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Review Article

Artificial intelligence: a key to relieve China's insufficient and unequally-distributed medical resources

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Abstract: In this manuscript, we firstly reviewed the challenges faced by China in its health care reform. Though Chinese governments have made tremendous efforts, problems like the difficulties and high expense in medical care and the nervous doctor-patient relationship have been reported a lot, whose key problem is the insufficiency of high-quality medical resource and the supply-demand imbalance. Presently, it's almost old news: artificial intelligence will overturn the existing medical model. Artificial intelligence technology will transform the medical sector and trigger an estimated $147 billion market during the next 20 years. We hereby pointed out the strengths of medical artificial intelligence and its potentials to relieve China's insufficient and unequally-distributed medical resources. Also, we analyzed China's advantages in developing medical AI due to its huge medical big data and China government's powerful promotion policy. Finally, we put forward some challenges for China to practice this.

Keywords: Artificial intelligence, China, medical reform

Status of china's challenging health care reform

China has made painstaking efforts to improve the medical care standards for its 13 billion population. It is of vital importance to search for the better ways to gradually increase and make full use of limited medical resources. Though Chinese governments at all levels have made tremendous efforts, the systematic health reform remains challenging. Problems like the difficulties and high expense in medical care and the nervous doctor-patient relationship have been reported a lot, whose key problem is the insufficiency of high-quality medical resource and the supply-demand imbalance.

Table 1. AI solutions to healthcare landscape

Items	Speech Recognition	Image Recognition	Natural Language Processing	Data Mining	Robotics
Electronic Medical Record	Medical Speech Recognition and Document		Structured Reporting, EMR Classification	Clinical Knowledge Minding, Similarity Analysis	
Medical Image Diagnosis		Medical Image Registration, Segmentation		Medical Image Classification	
Medical Decision Making	Speech Knowledge Machine Learning	Medical Imaging Machine Learning	Medical Knowledge Machine Learning	Treatment Recommendation, Decision Making	
Medical Robot					Surgical Robot, Guide Robot
Drug Discovery				Virtual Screening, Lead Optimization	
Precision Medicine				Genomics Data Mining	
Mobile Device		Mobile Phone and Wearables		Personal Health Care	

Table 2. Types of machine learning algorithms in AI solutions

Items	Supervised Learning		Unsupervised Learning		Semi-supervised Learning	
Methods	Neural Network	Other	Neural Network	Other	Reinforcement Learning	Transfer Learning
Features	With labels		Without labels		Trial and Error	Domain Adaptation
Applications	Classification	Regression	Clustering	Dimensionality Reduction	Decision Making	Pre-training, Fine-tuning
Algorithms	Deep Learning	Logistic Regression	K-means	Representation Learning	Deep Reinforcement Learning	Inductive Transfer Learning
Examples	Diabetic Retinopathy Diagnosis [1]	Transcription Factors Analysis [2]	Disease and Patient Categorization [3]	Morphological Phenotypes [4]	Drug Development [5]	Radiology Image Classification [6]

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For patients, Chinese hospitals are becoming battlegrounds and doctors become the target of criticism. Chinese medical workers are often attacked or even killed by patients and their relatives. The reasons are known to all: long wait time and short appointment time, high care cost, and widespread lacks trust in hospitals and doctors. Though hospital violence in big cities has received great attentions, it is still severe in small and local hospitals. On the other hand, for doctors, their workloads increased a lot along with the new two-child policy and Chinese population ageing. A Chinese doctor often sees more than fifty patients every day in outpatient clinics. Some young Chinese physicians have been reported to die due to being overworked. Violence against doctors makes the doctors' working environments severely deteriorate in the past 20 years [1]. Due to the overload situation and poor working environments, numerous Chinese medical students and young doctors weakened enthusiasm and regretted choosing to learn medicine [2]. Every year, around six hundred thousand medical students graduate in China, but only one-sixth of them are finally engaged in medical profession.

Though China has tried to establish its community general practitioner (GP) system, multiple challenges still exist: (1) The teaching and training face the problem of imbalanced development across the nation; (2) Because of GP's limited career opportunities, low social status, and low salary, the lack of students is increasingly apparent [3]. Worrying vocational outlooks, poor occupation recognition and working conditions, contributed as well. Thus currently, qualified GPs are still in great shortage and the differences of academic and professional qualities between specialists and GPs are big. Consequently, patients worry about GPs' care quality and would not love to see doctors in county hospitals [3]. Chinese reforms on its medical health system are at the crossroad. It's urgently for China to enact detailed protocols, find effective strategies, and adopt new science and technologies, to break through the bottleneck of optimizing the medical resource allocation.

Overview of artificial intelligence in medical field

Presently, it's almost old news: artificial intelligence will overturn the existing medical model. In many fields, machine learning, or artificial intelligence has been widely indispensable to solve complex problems. Artificial intelligence technology will transform the medical sector and trigger an estimated $147 billion market during the next 20 years. It will definitely open numerous new possibilities in the medical field. It has already been with human's grasp for many previously unimaginable plans to apply artificial intelligence to medical practice. Based on calculating predictive powers of variables, accommodating various raw-data configurations, and assigning context weightings, artificial intelligence algorithms could provide valuable prognostic information and diagnostic information.

Typical AI solutions to healthcare landscape are demonstrated in **Table 1**. In this table, the horizontal axis shows common technologies in AI, the vertical axis shows typical healthcare landscapes, thus the intersection represents the promising solution to the healthcare landscape with the AI technology. For example, electronica medical records can be generated from users' speech via speech recognition technology, which can save much time for doctors.

As shown in **Table 2**, the types of machine learning algorithms in AI solutions can be divided into supervised learning, unsupervised leaning, and semi-supervised learning (reinforcement learning and transfer learning), which can be implemented via neural networks (eg: deep learning), decision trees, Bayes methods and so on. These methods can be used for classification, regression, clustering and dimensionality reduction, and so on. Typical examples have also been shown in this table, for example diabetic retinopathy diagnosis, radiology image classification and so on. In supervised-learning, the computers are given a data set for each entity of interest, and a "label" that indicates how the object or event should be classified. In unsupervised-learning, the computers are given a data set for each entity, but no labels. The algorithms group together similar entities, considering the similarity in their individual features. The artificial intelligence applications in medical and hygienical fields are groundbreaking, especially for medical image fields, in which, many new image features detected by algorithms have been found to be related to diagnoses or prognoses. In China, the typical application scenarios of artificial intelligence in

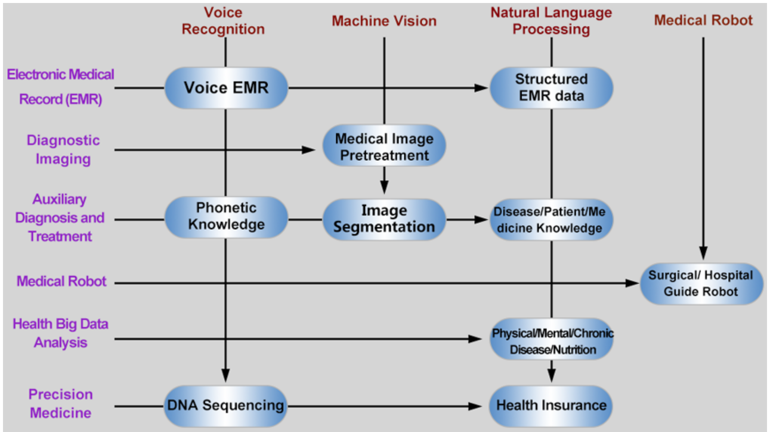

Figure 1. Some application scenarios for medical AI in China.

primary health care lies in taking advantage of the assistance of AI to help most grass-roots doctors reach the standard of at least moderately experienced experts, thus consequently more patients would accept the hierarchical medical system. Some application scenarios for medical AI are listed in **Figure 1**.

Artificial intelligence applications in improving China's public health service

How artificial intelligence help with improving China's medical service level? In short, prime applications include clinical decision support, patient monitoring and guidance, surgery assistance with automated devices, healthcare systems management.

Diagnostics

First, artificial intelligence will improve diagnostic accuracy. For instance, arrhythmia detection from electrocardiogram (ECG) recordings is usually performed by expert technicians and cardiologists given the high error rates of computerized interpretation. Rajpurkar et al. recently develop an algorithm whose performances were better than the board-certified cardiological doctors in detecting diverse types of cardiac arrhythmias from ECGs. They established a data set with over 500 times the number of individuals with arrhythmias than previous data sets studied. Upon this dataset, a convolutional neural network (CNN) with 34 layers was trained to accordingly map ECG samples. Committees of board-certified cardiologists annotated a gold standard test set. In precision and sensitivity, the algorithm's performance exceeded the average level of 6 other certified cardiologists. Recently, Acharya et al. developed a convolutional neural network (CNN) technique to automatically detect the different ECG segments. Their algorithm consists of an eleven-layer deep CNN with the output layer of four neurons, each representing the normal (N-sr), A(fib), A(fl), and V-fib ECG class. In this work, they used ECG signals of 2 seconds and 5 seconds' durations without QRS detection. They achieved an accuracy, sensitivity, and specificity of 92.50%, 98.09% and 93.13% respectively for 2 seconds of ECG segments. They obtained an accuracy of 94.90%, the sensitivity of 99.13%, and specificity of 81.44% for five seconds of ECG duration [4]. As for another strength for developing medical artificial intelligence products, physicians' common optimism bias could be avoided greatly. As known, doctors generally tend to arrange certain patients' problems into specific disciplines to which the doctors belong. Imagine an intelligent system where patients firstly fill out questionnaires on the basis of big data obtained from previously diagnosed patients. Envision how useful this kind of system could become in rural areas with few doctors of rich experience.

Saving and optimizing medical resources

Second, machine learning will extend the reach of doctors of the hospitals and provide low-cost universal access to qualified health care. In Emanuel and Obermeyer's words, "machine learning will displace much of the work of radiologists and anatomical pathologists". It would save us lots of routine medical work. Artificial intelligence in medical-image field has increasingly played pivotal roles in content-based image retrievals, image annotations, image-guided therapies, image fusions, image registrations, image segmentations, and computer-aided diagnoses [5]. Doctors in these fields focus largely on interpreting digitized images, and further feed these annotated data to computers. Along with the development of computer visions, this kind of data utilization method will sure to promote rapid improvements in the performances for diagnosing and prognosis-prediction, whose precision will soon exceed that of average doctors [6]. Even more exciting is the finding that in some cases, computers seem to be able to "see" patterns that are beyond human perception. In the black box, pathophysiological and biological mechanisms underlying the processes of diagnosis and treatment are not clear nor important [7]. For instance, as one of the commonest human malignancies, skin cancers are mainly diagnosed visually, commonly starting with initial clinical screenings. Recently, Esteva et al. trained a CNN to help diagnose skin cancers by virtue of a data set with 129,450 skin images. Their CNN achieves performance on par with all tested experts across 2 tasks (keratinocyte carcinomas versus benign seborrheic keratoses; and malignant melanomas versus benign nevi), demonstrating a machine learning algorithm able to classify skin cancers with a level of competence comparable to dermatologists [8]. The authors commented that "Outfitted with deep neural networks, mobile devices can potentially extend the reach of dermatologists outside of the clinic, thus potentially providing low-cost universal access to vital diagnostic care" [8].

Disease screening and prognosis prediction

Third, artificial intelligence helps with disease screening and predicting disease progression [9]. For instance, an acromegaly diagnosis should be considered in individuals presenting with certain typical clinical features of growth-hormone excess, including the enlargement of jaw, nose, zygomatic-arch, frontal-bone, feet, and hands, etc [10]. People with these features are recommended to go to the hospital to undergo biochemical testing to confirm the clinical diagnosis, followed by radiologic testing to determine the cause of the excess growth hormone secretion. Therapeutic strategies, like trans-sphenoidal surgery, medical therapy, and radiation therapy, will be based on the concrete conditions [11]. The most demanding thing for predicting disease progression or suspecting a disease diagnosis is find key risks factors, typical syndromes and signs, and the weights of them. Currently, this process depends mainly on doctors' experience accumulation. They generally put forward a certain hypothesis and spend long time collecting related data, and finally get a conclusion through the statistical analysis of the data. From the perspectives of artificial intelligence, the main application scenarios in disease screening or disease progression prediction lie in utilize different classification algorithms: (1) Automatic data mining from electronic medical records, laboratory testing reports, imaging materials, life-style data, and social media data, etc.; (2) Building forecasting models to automatically predicting disease possibility. As for acromegaly mentioned above, in our unpublished study, developed an automatic and handy diagnosis system for acromegaly, which can allow patients and doctors to track face changes proactively and detect acromegaly earlier and automatically, thus to facilitate cures and increase the likelihood of preventing irreversible complications of excessive secretion of growth hormone. The best result of our proposed methods showed a positive predictive value (PPV) of 96%, a negative predictive value (NPV) of 95%, a sensitivity of 96% and a specificity of 96%. This scalable and rapid algorithm is deployable on mobile phones and holds strong potentials for substantial clinical impact, which include extending the scopes of primary care practices, and augmenting clinical decision-making for neuroendocrinologists in real-world and clinical settings.

Facilitating electronic medical record

Voice electronic medical record systems will greatly improve the traditional outpatient medical records and help doctors save a lot of time [12]. From the survey done recently by the famous medical professional website 'Ding-Xiang-Yuan', it was shown that for most Chinese doctors, time spent on the medical records was more than four hours, sometimes even more than seven hours. Some residents even said that because they must spend much time on medical records, only little time was left to communicate with patients and check their conditions. Recently, voice electronic medical record systems developed by some companies (iFly-Tek and etc) were put into use by some hospitals (CAMS&PUMC and etc) in China. This has many benefits: for hospital, the scientific management of the diagnosis and treatment process will help accumulate and reuse the medical data; for doctors, medical records can be completed efficiently and accurately at the same time with the diagnosis and treatment, with the recognition accuracy of more than 95%; and for patients, they are able to get the complete and clear records timely by printing the documents converted from voice electronic medical records. There is a trend that these voice medical records systems will be used by many other hospitals soon, thus will facilitate more and more doctors and patients.

Drug discovery and repurposing

Recent advances in machine learning have made significant contributions to drug discovery. Deep neural networks in particular have been demonstrated to provide significant boosts in predictive power when inferring the properties and activities of small-molecule compounds [13]. Recently, Altae et al. demonstrated how one-shot learning can be used to significantly lower the amounts of data required to make meaningful predictions in drug discovery applications. They introduced a new architecture, the iterative refinement long short-term memory, that, when combined with graph convolutional neural networks, significantly improved learning of meaningful distance metrics over small-molecules [14]. In addition, using deep generative adversarial networks (GANs), an emerging technology in drug discovery and biomarker development, Kadurin et al. demonstrated a proof-of-concept of implementing deep generative adversarial autoencoder (AAE) to identify new molecular fingerprints with predefined anticancer properties [14]. Aliper et al. trained deep neural networks (DNN) on large transcriptional response data sets to classify various drugs to therapeutic categories solely based on their transcriptional profiles, which is another proof of principle for applying artificial intelligence to drug discovery and development.

Drug discovery and evaluation is expensive, time-consuming, and risky; computational approaches and various prediction algorithms can help reduce risks and save resources. One of the important tasks in drug discovery is identifying interactions between known drugs and targets. Targets (proteins) often have one or more binding sites with substrates or regulatory molecules; these can be used for building prediction models [15]. However, including other protein sites could bring bias into the analysis. Nowadays, many in silico approaches have also been proposed to identify new drug-target interaction. To accurately predict new drug-target interactions between approved drugs and targets without separating the targets into different classes, Chinese scholars Wen et al. developed a deep-learning-based algorithmic framework named DeepDTIs [16]. It first abstracts representations from raw input descriptors using unsupervised pretraining and then applies known label pairs of interaction to build a classification model. Compared with other methods, it is found that DeepDTIs reaches or outperforms other state-of-the-art methods. The DeepDTIs can be further used to predict whether a new drug targets to some existing targets or whether a new target interacts with some existing drugs [16].

Data types for artificial intelligence development

The ability to work with multiplatform data is a major advantage of deep learning algorithms. Since biological systems are complex, with multiple interrelated elements, the systems level integration of multiplatform data is key to extracting the most valid, biologically meaningful results. The integration process is not computationally trivial, but the payoff is a gain in biomarker specificity and sensitivity over single-source approaches [15].

Generally, three types of medical data are the cornerstone of medical artificial intelligence development-clinical data mainly generated in hospitals, genetic data currently mainly for cancer patients, and big health data (from healthy physical examinations, mobile wearable medical devices, etc.). China has obvious advantages to develop artificial intelligence in the medical filed compared with other countries. China has the largest population in the world and can make great contribution to big data in this regard. Chinese doctors are one of the busiest in the world and one doctor typically must see at least 50 patients per day on average, so clinicians have rich resources for data accumulation. The electronic medical record system has already been used in nearly all hospitals in China. The information of laboratory findings, demographics, imaging studies and follow-up results as well as economic information with large sample sizes can be easily extracted. Seizing these opportunities and advantages to improve research and health care decision-making is sure to directly help promote the development and wildly applications of medical artificial intelligence, thus greatly relieving China's insufficient and unequally-distributed medical resources.

Support of the Chinese government

The era of AI is inevitable and has already been broadly applied to the healthcare area in China. The government has been encouraging the application of medical big data since 2015 as well as rolling out policies dealing with artificial intelligence development in the healthcare industry. The Ministry of Science and Technology, and the National Health and Family Planning Commission launched a blueprint to support medical innovation during the 13th Five-Year Plan (2016-2020). This involved guidelines on research in techniques in bioscience, precision medicine and medical artificial intelligence. During the two sessions in 2017, artificial intelligence has been written into the Central People's Government work report. Chinese government strongly supports the development of artificial intelligence in medicine. In April 2017, CAMS&PUMC and iFLYTEK Co., Ltd. signed a strategic cooperation framework agreement on the first floor of the new Teaching and Scientific Research Building. The two sides announced that they would jointly build an Artificial Intelligence Platform in Medicine, and jointly push forward the application of artificial intelligence in basic medical research and clinical medicine. China State Council recently issued a new generation of artificial intelligence development planning, presented for 2030 China's new generation of artificial intelligence development of the guiding ideology, strategic objectives, tasks and safeguard measures, the deployment of China's artificial intelligence to build the first-mover advantage, accelerate the construction of innovative countries and the world's science and technology power.

Commercial layout of AI-tech companies

With the rapid development in artificial intelligence, especially voice interaction, computer vision and cognitive computing, more and more companies have settled the purpose to improve healthcare with the help of artificial intelligence. Last year, there were 144 Chinese AI companies involved in the medical sector. The majority of them were based in Beijing, Guangdong and the Yangtze River Delta. Here, we collected some representative Chinese companies currently on the market ranging from start-ups to tech giants to keep an eye on in the future. (1) In voice medical record, iFLYTEK and Unisound Co., Ltd have been working to integrate voice recognition technology in medical area, and many hospitals nationwide have tested this service wherein doctors can use voice input instead of typing words to save a medical record thus can quicken the process of diagnosis. (2) In medical imaging, tech giants such as iFLYTEK, Neusoft, Alibaba and etc have recruited some groups for medical product research and development; Besides, this area has also attracted many innovative AI-start-ups, for example Yasen, JianPei, HuiyiHuiying, Deepcare, Tuixiang and etc. (3) In disease diagnosis and treatment, Lianxin and Diyingjia have achieved some progress. (4) In surgical robots, iFLYTEK have launched a service robot "Xiao Man", which integrated AIUI artificial intelligence technology to identify the registered customer and provide personalized recommendations in medical areas. Similar medical and service robots included Xiaopang developed by Evolver, and so on. (5) In personal health data analysis, Donghua, iFLYTEK and etc have launched some programs to develop big data analysis-based health care platforms for more accurate disease prediction and prevention.

Challenges for China's medical artificial intelligence development

Although China has already been a leader in several medical artificial intelligence segments with multiple research publications demonstrating achievement, there will be some primary problems in bringing artificial intelligence to the medical area in China.

Data heterogeneity

The major challenge is the intelligent exploitation of heterogeneous data [17]. The type, the provenance, and the structure of such data is becoming increasingly complex, as we must deal with social network data, clinical pathway data, genetic data, biomedical images and signals, temporal health and clinical data, demographic data, and biomolecular data. Many diseases or disorders do not have 1:1 translations into specific imaging patterns. Under the circumstances, the medical specialists are the integrators of images or other medical data related to the patients. The algorithms would give a list of best matches from imaging point of views, and then the specialists should discuss the different possibilities with the referring physicians [18].

Limited data sharing

Secondly, in the era of big data, the unlocked information and privacy protection for their own differences in nature have been a pair of natural contradiction, especially for patients' personal data gathered in the context of daily life. The possibility of misusing human health data and disease data is troubling [19]. As artificial intelligence is more and more involved in up-to-the-minute clinical practices, medical workers therefore have the heavy obligations to ensure that artificial intelligence or machine learning could be harnessed for the good of individuals and the society to fulfill the ethical basis. No matter at which phase of artificial intelligence applications and algorithm developments, privacy protection with ethical design thinking shall be always kept in mind. In light of this, doctors with sophistication and integrity are deserved to closely partner with computer scientists to anticipate the ethical implication and reimagine the clinical medicine [19].

Insufficient professional data talents

Thirdly, the lack of professional talents in big data and artificial intelligence in China is also a challenge. Only a few companies and talents master artificial intelligence technology. Even if they are proficient in data industry, few of them are familiar with the medical knowledge and thus are incapable of discovering key business intelligences with big data applications in the medical practice, to some extent limiting medical artificial intelligence's developments in China [20].

At present, AI is far away from widely practicing real clinical works including diagnoses and treatments. The clinical manifestations including symptoms and signs of a certain disease are quite complex. Symptoms are often narrated by patients themselves or their relatives, and signs are always obtained by doctors or medical instruments. All of them are difficult to quantify. Additionally, the progression of a certain disease is affected by so many factors. Some of the factors even could not be eventually found by experienced doctors. It is difficult for AI system to solve such issue without any causation. This is a very challenge for computer to do machine learning and deep learning. Moreover, in China, there is no uniform criterion for doing medical examinations, such as EEG, MR or CT, even pathological slices among the different hospitals. Many of the medical images will not provide objective and reliable information to AI system.

In closing, medical artificial intelligence must be given great impetus to and deeply pushed ahead with in China. The ultimate objective is to support care providers to reach the best possible decisions for any patient at the right time and thus relieve China's insufficient and unequally-distributed medical resources as much as possible.

Disclosure of conflict of interest

None.

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