The Innovative tool of Dentistry- Artificial Intelligence

Running title- Artificial Intelligence in Dentistry.

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Abstract: The increasing use of three-dimensional (3D) imaging techniques in dental medicine has boosted the development and use of artificial intelligence (AI) systems for various clinical problems. This review focuses on current developments and performance of AI for 3D imaging in dento- maxillofacial radiology (DMFR) as well as intraoral and facial scanning. In DMFR, machine learning-based algorithms proposed in the literature focus on three main applications, including automated diagnosis of dental and maxillofacial diseases, localization of anatomical landmarks for treatment planning, and general improvement of image quality. Automatic recognition of teeth and diagnosis of facial deformations using AI systems based on intraoral and facial scanning will very likely be a field of increased interest in the future. The review is aimed at providing dental practitioners and interested colleagues in healthcare with a comprehensive understanding of the current trend of AI developments in the field of 3D imaging in dental medicine.

Keywords: Artificial Intelligence; DMFR(Dento maxillofacial radiology);facial scanning.

INTRODUCTION

Radiologists are primarily known for their image interpretation skills [1]. Advanced breakthroughs in image recognition introduced by deep learning techniques, and media statements by researchers have portrayed artificial intelligence as the cause of demise of radiologists. However, the complex work performed by radiologists includes many other tasks that require common sense and general intelligence for problem solving tasks that cannot be achieved through AI. Understanding a case requires multiple basic medical and clinical specialties to provide plausible explanations for imaging findings. Also, advanced imaging modalities necessitate specialized intelligence for detection of anomalies, segmentation, and image classification[2]. Artificial intelligence (AI) is a technology, which has shifted from science fable into reality in the radiology practice in the last two decades. Allan Turner one of the founders of AI defined it as the ability to achieve human-level performance in cognitive tasks by computers. Implementation of AI in radiology is anticipated to significantly revolutionize the quality, value, and depth of radiology's contribution to patient care and population health, and radiologists work flow in next decade [3]. This makes it imperative that a radiologist be aware of AI and its applications in their field. This mini review provides an insight to the various concepts and terminologies used in AI from a dent-maxillofacial radiology perspective.

HISTORY

The term "artificial intelligence" (AI) was coined in the 1950s and refers to the idea of building machines that are capable of performing tasks that are normally performed by humans. Machine learning (ML) is a subfield of AI, in which algorithms are applied to learn the intrinsic statistical patterns and structures in data, which allows for predictions of unseen data . A popular type of ML model are neural networks (NNs), which outperform more classical ML algorithms in particular on complex data structures such as imagery or language. AI is a branch of computer science dedicated to the development of computer algorithms to accomplish tasks traditionally associated with human intelligence, such as the ability to learn and solve problems . This includes machine learning (ML), representation learning and deep learning[4,6].

PARTS OF ARTIFICIAL INTELLIGENCE

Machine learning (ML) : Is a part of research on AI that seeks to provide knowledge to computers through data and observations without being explicitly programmed. This allows a computer to correctly generalize a setting by tuning of parameters within the algorithm to optimize the goodness of fit between the input (i.e, text, image, or video data fed into the algorithm) and output (ie, classification). For example, for a ML algorithm can detect a lymph node in head and neck image as normal or abnormal provided it is trained Radiologist by analyzing thousands of such images which are labeled as normal or abnormal . To sum it up ML algorithms are trained to give a specific answer by evaluating or learning a large number of exams that have been hand-labeled[4,8].

Representation learning: Is a sub type of ML in which the computer algorithm learns the features required to classify the provided data.This does not require a hand labeled data like ML[7].

Deep learning : Is a sub field of representation learning relying on multiple processing layers (hence, deep) to learn representations of data with multiple layers of abstraction. This algorithm uses multiple layers to detect simple features like line, edge and texture to complex shapes, lesions, or whole organs in a hierarchical structure. Basis of any radiologic interpretation is logical elimination of possible diagnosis. In this context, deep learning can potentially excel by learning a hierarchical normal representation of a specific type of image from a large number of normal exams[9]. Clinical decision-support systems (CDSSs) AI programs that are designed to provide expert support for health professionals are known as CDSS. They are designed to support healthcare workers in their everyday duties, assisting with tasks that rely on the manipulation of data and knowledge. These systems include Artificial neural networks (ANNs), fuzzy expert systems, evolutionary computation and hybrid intelligent systems. Each AI technique has its own strengths and weaknesses. Neural networks are mainly concerned with learning, fuzzy logic with imprecision and evolutionary computation with search and optimization [10,5,9].

Artificial neural networks (ANNs) : Are the most popular AI analytic tool in used for image analysis inspired by the biological nervous system [1,10.] This involves a networks of highly interconnected computer processors that has the ability to learn from past examples, analyse non-linear data, handle imprecise information and generalise enabling application of the model to independent data has making it a very attractive analytical tool in the field of medicine [1]. ANNs have been used to interpret plain radiographs, ultrasound, CT, MRI, and radioisotope scans[8].

Fuzzy logic :Is the science of reasoning, thinking and inference that recognizes that everything is a matter of degree of shades of grey rather than conventional white and black. It has the ability to recognize that most things would fall somewhere in between with varying shades of grey. This data handling methodology that permits ambiguity and hence is particularly suited to medical applications. They have been used to characterize ultrasound images of the breast, ultrasound and CT scan images of liver lesions and MRI images of brain tumors [1].

Evolutionary computation :Are a class of stochastic search and optimization algorithms based on natural biological evolution. The most widely used form of it being used for 'genetic algorithms'. It has better application in medical field where they work by creating many random solutions to the problem at hand. Commonly used in computerized analysis of mammographic micro calcification, MRI segmentation of brain tumors to measure the efficacy of treatment strategies and for analyzing computerized 2-D images to diagnose malignant melanomas [1].

Hybrid intelligent systems: Has the advantages of all the above technologies combined together to work in a complementary manner. The synergistic system allows to accommodate common sense, extract knowledge from raw data, use human-like reasoning mechanisms, deal with uncertainty and imprecision, and learn to adapt to a rapidly changing and unknown environment. There are various hybrid systems available, the popular ones being ANNs for designing fuzzy systems, fuzzy systems for designing ANNs, and Genetic Algorithms for automatically training and generating neural network architectures.

APPLICATIONS

Adapting of AI in maxillofacial radiology its clinical applications can be divided into 3 types

1. Clinical workflow,
2. Types of applications
3. Classes of use cases.

Clinical workflow these are the diagnostic tests inserted in existing clinical pathways. For example, when a patient requires a diagnostic imaging, radiologist is the one who decides the image selection and other protocols. Alternatively, AI applications can be applied using various scenarios to reduce the radiologist burden. Different scenarios used in clinical work flow are triage, replacement and add-on which are based on the conceptual frame work developed by Bossuyt., et al [11]. Triage scenario adapted from is used as a screening tool to sort examinations based on the probability of disease being positive or negative according to AI. For example, AI will assess the not interpreted x-rays for highest probability of disease determined by an algorithm according to the content of images or other data available and determine which examination should be interpreted first. Replacement scenario, AI may replace radiologists if results are consistently more accurate, rapid, reproducible, and easier to obtain. Most common application of it being estimation of bone age by an AI software. AI is found to consistently provide better performance than a radiologist in bone age estimation. Add-on scenario may use AI in a subgroup of patients where the existing clinical pathway is dependent on the radiologist interpretation.

Types of application

This can be divided into :

1.Detection: To identify an anomaly within an image (eg, a nodule);

2.Segmentation: To isolate a structure from the remainder of the study (eg, defining the boundary of an organ); and
3.Classification: To assign an image or lesion within an image is assigned to a category (eg, is presence or absence of pulmonary embolism on a CT scan).

USES

1.For workflow optimization and quality assurance: AI can detect minor changes in the images saving the observers time and also can help by retrieving previous data of the patient or finding similar findings in other images providing a list of possibilities.
2.Grading and classification of images: The ACR Reporting and Data Systems (RADS) provide assessment structure and classification for reporting in patient imaging [12].
3.Radiomics process extracts a large number of quantitative features from medical images. Though t can potentially be applied to any medical condition, it is currently applied mostly in quantification of tumor phenotype and development of decision support tools in oncology [13].
4.Natural language processing (NLP): NLP is commonly defined as the conversion of unstructured text into a structured form to allow for the automated extraction of information, synonymous with text mining or information extraction. AI analyses the large amount of unstructured information in full-text radiology reports to extract potentially invaluable source of information for clinical care quality improvement and research, which would have been a challenge otherwise due varied and individual reporting styles of narrative reports [1,14].

Applications in maxillofacial radiology

Following aspect of the dent-maxillofacial radiology has been researched with respect to AI.
1. Interpretation of radio graphic lesions and automated interpretation of dental radiographs [10.]
2. Using the radiologists work as data, AI may enable programs to identify details of individual radiologists' practice pattern and categorizing them to create a sophisticated radiology report card [1].
3. Caries detection: Logicon Caries Detector™ program (Logicon Inc., USA) is designed to assist dentists in the detection and characterization of proximal caries [16].
4. Diagnosis of vertical root fractures on CBCT images of endodontically treated and intact teeth[17].
5. To stage tooth development [18].
6. Computer based digital subtraction imaging [19]
7. Computer-assisted image analysis is useful to visualize and evaluate the bone architecture directly from the dental panoramic radiograph.
8. 3 dimensional orthodontics visualisation using patient models and OPGs [21]
9. Bone density evaluation to predict osteo porosis using OPGS [20]
10. Automatic segmentation of mandibular canal [22]Gerlach reported accuracy of automatic segmentation of the mandibular canal by the AAM and ASM methods is inadequate for use in clinical practice.
11. Forensic dental imaging: Personal Identification System Using Dental Panoramic Radiograph based on Meta_Heuristic Algorithm reported to have 97.7% precision [23]
12. Dental biometrics [24.]

ADVANTAGES

1.It is a powerful tool to identify patterns, predict behaviour or events, or categorize objects [1].
2.Improve radiology departmental workflow through precision scheduling, identify patients most at risk of missing appointments, and empower individually tailored exam protocols [1].
3.Machine Learning directly with medical data can help in preventing the errors due to cognitive bias [25].

DISADVANTAGES

Requires a very huge and sound data base of knowledge, if not may result in inappropriate answers when presented with images outside of their knowledge set [26,27]. For example, when image techniques not appropriate or if there are any artefacts may result in faulty interpretation of image. May not adapt with new imaging software or new machine immediately .Not all the algorithms used are apt for clinical application [22]. More trials to recommend the apt analytic programmes for different scenario.

THE CHANCES OF AI IN MEDICINE AND DENTISTRY

There has been a significant uptake of these technologies in medicine, too, so far mainly in the field of computer vision. A number of drivers for this uptake have been identified (Naylor 2018): 1) Diagnostic imaging is central in many healthcare fields, with AI being especially suitable to overcome the variability in subjective individual examination and to increase the effectiveness of care while lowering costs by eliminating routine tasks. 2) Digital health data are ubiquitously co while so far these data are rather heterogeneous, organizations are increasingly striving to provide cleaned, curated, and structured data. 3) AI allows to integrate different and heterogeneous data domains, for example, medical/dental history, sociodemographic and clinical data, imagery data, bio molecular data, social network data, etc., thereby making the best use of these multi-level data and allowing to grasp their interaction. 4) AI facilitates research and discovery, by adding in silico experimentation options to conventional research hierarchies, complementing other research levels and existing modeling strategies. 5) As discussed, AI may streamline routine work and increase the face-to-face time doctors/dentists and their patients have (“humanizing care”). This may not only come via diagnostic assistance systems, but voice, speech, and text recognition and translation, enabling doctors/dentists to reduce time for record keeping (Israni and Verghese 2019). 6) AI also promises to make healthcare more participatory, especially if patients provide their data actively, for example using wearable, etc. Patients will be empowered by self-monitoring and self-management. 7) Using these continuously collected data may also overcome the disadvantages of “on-off-medicine” (Topol 2019), where patients are seen only for a few minutes, while most health conditions are usually acquired over years, and come and go in (oftentimes escalating) intervals (e.g., periodontal disease). Continuous non-invasive monitoring of health and behavior will enable a much deeper, individual understanding of the drivers and processes underlying health and disease. 8) Diagnostic and treatment costs may be decreased, thereby relieving healthcare systems burdened by an ageing society with an increasingly high numbers of complex, chronically ill cases. AI may also help to address shortages in workforce, as observed and expected to continue in many parts of the globe, thereby supporting to reach the World Health Organization (WHO)’s Sustainable Development Goals.[15]

FUTURE DIRECTION

1. Radiologists should be familiar with AI terminology and hierarchy. [15]

2. Radiology programs should begin to integrate health informatics, computer science and statistics courses in their curriculum.[15]

3.To train the radiologist for logic, statistics, and data science and be aware of other sources of information such as genomics and biometric, insofar as they can integrate data from disparate sources with a patient’s clinical condition.[15]

4. Radiologists should understand the challenges related to preparation of training datasets for supervised learning.[15]

THE CHALLENGES AND WAY FORWARD

Despite all the potential, AI solutions have not by large entered routine medical practice. In dentistry, for example, convolutional NNs have only been adopted in research settings from 2015 onwards, mainly on dental radiographs, and the first applications involving these technologies are now entering the clinical arena (Schwendicke et al. 2019). This is all the more surprising when acknowledging that dentistry is especially suited to apply AI tasks: 1) In dentistry, imagery plays an important role and is at the cornerstone of most patients’ dental voyage, from screening to treatment planning and conduct. 2) Dentistry regularly uses different imagery materials from the same anatomical region of the same individual, regularly accompanied by non-imagery data like clinical records and general and dental history data, including systemic conditions, and medications. Moreover, data are often collected over multiple time points. AI is suited to integrate and cross-link the data effectively and improve diagnostics, prediction, and decision-making. 3) Many dental conditions (caries, apical lesions, periodontal bone loss) are relatively prevalent. Building up datasets with a high number of "affected" cases can be managed with limited efforts.[15]

We see three main reasons why dentistry has not yet fully adopted AI technologies. Tackling these reasons will help to make dental AI technologies better and facilitate their uptake in clinical care.First, medical and dental data are not as available and accessible as other data, due to data protection concerns and organizational hurdles. Data are often locked within segregated, individualized, and limitedly interoperable systems. Datasets lack structure and are often relatively small, at least when compared with other datasets in the AI realm. Data on each patient are complex, multi-dimensional, and sensitive, with limited options for triangulating or validating them. Medical and dental data, for example from electronic medical records, show low variable completeness, with data often missing systematically and not at random. Sampling often leads to selection bias, with either overly sick (e.g., hospital data), overly healthy (e.g., data collected by wearable devices), or overly affluent (e.g., data from those who afford dental care in countries lacking universal healthcare coverage) individuals being over represented. AI applications developed on such data will be inherently biased (Gianfrancesco et al. 2018).Second, processing data, and measuring and validating results is oftentimes insufficiently replicable and robust in dental AI research (Schwendicke et al. 2019). It remains unclear how datasets were selected, curated, and preprocessed. Data is oftentimes used for both training and testing, leading to "data snooping bias" (Gianfrancesco et al. 2018; England and Cheng 2019). It is usually not possible to define a "hard" gold standard and there is no agreement on how many experts are required to label a data point and how to merge different labels of such "fuzzy" gold standards (Walsh 2018).Third, the outcomes of AI in dentistry are often not readily applicable: The single information provided by most of today's dental AI applications will only partially inform the required and complex decision-making in clinical care (Maddox et al. 2019). Moreover, questions toward responsibilities and transparency

CONCLUSION

Integration of artificial intelligence eases the radiologist's job rather than take it away. If artificial intelligence becomes adept at screening for diseases in images, it could screen populations faster than radiologists and at a fraction of cost. The radiologist could ensure that images are of sufficient quality and that artificial intelligence is yielding neither too many false-positive nor too many false negative results. Economically it could translate into better patient care specially in developing countries hampered by access to specialists. A single specialist, with the help of artificial intelligence, could potentially manage screening for a large population at reduced time and cost.

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