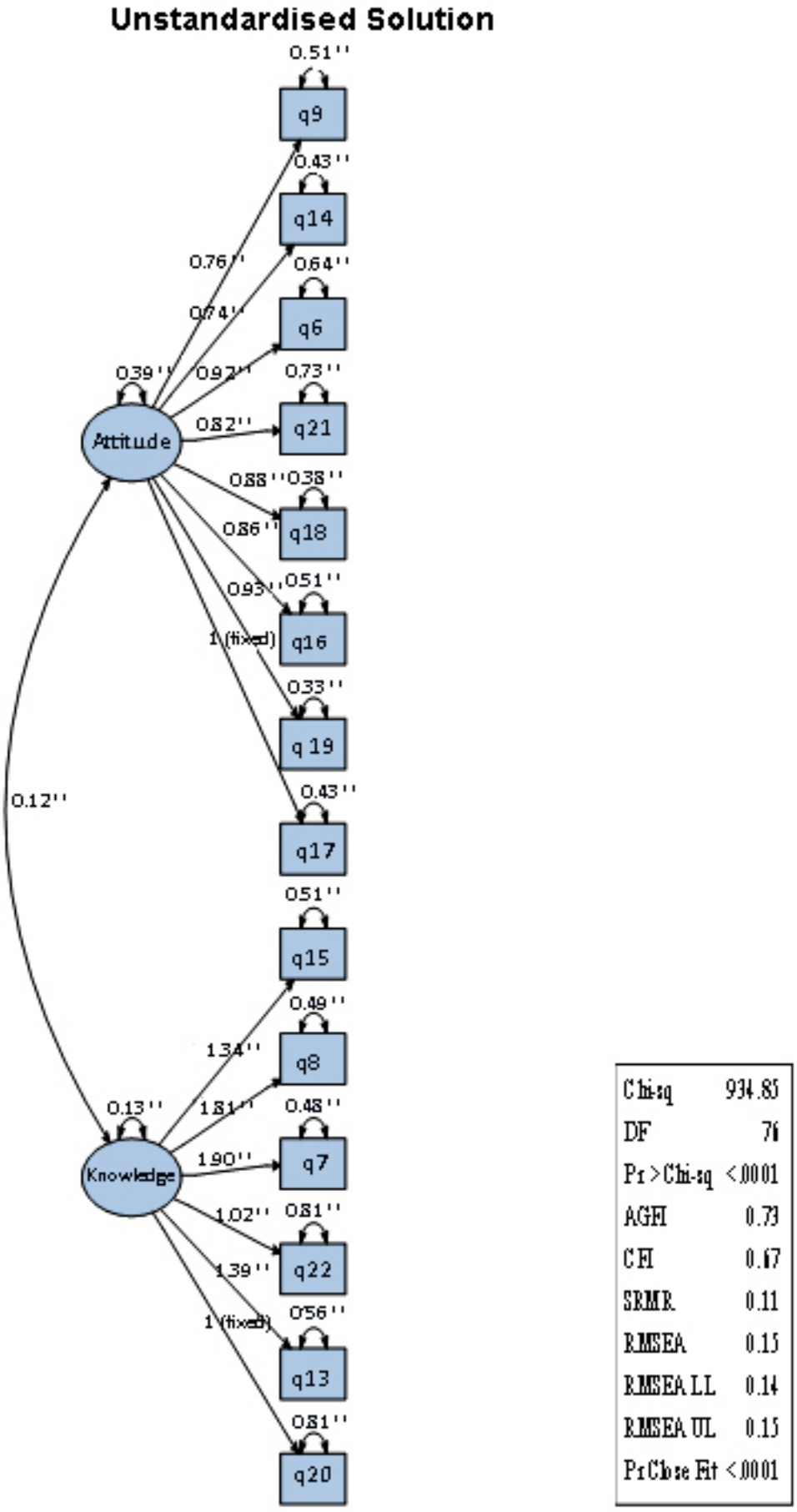


Table 5 and Table 6 indicate the association between Attitude and Knowledge between the demographic variables. From the derived items of factors Attitude and Knowledge above and below means were calculated. Attitude consisted of 10 items with the least score of 8 and a maximum score of 31; 17.80±4.75 and for Knowledge domain had 6 items with the least score at 6 to the highest score at 24; 16.85±3.71. The demographic variables such as gender, age, current year of study, and GPA score were associated, of which age did not have any association between the attitude, or knowledge. There was a significant association between male and female students with respect to the attitude but not with the knowledge. There was a significant association between the current year of study and GPA in both attitude and knowledge.

Table 5: Distribution of Attitude with demographic variables

Attitude	Less than Mean, n (%)	Greater than mean, n (%)	P value
Gender			
Male	175(65.5)	205(75.6)	0.010*
Female	92(34.5)	66(24.4)	
Age in Years			0.322
18-20	31(11.6)	37(13.7)	
21-23	107(40.1)	112(41.3)	
24-26	126(47.2)	114(42.1)	
>26	3(1.1)	8(3.0)	
Current Year of study			<0.001*
First Year	25(9.4)	36(13.3)	
Second year	20(7.5)	17(6.3)	
Third year	21(7.9)	27(10.0)	
Fourth year	17(6.4)	45(16.6)	
Fifth year	132(49.4)	128(47.2)	
Intern	52(19.5)	18(6.6)	
GPA			<0.001*
2-2.74	4(1.4)	14(5.4)	
2.75-3.74	49(17.8)	37(14.0)	
3.75-4.49	138(50.6)	108(40.9)	
4.50-5	70(25.5)	93(35.2)	
Prefer not to answer	13(4.7)	12(4.5)	

*Statistically significant

Table 6: Distribution of Knowledge with demographic variables

Knowledge	Less than Mean, N (%)	Greater than mean, N (%)	P value
Gender			
Male	166(74.1)	214(68.2)	0.135
Female	58(25.9)	100(31.8)	
Age in Years			
18-20	29(12.9)	39(12.4)	0.201
21-23	80(35.7)	139(44.3)	
24-26	111(49.6)	129(41.1)	
>26	4(1.8)	7(2.2)	
Current Year of study			
First Year	32(14.3)	29(9.2)	0.023*
Second year	10(4.5)	27(8.6)	
Third year	13(5.8)	35(11.1)	
Fourth year	23(10.3)	39(12.4)	
Fifth year	111(49.6)	149(47.5)	
Intern	35(15.6)	35(11.1)	
GPA			
2-2.74	7(3.2)	11(3.4)	0.012*
2.75-3.74	34(15.9)	52(16.0)	
3.75-4.49	97(45.3)	149(46.0)	
4.50-5	67(31.4)	96(29.6)	
Prefer not to answer	09(4.2)	16(5.0)	

*Statistically significant

Discussion

The study was conducted to determine medical students' perceptions of ML in otorhinolaryngology, head, and neck surgery and its applications in diagnosis and management, and also to assess medical students' awareness of current challenges facing the application of ML in medical practice in the KSA.

The findings of our study revealed that more than half of the participants (57.3%) have a good knowledge of ML in general. In a similar study, the results showed that 78.9% of their respondents had a good understanding of AI (24), and another study found that approximately 50% believed they had a good understanding of AI; however, when knowledge of AI was tested using five questions, on average, only 22% of the questions were answered correctly (25).

Our study showed that there is a significant difference related to the familiarity of ML application in medical practice as 55.2% of the participants were aware of it; however, only 34.2% of the participants were familiar with ML application in the field of otorhinolaryngology, head, and neck surgery. These findings might be explained by the short duration of the ENT course that is taught in the medical schools in the KSA, during which, there is a limited time to cover the fundamentals of ENT, and ML cannot be covered as well. This notion was supported by the findings of a study conducted by Park SH et al which showed that 32% of the participants agreed that ML was covered very well in the ENT curriculum in their medical school (26) which is similar to the findings of our study where 32.1% had it covered in ENT curriculum. A systematic review showed that although using AI and ML in teaching and practicing medicine is advised, they are still not taught in traditional medical and health informatics curricula (27). To overcome this drawback, ML should be taught as an elective subject for undergraduate medical students. Even some medical colleges in the Republic of Korea such as the University of Ulsan and Yonsei University have recently started providing AI-dedicated elective courses to the students (27).

In our study, we found that the main challenge in applying ML in medical practice will be unfamiliarity with ML (35.1%) and they believe that to overcome this challenge, medical students need more exposure by adding ML to the curriculum in medical schools (32.9%). Although this was not the only challenge, there were other challenges affecting the application of ML in the medical field, such as machine errors that compromise patient care (29.2%) and affordability (28.2%). A survey conducted in the UK showed that 63% of the adults were uncomfortable permitting their personal data to be used to improve healthcare and were opposed to AI systems substituting medical professionals in their usual tasks (28).

The majority of the participants (25.1% and 45.7% were strongly agreeing and agreeing respectively) in our study thought that ML will be important in the field of otorhinolaryngology, head, and neck surgery and have a positive effect in terms of reducing the duration of ENT surgery. Similarly, an online survey conducted on fellows and trainees in Australia and New Zealand of different specialties ophthalmology, radiology/radiation oncology, and dermatology found that the majority (71.0%) considered AI would advance their field of medicine and that medical practitioner's needs would be impacted by the technology over the next decade (29). Sit C et al received 484 responses from 19 UK medical schools and found that 88% of the students believed that AI would play an important role in healthcare and in health complications (30). Similarly, 69.2% of participants in our study considered that ML was important in health practice.

In the present study, a total of 54.8% felt that there was a great future for ML in ENT in the KSA. A study conducted by Park CJ et al among 156 medical students in the US agreed that AI would have a significant role in the future of medicine (75%) (31). Another cross-sectional study conducted by Bin Dahmash A et al in the KSA found that 44.8% of the participants believed that AI would minimize the number of radiologists needed in the future (25).

Deeper knowledge and a good understanding of ML can be a shift toward specialties with high quality and fewer mistakes, not only in ENT or in medicine in general, but also in other careers (32,33). ML has many potential applications in the medical field, not only with diagnosis and treatment but also with the medical education of medical students (34). AI can also help with training and improving the surgical skills of residents (35), and ML can also possibly help with evaluating medical professionals (36).

We faced some limitations in this study. Given the current situation of the COVID-19 pandemic and the restrictions of social distancing and lockdown, we had to work online at the beginning of the study and some work was postponed due to the pandemic. Further, there is limited research on this topic published. Therefore, we could not compare our findings to other studies. We were also limited by the nascency of ML in the medical field; ML is not yet taught or not taught enough in the curriculum in medical schools.

Recommendations

There should be more medical research conducted on ML with clinical trials for an accurate assessment of the efficacy of ML on patients' health care to improve the healthcare system and take the next step toward the future and advancing medical science. Surveys should also be conducted in the KSA to determine whether the adult population is comfortable with allowing their personal data to be used in ML to improve the healthcare system. ML should be more covered in medical schools in the KSA to enhance students' understanding of the possibilities that ML could provide.

Conclusion

To conclude, the medical students in the KSA demonstrated a good knowledge of machine learning in general, although many were not familiar with machine learning applications in the field. Therefore, further research about medical students' attitude toward ML in other medical specialties in the KSA is recommended to evaluate the awareness of current challenges facing the applications of ML in medical practice. Similar studies should also be conducted on medical physicians in the KSA to assess their perception and stance on applying ML to treat and diagnose patients and to know obstructions faced while applying ML.

Acknowledgements
We are thankful to Dr. Sulaiman Al Habib Medical Group's research Center for their tremendous support

References

1 Handelman GS, Kok HK, Chandra RV, Razavi AH, Lee MJ, Asadi H. eDoctor: Machine learning and the future of medicine. J Intern Med. 2018;284(6):603-619. doi: 10.1111/joim.12822.
2 Angus DC. Fusing randomized trials with big data: the key to self-learning health care systems? JAMA 2015;314:767–768.
3 Cruz JA, Wishart DS. Applications of machine learning in cancer prediction and prognosis. Cancer Inform 2007;2:59–77.
4 Maleki F, Muthukrishnan N, Ovens K, Reinhold C, Forghani R. Machine learning algorithm validation: from essentials to advanced applications and implications for regulatory certification and deployment. Neuroimaging Clinics of North America, 2020;30(4).
5 Li W, Ma J, Shende N, Castaneda G, Chakladar J, Tsai J, et al. Using machine learning of clinical data to diagnose COVID-19: A systematic review and meta-analysis. BMC Medical Informatics and Decision Making, 2020;20(1).
6 Alzubaidi L, Zhang J, Humaidi AJ, Al-Dujaili A, Duan Y, Al-Shamma O, et al. Review of deep learning: Concepts, CNN architectures, challenges, applications, future directions. J Big Data. 2021;8(1):53. doi: 10.1186/s40537-021- 00444-8.
7 Vasey B, Ursprung S, Beddoe B, Taylor EH, Marlow N, Bilbro N, et al. Association of clinician diagnostic performance with machine learning-based decision support systems: A systematic review. JAMA Netw Open. 20211;4(3):e211276. doi: 10.1001/jamanetworkopen.
8 Wu J, Liu X, Zhang X, Zhiyang He, Ping LV. Master clinical medical knowledge at certificated-doctor-level with deep learning model. Nat Commun 2018;9:4352.
9 Fenton RA. A brief history of otolaryngology in the United States from 1847 to 1947. Arch Otolaryngol 1947;46:153–162.
10 Freeman DT. Computer applications in otolaryngology: computer recognition of brain stem auditory evoked potential wave V by a neural network. Ann Otol Rhinol Laryngol 1992;101:782–790.

11 Whipple ME, Mendez E, Farwell DG, Agoff SN, Chen C. A genomic predictor of oral squamous cell carcinoma. Laryngoscope 2004;114:1346–1354.
12 Schönweiler R, Hess M, Wübbelt P, Ptok M. Novel approach to acoustical voice analysis using artificial neural networks. J Assoc Res Otolaryngol 2000;1:270–282
13 Fang SH, Tsao Y, Hsiao MJ, Chen JY, Lai YH, Lin FC, et al. Detection of Pathological Voice Using Cepstrum Vectors: A Deep Learning Approach. J Voice. 2019;33(5):634–41.
14 Fujimura S, Kojima T, Okanoue Y, Shoji K, Inoue M, Hori R. Discrimination of "hot potato voice" caused by upper airway obstruction utilizing a support vector machine. Laryngoscope.2019;129(6):1301–7.
15 Halicek M, Dormer JD, Little JV, Chen AY, Fei B. Tumor detection of the thyroid and salivary glands using hyperspectral imaging and deep learning. Biomed Opt Express. 2020;11(3):1383.
16 Halicek M, Dormer JD, Little JV, Chen AY, Myers L, Sumer BD, et al. Hyperspectral imaging of head and neck squamous cell carcinoma for cancer margin detection in surgical specimens from 102 patients using deep learning. Cancers (Basel). 2019;11(9):1367.
17 Bing D, Ying J, Miao J, Lan L, Wang D, Zhao L, et al. Predicting the hearing outcome in sudden sensorineural hearing loss via machine learning models. Clin Otolaryngol. 2018;43(3):868–74.
18 Formeister EJ, Baum R, Knott PD, Seth R, Ha P, Ryan W, et al. Machine Learning for Predicting Complications in Head and Neck Microvascular Free Tissue Transfer [published online ahead of print, 2020 Jan 28]. Laryngoscope. 2020. 10.1002/lary.28508.doi:10.1002/lary.28508
19 Krause J, Gulshan V, Rahimy E, Karth P, Widner K, Corrado GS, et al. Grader variability and the importance of reference standards for evaluating machine learning models for diabetic retinopathy. Ophthalmology. 2018;125(8):1264-1272. doi: 10.1016/j.ophtha.2018.01.034.
20 McDonald RP, Ho MH. Principles and practice in reporting structural equation analyses. Psychol Methods. 2002;7(1):64–82.
21 Musil CM, Jones SL, Warner CD. Structural equation modeling and its relationship to multiple regression and factor analysis. Res Nurs Health. 1998;21(3):271–81.
22 Crowley SL, Fan X. Structural equation modeling: basic concepts and applications in personality assessment research. J PersAssess. 1997;68(3):508–31.
23 Jeyaseelan L, Kumar S, Mohanraj R, Rebekah G, Rao D, Manhart LE. Assessing HIV/AIDS stigma in south India: validation and abridgement of the Berger HIV Stigma scale. AIDS and behavior. 2013; 17(1): 434–443. https://doi.org/10.1007/s10461-011-0128-3.
24 Gong B, Nugent JP, Guest W, Parker W, Chang PJ, Khosa F, et al. Influence of artificial intelligence on Canadian medical students' preference for radiology specialty: A National survey study. Acad Radiol 2019; 26: 566–77. doi: 10.1016/j.acra.2018.10.007
25 Bin Dahmash A, Alabdulkareem M, Alfutais A, Kamel AM, Alkholaiwi F, Alshehri S, et al. Artificial intelligence in radiology: Does it impact medical students' preference for radiology as their future career? BJR Open. 2020 Dec 11;2(1):20200037. doi: 10.1259/bjro.20200037.
26 Park SH, Do KH, Kim S, Park JH, Lim YS. What should medical students know about artificial intelligence in medicine? J Educ Eval Health Prof. 2019;16:18. doi:10.3352/jeehp.2019.16.18
27 Sapci AH, Sapci HA. Artificial Intelligence Education and Tools for Medical and Health Informatics Students: Systematic Review. JMIR Med Educ. 2020;6(1): e19285. doi:10.2196/19285
28 Fenech M, Strukelj N, Buston O. Ethical, social and political challenges of artificial intelligence in health. 2018 April [Cited 19 Sept 2021]. Available at: http://futureadvocacy.com/wp-content/uploads/2018/04/1804_26_FA_ETHICS_08-DIGITAL.pdf.
29 Scheetz J, Rothschild P, McGuinness M, Hadoux X, Soyer HP, Janda M, et al. A survey of clinicians on the use of artificial intelligence in ophthalmology, dermatology, radiology and radiation oncology. Sci Rep. 2021;11(1):5193. doi: 10.1038/s41598-021-84698-5.
30 Sit C, Srinivasan R, Amlani A, Muthuswamy K, Azam A, Monzon L, et al. Attitudes and perceptions of UK medical students towards artificial intelligence and radiology: A multicentre survey. Insights Imaging. 2020;11(1):14. doi: 10.1186/s13244-019-0830-7.
31 Park CJ, Yi PH, Siegel EL. Medical student perspectives on the impact of artificial intelligence on the practice of medicine. Curr Probl Diagn Radiol. 2021;50(5):614-619. doi: 10.1067/j.cpradiol.2020.06.011.
32 LeCun Y, Bengio Y, Hinton G. Deep learning. Nature 2015;521: 436-444. doi:10.1038/nature14539
33 Ardila D, Kiraly AP, Bharadwaj S, Choi B, Reicher JJ, Peng L, et al. End-to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography. Nat Med 2019;25:954–961. 10.1038/s41591-019-0536-x.
34 Winkler-Schwartz A, Bissonnette V, Mirchi N, Ponnudurai N, Yilmaz R, Ledwos N, et al. Artificial intelligence in medical education: Best practices using machine learning to assess surgical expertise in virtual reality simulation. J Surg Educ. 2019;76(6):1681-1690. doi: 10.1016/j.jsurg.2019.05.015.
35 Bissonnette V, Mirchi N, Ledwos N, Alsidieri G, Winkler-Schwartz A, Del Maestro RF. Neurosurgical simulation & artificial intelligence learning centre. Artificial intelligence distinguishes surgical training levels in a virtual reality spinal task. J Bone Joint Surg Am. 2019;101(23): e127. doi: 10.2106/JBJS.18.01197.
36 Winkler-Schwartz A, Yilmaz R, Mirchi N, Bissonnette V, Ledwos N, Siyar S, et al. Machine learning identification of surgical and operative factors associated with surgical expertise in virtual reality simulation. JAMA Netw Open. 2019;2(8):e198363. doi: 10.1001/jamanetworkopen.2019.8363.