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CHINA

AI HEALTHCARE





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PREFACE

DENMARK recently released the 'Danish Strategy for AI', which aims to support the ability of Danish business and industry to develop and offer world-class AI services to the domestic and international markets. Healthcare is one of the prioritized areas.

CHINA is also placing strategic focus on AI in healthcare. Primarily, as a means to solve its domestic problems related to the unbalanced distribution of healthcare resources and rise in non-communicable diseases. The municipal government in Shanghai plans to invest \$15 billion, more than many national governments, demonstrating the strong drive for innovation.

Against this background, it is clear that China is not only an attractive market for AI healthcare because of its market size, but also because of the vast amount of accessible health records, which can be used to develop advanced algorithms.

With two main reasons, this report is drafted to give Danish audience an in-depth analyse of each segments in AI healthcare in China, i.e. AI imaging, AI assisted diagnosis, AI disease prediction, AI health management and AI drug development. Firstly, we lack the specialised knowledge to help experts working in specific use-cases and different areas AI healthcare. Secondly, innovation and disruptive technology development in AI healthcare is largely driven by data. To access patient data for research and product development, identifying the right clinical partner and have close cooperation with hospitals is a must-have in China.



1 AI POLICY DEVELOPMENT

Since 2009, China's artificial intelligence (AI) policy has undergone five stages with changing keywords which indicate the different priorities in different stage. The focus shifts from basic research in such categories as Internet of Thing (IoT), information security and database in the early period, to big data and infrastructure in the middle period, to AI itself and also intellectual property protection after 2017. In general, China's AI policy mainly focuses on six categories: "made in China", innovation-driven development, IoT, Internet+, big data, and scientific and technological R&D.

In July 2015, State Council issued *Guiding Opinions on Vigorously Advancing the "Internet +" Action*, which for the first time prioritizes AI as one of the key tasks. *The 13th Five-Year National Science and Technology Innovation Plan* called for China to seize the "high ground" in international scientific development, launching a series of fifteen "Megaprojects for Science and Technology Innovation 2030" that both big data and intelligent manufacturing and robotics are included.

In July 2017, State Council propagated *Development Plan on the New Generation of Artificial Intelligence* which marks that AI became national strategy. As in November of the same year, the Ministry of Science and Technology convened a high-level meeting that marked the official launch of the plan, standing up the New Generation AI Development Plan Promotion Office. In support of the plan, the New Generation AI Strategic Advisory Commission was also created at that time, convening senior academicians and experts from prominent private sector players, including Baidu, Alibaba, Tencent, iFlytek, and Horizon Robotics. In December, Ministry of Industry and Information Technology propagated *Three-Year Action Plan for Bolstering the Development of the Next-Generation Artificial Intelligence Industry* in which built up the prior plan to concentrate with greater specificity on objectives that will support the development of a world-leading AI industry. The new plan recognized the importance of an AI industry "support system" to include a data resource base with standard test data sets, cloud-based training frameworks, and initial test and evaluation systems.

In April 2018, the General Office of the State Council issued *the Opinions on Promoting the Development of "Internet plus Health Care"* which primarily pertained to three aspects with the improvement of the "Internet plus health care" service system and its support system. A total of fourteen recommendations were made to encourage medical institutions to leverage the Internet and other information technologies to expand the scope and content of health care services, and to construct an integrated online and offline health care model covering the entire health care process. It also encouraged medical institutions to cooperate with Internet companies for strengthening the integration of regional medical and health information resources, with the use of big data to make epidemiological trend predictions and enhance the smart monitoring of contagious diseases. It also encouraged the development of AI-based clinical diagnosis and treatment decision support systems, the development of intelligent medical image recognition, pathological classification and multidisciplinary consultation as well as intelligent voice technology applications in a variety of medical scenarios for improving the efficiency of medical services. In the development of "internet plus" medical services, the development of Internet hospitals relying on medical institutions will be allowed. Medical institutions can use the internet hospital as the second name, and on the basis of the real hospital, allow some common diseases and chronic diseases to be visited online.

In September 2018, the National Health Commission (NHC) released *Measures for the Administration of Internet Diagnosis and Treatment (For Trial Implementation)*, *Measures for the Administration of Internet Hospital (For Trial Implementation)* and *Specifications for the Administration of Remote Medical Services (For Trial Implementation)*. Those documents clearly defined Internet diagnosis, which means medical institutions could ask their own registered doctors to provide "Internet plus" family doctor signing services for



some common diseases and follow up consultations for chronic diseases by using internet and other information technologies.

In order to better evaluate and standardize the digital services produced by hospitals, China implemented a smart medical service grading system for the development of "smart hospitals," on March 2019. A typical "smart hospital" features information-based service systems including a database of patients' medical records, a registration system, a hospital navigation system and a logistics management system. By introducing the grading system, hospitals will have a better idea about their advantages and shortcomings, giving them the ability to better allocate their resources in building themselves into "smart hospitals,"

In parallel to these efforts at the national level, cities throughout China have started to develop and release their own plans and policies for AI, including Beijing, Shanghai, Hangzhou, Zhejiang, and Tianjin etc. Notably, Beijing plans to build a 13.8 billion RMB (\$2.12 billion) AI development park that could host up to 400 AI enterprises. At the same time, Shanghai plans to establish a special fund, with a target size of 10 billion RMB in the first phase, to invest in AI development, and Hangzhou has launched its own AI park, along with a fund that will invest 10 billion RMB in it.



Table 1 Summary of healthcare AI relevant policies in China

2015.05 SC	Made in China 2025	<ul style="list-style-type: none"> Development of next generation information technology Smart manufacturing
2015.07 SC	Guiding Opinions on Vigorously Advancing the "Internet +" Action	Artificial Intelligence is one of the eleven key actions
2016.03 NPC	The Thirteen Five Year Plan for Economy and Social Development	Focusing on making breakthroughs in key big data and cloud computing technologies, independently controllable operating systems, high-end industrial software and large management software and artificial intelligence technologies for emergency areas
2016.05 NDRC	"Internet Plus" Artificial Intelligence Three-Year Action Implementation Plan	Promoting development of new generation artificial intelligence industry
2016.06 SC	Guiding Opinions on Promoting and Regulating the Application and Development of Big Data in Health and Medical Care	The application and development of big data in health and medical care shall be incorporated into the state strategic arrangement of big data
2016.08 SC	The 13th Five-Year National Science and Technology Innovation Plan	Launching a series of 15 "Science and Technology Innovation 2030 Megaprojects" that included both big data and intelligent manufacturing and robotics.
2016.09 NDRC/ MIIT	Special Action on the Innovative Development of Smart Manufacturing Software Industry (2016-2018)	Key developing areas including smart wearable devices, smart healthcare devices, smart service robotics, etc.
2017.01 NHFPC	"13th FYP" National Population Health Information Development Plan	By 2020, establish an integrated and shared population health information platform
2017.07 SC	Development Plan on the New Generation of Artificial Intelligence	<ul style="list-style-type: none"> Artificial intelligence became the national strategy Three-steps: ultimately by 2030, make the competitiveness of artificial intelligence industry reach the international advanced level, and make core industry scale of artificial intelligence be more than 1 Trillion yuan,
2017.12 MIIT	Three-Year Action Plan for Bolstering the Development of the Next-Generation Artificial Intelligence Industry (2018 - 2020)	Promote AI industry development and the merge of AI with real economy
2018.03 SC	Annual Government Work Report 2018	<ul style="list-style-type: none"> New generation artificial intelligence development and application Promote Internet plus initiatives in healthcare, elderly care etc.
2018.05 SC	Opinion on Promoting the Development of "Internet plus Health Care"	Promoting the development of "Internet plus health care", including improving the "Internet plus health care" service system and support system, strengthening the supervision and security in the industry.
2018.09 NHC	Specifications for the Administration of Remote Medical Services (For Trial Implementation)	Clearly defined internet diagnosis and how the internet diagnosis should be conducted
2018.09 NHC	Measures for the Administration of Internet Hospital (For Trial Implementation)	
2018.09 NHC	Measures for the Administration of Internet Diagnosis and Treatment (For Trial Implementation)	
2018.09 NHC	Administrative Measures on the Standards, Security and Service of National Health and Medical Big Data	Definition and regulatory rules of medical big data
2018.11 NHC	The Performance Indicators for Action Plan for Further Improving Medical Services (2018-2020)	Remote medicine is included as one of the indicator to evaluate medical services
2019.03 NHC	Hospital Smart Service Scoring System (For Trial Implementation)	Implemented a smart medical service grading system for the development of "smart hospitals"
2019.08 NHSA	Guiding Opinions on Improving the Policies of "Internet Plus" Medical Service Prices and Medical Insurance Payment	Include "Internet plus" medical service into current medical service pricing scheme

SC: State Council
NHC: National Health Commission
NPC: National People's Congress
NDRC: National Development and Reform Commission
MIIT: Ministry of Industry and Information Technology
NHSA: National Healthcare Security Administration



2 HEALTHCARE AI IN CHINA

In China, the growing aging population and the uneven distribution of medical resources opens great needs for AI in healthcare. At the same time, the big population number and the size of application market provide a good basis for developing AI technologies. AI plays an important role in many aspects of medical services, including clinical assistive decision, disease prediction, medical service, personalized treatment etc.

Different from many other developed countries, where family doctors serves as the gateway to specialist hospitals, China doesn't have hierarchical medical system, which means the patients can visit any hospital at any time they want. The flow of visiting a doctor in hospital in China could be illustrated as below. AI can target at each steps to provide solutions to improve the quality of healthcare service. The administration department also rely on AI to innovate the development of Chinese medical industry.

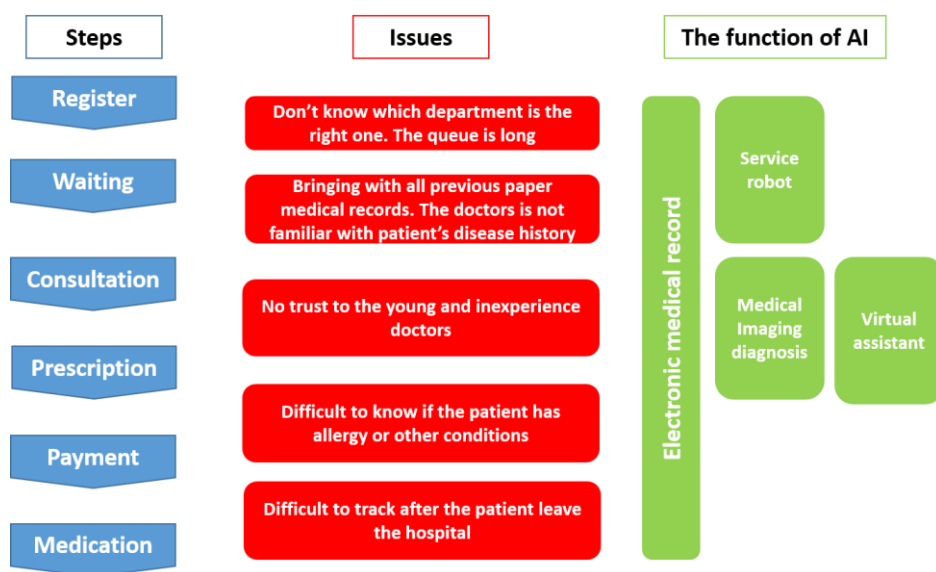


Fig. 1 The flow of visiting a doctor and the role of AI.

Chinese AI companies are highly concentrated in Beijing, Shanghai and Guangdong. Among the world's top 20 cities in terms of AI companies hosted, Beijing ranks first with 395 companies, and Shanghai, Shenzhen and Hangzhou are also among the top 20. China's AI companies mainly specialize in three categories—voice, vision and natural language processing—with only a small percentage focusing on basic hardware.

AI is transforming China's healthcare industry. Hospitals across the country have started adopting AI-assisted medical products and services that include not just image-assisted diagnosis, but also range from surgical robots to smart patient health monitoring and virtual medical assistants. New medical AI start-ups are emerging and traditional healthcare companies and leading technology firms are betting big on AI solutions.

China's healthcare AI boom is also strongly supported by the central government that aims for China to become the world's leading AI innovation center by 2030. The application of AI in healthcare is a priority as Chinese leaders look for ways to relieve the immense pressure that a rapidly urbanizing and aging population is putting on the country's healthcare system. The hope is that new AI-driven treatment methods can address doctor shortages, high misdiagnosis rates, inaccuracies in early disease prediction, and much more.



Based on the statistics in the *Bluebook of World Artificial Intelligence Industry 2018*, Chinese AI related companies focus on sectors including healthcare, finance, security, business, education etc., and the percentage of companies in healthcare sectors is 22%, which rank as top 1 among other sectors. The application areas of AI in healthcare sectors are mainly focusing on medical imaging, assisted diagnosis, drug development, health management and disease prediction.

2.1 AI medical imaging

AI could help radiologist analyse the medical images and design treatment programmes which are personalised to the patients. AI may have multiple applications in medical imaging, such as imaging acquisition, imaging processing, aided reporting, follow-up planning, data storage, etc.

AI medical imaging is one of the most common application of AI in healthcare industry in China. Currently, it is the second-largest market segment of AI medical applications in China and was predicted to grow at a growth rate of more than 40% and reach a scale of 2.5 billion US dollars in 2024. In addition, AI medical imaging in China is considered by industry insiders to be the first market to commercialize AI in the healthcare industry in China.

2.1.1 Painpoints

As one of the very important diagnostic procedure, medical imaging allows doctor to diagnose people more accurately without being intrusive. The painpoints of medical imaging field in China are

- Doctor's heavy workload in top-level hospitals. Take pulmonary nodule as an example, on average, a top-level hospital will receive about 200 patients for pulmonary nodule screening, and each patients will have 200 – 300 CT images. Each radiologist need to read 40,000 – 60,000 CT images. The overwork has affected the image interpreting quality and the diagnostic accuracy of radiologists.
- There is a huge gap in the number of professional doctors in medical imaging in China. The dataset of medical imaging increases 30% every year in China, which also account for 90% of digital data volume for a hospital. In contrast, the numbers of radiologist increase by only 4% a year.

Under such circumstance, AI technology is expected to improve the diagnostic accuracy while shortening the image reading time.

2.1.2 Application scenario

The application of AI in medical imaging include

1. CT/PET image reconstruction. AI has the potential to improve image quality, and reduce the radiation dose.
2. Read and analyze chest X-rays. AI can help doctors in medical images analysis for many disease screening, and improve work efficiency and diagnostic accuracy.
3. Eye diseases screening. AI could improve the diagnosis accuracy of Glaucoma, Diabetic retinopathy and age-related macular degeneration.
4. Brain MRI segmentation. Quantitative analysis of brain MRI is routine for many neurological diseases and conditions and relies on accurate segmentation of structures of interest. Deep learning-based segmentation approaches for brain MRI are gaining interest due to their self-learning and generalization ability over large amounts of data.



5. Intracranial hemorrhage detection. AI algorithm was able to accurately identify acute intracranial hemorrhage on head CT scans and even find some tiny hemorrhages that could be overlooked by radiologists.
6. Target volume delineation for radiotherapy. AI algorithm is able to provide accurate, fast, and automated contouring of primary tumor volumes on multiparametric MR images.
7. Bone fractures detection. AI would be capable to automatically detecting and classifying the bone fractures and avoid missed diagnosis.
8. Breast cancer diagnosis. AI could improve the accuracy in detecting breast cancer.
9. Bone-age analysis. Each doctor needs around 1-2 hours to make an analysis, and with AI, it will only need 15 – 30 min.

2.1.3 Advantages of development in China

The AI enterprises in United State cover a variety of fields in the medical care system, while in China, AI enterprises have been mostly working on medical imaging due to the rapid growth of clinical demands, the imbalanced distribution of high-quality healthcare resources and the lack of medical imaging doctors around the country. AI in medical imaging has become the most commonly used applications in China, because of several developing advantages of AI in the healthcare industry.

First, the medical imaging data is huge; more than 90% of the medical data comes from medical images. The picture data structure is simple, which is convenient for machine learning. It is estimated that the volume of medical data will reach 40 trillion gigabytes by 2020, 30 times that of 2010.

Another developing advantage of AI in China's healthcare industry is about the fast iteration of big data, and intelligent image diagnosis algorithm is relatively mature. In addition, medical imaging in China is strongly supported by national policies. The government has issued several policies to increase support for domestic medical imaging since 2013. In 2017, the total amount of financing in this field exceeded 1.7 billion RMB.

2.1.4 Current industrial status and key players

AI health market in China was about 20 billion RMB in 2018, a 53% increase over 2017, and investment in AI in the healthcare industry in China is ranked as No. 1 in the world.

With regard to application, the AI medical imaging products mainly applied to disease screening, with a focus on pulmonary nodule, diabetic retinopathy and stroke.

Pulmonary nodule screening

Lung cancer is the leading cause of cancer-related deaths in China, with over 690,000 lung cancer deaths estimated in 2018. Products for pulmonary nodule screening is, no doubt, the most mature among other AI powered medical products. By July 2018, there were over 20 companies in China claiming to have developed products in this area. For now, AI enabled lung cancer or pulmonary nodule screening system have been landed in many hospitals. However, all those initiatives focus on research cooperation with hospitals, since it is still under discussion how to charge AI enabled product or service. Below table lists some Chinese companies and their clinical partners in developing enabled lung diseases screening system.



Table 2 Chinese AI medical imaging companies

Company	Clinical partners for product development	Disease	Numbers of cooperated hospitals for product implementation	Examinations per day
Huiyihuiying	Own Developed	Lung cancer	480	45,000
Imsight	309 th Hospital, Shenzhen People's Hospital	Small pulmonary nodules	17	-
12Sigma	-	Lung cancer, pulmonary nodule	200	20,000
YiTu	Huxi Hospital, Wuhan Union Hospital, Zhejiang University affiliated No. 2 Hospital, Zhejinag People's Hospital, Shanghai Ninth People's Hospital	Lung cancer	100+	150 – 200/day/hospital
VoxelCloud	Ruijin Hospital, Shanghai Jiaotong University	Pulmonary nodule	12 hospitals and 5+ companies	
DianNei	Fudan University Affiliated Huadong Hospital, Shanghai Chest Hospital, Shanghai Pulmonary Hospital	Lung cancer	26	60/day/hospital
Dexhin	School of Medicine University of Pittsburgh, Tsinghua University, Olympus, 301 th Hospital, Beijing Union Hospital	Lung cancer assistive diagnosis	100+	10,000+

Diabetic retinopathy screening

Diabetic Retinopathy (DR) is the most common causes of vision loss in adults aged from 20 – 74. DR often dose not have early warning signs, so it can cause rapid vision loss. Screening is recognized as an important way of early identification of the eye with mild DR, which allows prompt intervention to prevent disease progression. However, due to the lack of eye doctors and low awareness, the screening rate is less than 10%. AI is expected to perform the primary screening, which can largely increase the early screening rate in China. Below table shows the leading companies in China developing AI enable DR screening system.

Table 3 Chinese AI companies developing DR screening system.

Company	Clinical partners for product development	Disease	Numbers of cooperated hospitals for product implementation	Examinations per day
VoxelCloud	NIH, Beijing Union Hospital, Ruijin Hospital,	Retina disease screening	100+	-
Jianpei	Wenzhou Medical University	Fundus image analysis	15	60/day/hospital
Dexhin	Tongren Hospital	Diabetic retinopathy	300+	2,000

Target volume delineation

Radiotherapy is one of the three most important cancer treatments (the other two are surgery and chemotherapy). Each patient has about 200 CT images, and doctor needs to mark the position of the tumour on every image. AI could help doctors delineate the target areas automatically, and then deliver the



treatment plan. The doctor only needs to give the final confirmation of the treatment plan. Currently in China, there are few companies focusing in target volume delineation, and two of them are listed in below table. In August 2019, Linking Med, an AI company focusing in radiation oncology, received Class III medical device license for its cloud-based product, which is of enormous importance as the first-of-its-kind license in China.

Table 4 Chinese AI companies developing radiotherapy planning system.

Company	Clinical partners for product development	Disease	Numbers of cooperated hospitals for product implementation	Examinations per day
Linking Med	Sichuan Cancer Hospital, Peking University Third Hospital,	Radiotherapy for head and neck cancer	50	200-300
Jianpei	Zhejiang University Affiliated No. 1 Hospital	Radiotherapy for chest tumors	5	20

Besides, products for bone-age assessment, breast cancer screening, cervical cancer screening etc., start to be landed in hospitals also. Some relevant companies are listed in below table.

Table 5 Chinese Companies focusing on other AI-enabled medical imaging solutions.

Company	Clinical partners for product development	Disease	Numbers of cooperated hospitals for product implementation	Examinations per day
12Sigma	-	Breast cancer and hyperplasia of mammary glands	-	-
YiTu	Zhejiang University Children's Hospital, Wuhan Union Hospital, Affiliated Children's Hospital of Capital Institute of Pediatrics	Bone-age assessment	102	50-100/day/hospital
YiTu	Shanghai Tumor Hospital, Beijing Hospital	Breast cancer	104	50-80/day/hospital
DianNei	Fudan University Affiliated Huadong Hospital, Shanghai Chest Hospital, Shanghai Pulmonary Hospital	Breast cancer	6	80
Jianpei	Guizhou People's Hospital	Bone-age assessment	37	50/hospital

2.2 AI assisted diagnosis

AI assisted diagnosis includes medical imaging, electronic medical records, medical service robots, virtual assistant. Medical imaging has been elaborated in above chapter, and in this chapter we will introduce other applications, i.e. electronic medical record and virtual assistant.

Electronic medical record

The traditional electronic medical record (EMR) system in China doesn't meet the needs of specialization of disease data, structuring of medical case data, and cannot provide clinical decision support based on



medical records. AI can use natural language processing technology to standardize and structure medical records and use speech recognition and speech synthesis to process large amounts of text entry.

Virtual assistant

Virtual assistant can provide real-time support to doctors. For example, patients need to know the necessary information about the disease when they go offline for consultation, and these highly overlapping contents take up a lot of doctors' time. AI technology can help doctors respond to inquiries based on a large amount of historical information, saving time and energy.



Fig. 2 A woman uses a screen on a robot developed by iFlytek at the outpatient hall in a hospital.

2.2.1 Painpoints

China has lagged behind in the adoption of electronic health records (EHRs) in healthcare institutions but the use of EHR systems is now rapidly growing as a result of the new Medical Reform. The widespread adoption of EHRs has made it easier for researchers to access and aggregate longitudinal patient data. China is likely to be the country with the largest volume of EHR data because of the large population and the rapid development and deployment of information systems across the country in recent years. However, there are many factors influencing the quality of EHRs. The first is Chinese doctors' heavy workload. On average, Chinese doctors need to see over 100 patients each day in outpatient department, and each patient only has 3 – 4 min for consultation. It is very time-consuming for them to input each items carefully into the EHR system. Secondly, EHRs are mainly used by tertiary and secondary hospitals (Tertiary hospital is the best hospitals and primary is the lowest in China), and some primary hospitals in lower tier cities still use handwriting for recording. In 2018, NHC evaluated the EHR systems of 4329 secondary hospitals and 1695 tertiary hospitals, and found that the average grade of EHR system in secondary hospitals is 1.35 and that in tertiary hospitals in 2.81 (grade 0 – 8 and grade 8 represent the highest). Since 2009, relevant administrative departments issued several Notices to promote the application of EHR system in hospitals, however, after 10 years, the quantity increases, but the quality is still poor. According to the *Notice on Further Promoting the Construction for the Informationization of Medical Institutions with Electronic Medical Records as the Core* recently issued by NHC, by 2020, all tertiary hospitals should upgrade their EHR system into grade 4 and above. AI could use natural language processing technology to transfer voice messages into electronic records and also to standardize and structurize stored records.

Due to the lack of triage system, long queue for registration and consultation, and patients' knowledge deficit, patients normally spend a long time to find out which clinical department is the right one to go and which doctor should he/she visits. Based on facial recognition and natural language processing technologies, auxiliary medical robot could provide basic information to patients, such as the visiting process, clinical



department's introduction, preliminary triage etc., in order to response quickly to patients' needs and reduce the workload of the hospital.

In addition, due to the inconsistent health data and disconnection between different hospitals, patients normally need to bring all their historical examination results and health data to visit the doctor, and for doctor, it is waste of time to asking about patients' history everytime. Virtual assistant is intended to help doctors collect and analyse patients' historical data in order to improve the consultation efficiency.

2.2.2 Advantages of development in China

China is relatively more mature in auxiliary medical robot, and could be an advantage in developing other medical robots. In electronic health record based on speech, due to the big needs in the market, many Chinese companies put a lot of effort in developing advanced solutions.

2.2.3 Application scenario

In EHR field, the application could be intelligent voice recording, clinical decision supporting, natural language recognition. For auxiliary medical robot, the application is very clear which is for general guidance and preliminary triage. For virtual assistant, the primary application is for intelligence consultation.

2.2.4 Current industrial status and key players

Since most of the AI-assisted diagnosis products are software and hardware integrated solutions, healthcare AI companies in China cooperate with hospitals and continuously train models and optimize algorithms through hospital desensitization medical records data. Hospitals can use the products mostly for free. In the future, when the product becomes more mature, AI in diagnosis in China may be inclined to adopt the service charge business model. The below table lists some key industrial players in assisted diagnosis.

Table 6 Chinese companies focusing on AI assisted diagnosis.

Sector	Company	Established	Product	Landed in hospitals	Target customer
EHRs	Boshi Cloud	2014	Cloud-based patient information management system	Over 3000 clinical departments in 400 level 3 hospitals	Hospitals
	Unisound	2012	Voice assistant to help doctors with filing EHR	Over 500 hospitals	Hospitals
	Synyi.AI	2016	AI-powered medical data solution provider. Claimed to transforming low-value data into high-value data through data governance.	Over 30 hospitals	Hospitals, Healthcare AI companies, Insurance companies, pharmaceutical companies
	LinkDoc	2014	HUBBLE medical big data assistive clinical decision system	Over 500 hospitals	Hospitals
Auxillary medical robot	iFlytek	1999	Xiaoyi robot passed medical licensing exam.		Hospitals
Virtual assistant	Kangfuzi (purchased by Baidu)	2015	AI enabled consultation system	Over 20 hospitals	Hospitals and patients

2.3 AI drug development

Medicine discovery is an extremely expensive process, on average new drug discovery takes 10 years with 1 billion dollars. AI has already been successfully applied in all stages in drug development: literature search,



identify target molecules, discover effective drugs, speed up clinical trials, and find biomarkers for diagnostics.

2.3.1 Painpoints

At present, medicine discovery in China has several problems to be solved. Some of which can serve as the directions of AI development. Specifically, medicine discovery in China always takes a long-time duration, high costs, high-risk, and low rate of return. The integration of AI and drug discovery can greatly reduce time and development costs.

2.3.2 Application scenario

AI can be applied in the whole process of drug development as showed in below figure, such as target discover, compound synthesis and screening, crystal structure prediction, toxicity test, patient recruitment, clinical trial design etc.

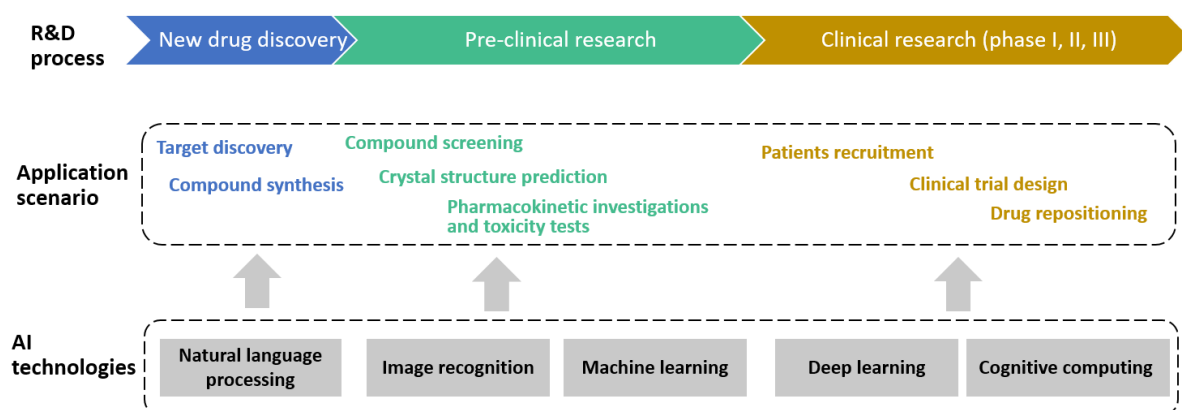


Fig. 3 The application of AI in new drug development.

2.3.3 Current industrial status and key players

Drug discovery applications accounts for over 35% market share of healthcare AI industry globally. In new drug discover, Chinese pharmaceutical companies are still mainly focusing on generic drugs and improved drugs, and foreign companies are focusing on innovative drugs. Regarding to the application of AI in new drug discovery, Chinese companies are lagging behind. By October 2018, there were 6 Chinese companies received investment successfully, and the total amount is 250 million dollars. Below table introduces the Chinese companies in drug discovery.



Table 7 Chinese companies focusing on AI drug development.

Company	Establishment	Product/solutions	Collaborator
XtalPi	2014	Provide accurate predictions on the physiochemical and pharmaceutical properties of small-molecule candidates for drug design, solid-form selection, and other critical aspects of drug development in order to improving the efficiency, accuracy, and success rate of drug research and development	Pfizer, Roche
Deep Intelligent Pharma	2017	AI-powered organic synthesis system assisting chemists to synthesize target compounds; clinical data process and analysis in clinical study	Bayer, GSK, Roche, Varian, BeiGene, Hrain Biotechnology, Highthink Med, etc
ForceCloud	2012	Cloud based data collection and project management during clinical trial in order to improve the quality of data and speed up clinical trial process	AstraZeneca, Bayer, Wyeth Nutrition, Eisai, Takeda, Mundipharma, Dentsply Sirona etc.
LinkDoc	2014	a third-party medical data and research provider in the pharmaceutical industry. With its gigantic medical data pool, LinkDoc provides IT support for drug developers and hospitals. The major revenue stream of the company is helping biopharmaceutical companies to complete the second phase of clinical trials by linking the volunteers.	CRO, e.g. Tigermed, Kun Tuo.
GigaCeuticals	2018	Based on artificial intelligence technology to analyze and predict the functions of all kinds of compounds and related properties of the compounds, and screen the target molecules, design and optimize specific functional compounds, predict drug toxicity and long-term side effects	-
Accutar Biotechnology	2017	Accutar offers two software packages: Chemi-Net is a molecular graph convolutional network for accurate drug property prediction. Orbital is a deep neural network based docking platform. In addition to these tools, AccutarBio offers services in virtual screening for lead discovery; intelligent-SAR for lead optimization and drug property prediction.	-

2.4 AI health management

AI health management is a way to change from passive disease treatment into proactive self-monitoring, and the main products are wearable devices. The market potential is big in China since the growing aging population and the release of Two-Child Policy.

2.4.1 Painpoints

For health management in China, the painpoints include



- Firstly, smart wearable devices in traditional health management fail to solve data correlation. Wearable devices only focus on data extraction, collection, and trend analysis, but fail to provide users with health portraits and improve their health.
- Secondly, staff in the health management field are not that professional; most having a non-medical background.
- Thirdly, there are growing population with chronic diseases in China. Hospitals, especially the tertiary hospitals are not able to provide medical services especially when the patients have been discharged. As planned by the national government, primary hospitals should take the main responsibilities for chronic disease management for the citizens living nearby. However, due to the quality of service in primary hospitals is low; people normally have very low trust to the doctors in primary hospitals.

2.4.2 Advantages of development in China

The massive big data in China is the prerequisite for AI development, especially in health management. From the technology-driven perspective, AI can make personalized health management possible through efficient calculation and accurate decision analysis. Even in the future, nutritionists and sports experts can generate accurate health intervention plans based on the AI system of healthtech in China.

Most importantly, national government highly supports the health management for general population especially after the release of Health China 2030.

2.4.3 Application scenario

The main application scenario of using AI in health management is chronic disease management, especially diabetes and high blood pressure. Mother and Child Care is also a focused area as the two-child policy released in China. The companies in these areas mainly use AI technologies to analyse individual data and provide personalized health management plan.

2.4.4 Current industrial status and key players

China's current amount of smart wearable device hardware is not high enough, and the accumulation of disease-related data is insufficient. Therefore, the main application of AI in health management in China is chronic disease management (such as diabetes and hypertension), maternal management, mental health management, and population health management.

Table 8 Chinese companies focusing on AI health management.

Application scenario	Company	Established	Product/service
Chronic disease management	Dnurse	2013	Based on smart device, Apps, could services and intelligence decision support system, in order to help diabetics to improve the accuracy of glucose control, decrease instances of complications and medical costs.
Mother& child care	Intellchildcare	2014	Developed lung sound machine learning algorithm to monitor children's health at home
Health management	iCarbonX	2015	AI-based platform that provides biological, psychological, behavioral healthcare big data solutions.
	More	2015	Based on AI, big data and IoT, the health platform could analyze patients' body parameters and other clinical data to provide clinical decision support in regards to activities and nutrition to doctors



2.5 AI disease prediction

In China, AI technology in disease prediction is mainly used for gene sequencing to forecast disease occurrence. Current business models of genetic testing services of AI in China's healthcare industry can be divided into two types: a hospital delivery model and third-party testing model. Compared with the hospital delivery model, the third-party testing model requires a higher threshold of qualifications, personnel, and funds of medical inspection institutions.

2.5.1 Painpoints

The main painpoints for disease prediction, mainly referring to gene sequencing, business in China include

- The amount of genome data is huge, and manual experiments are time-consuming and labor-intensive.
- Traditional gene sequencing costs too much.
- The general algorithm of gene sequencing diagnosis in different stages is ineffective and has low accuracy.

2.5.2 Advantages of development in China

The advantage of developing disease prediction technology and business in China is the increasing market size and the development of supercomputer. According to the trend of disease incidence, cancer incidence, and death rate have been continuously increasing in China in recent years. In 2015, the number of people with cancer increases to 4.3 million, and 2.8 million died because of cancer. Disease prediction receives a lot of attention. Data shows that from 2007 to 2016, China's revenue from gene sequencing increased by 62.2 percent annually, reaching 5.06 billion RMB in 2016. It is estimated that by 2022, China's gene sequencing market will reach about 30 billion RMB. Additionally, if supercomputer's powerful data processing ability is applied to gene sequencing, it will greatly shorten the time of gene testing and improve efficiency.

2.5.3 Application scenario

Companies dedicated in disease prediction can mainly be divided into two categories, one is controlling the core technology for gene sequencing and develop gene sequencing equipment, and the other one is using commercialized gene sequencing equipment to provide gene sequencing services to clinical institutions or individual customers.

2.5.4 Current industrial status key players

Currently in China, there are 45 companies claiming to provide "disease risk prediction" service, 10% of them have the capability to do gene sequencing. China is still lagging behind in the upstream of gene sequencing regarding to technologies for equipment development. In the middlestream, a lot of companies are competing intensively in providing gene sequencing services, and there is still no leading companies in this area.



Table 9 Chinese companies focusing on AI disease prediction.

Application scenario	Company	Established	Product/service
Gene sequencing	BGI	1999	Gene sequencing
Health management	iCarbonX	2015	AI-based platform that provides biological, psychological, behavioral healthcare big data solutions.
Disease prediction	PingAn Technology	2008	Using self-adaptive AI model to forecast influenza

2.6 Key stakeholders

2.6.1 Governmental and academic key stakeholders

Shanghai Hospital Development Centre (SHDC)

SHDC was founded in 2005 by the municipal government of Shanghai as a non-profit corporation. It manages the operation of 38 municipal tertiary hospital (almost all top-level hospitals in Shanghai) in Shanghai, and controls budget, staffing, strategic planning, and health-record sharing of municipal public hospital. SHDC is running a Hospital Link Project since 2006 with the main target to connect different systems (including Picture Archiving and Communication System, Hospital Information System, Laboratory Information System, Clinical Information System) in order to share data and information in-real time between all hospitals in Shanghai.

Chinese Innovative Alliance of Industry, Education, Research and Application of Artificial Intelligence for Medical Imaging (CAIERA)

CAIERA was set up in April 2018 with the commitment to effectively integrating various resources from industry, education, research and application for healthy development of AI in medical imaging. The original members of the Alliance include 120 well-known Tertiary hospitals in China, 55 enterprises of medical imaging AI and 35 scientific research institutions. The alliance has issued a certain number of consensus on relevant topics in AI, and one of them are *The White Paper on Medical Imaging Artificial Intelligence in China* issued in March 2019, which plays a guiding role in understanding the market demands and establishing standardized systems in the path of landing AI products in the field medical imaging.

Med-X Research Institute of Shanghai Jiaotong University

Med-X is China's newest research institute combines engineering, life science and physical science to cutting edge translational research to solve problems in biomedicine. The Institute consists of eight joint research centers. They include: The Med-X-Ruijin Hospital microPET/CT Research Center; The Digital Medicine Research Center of The Ministry of Education; The Med-X-Renji Hospital Clinical Stem Cell Research Center; The Shanghai Med-X Medical Equipment Engineering Research Center; The Med-X-Sixth Hospital Shanghai Medical Equipment Research Center; The Rehabilitation Engineering Research Center; The Med-X-Mental Hospital Neuroimaging Center; and finally the Nano Biomedical Research Center.

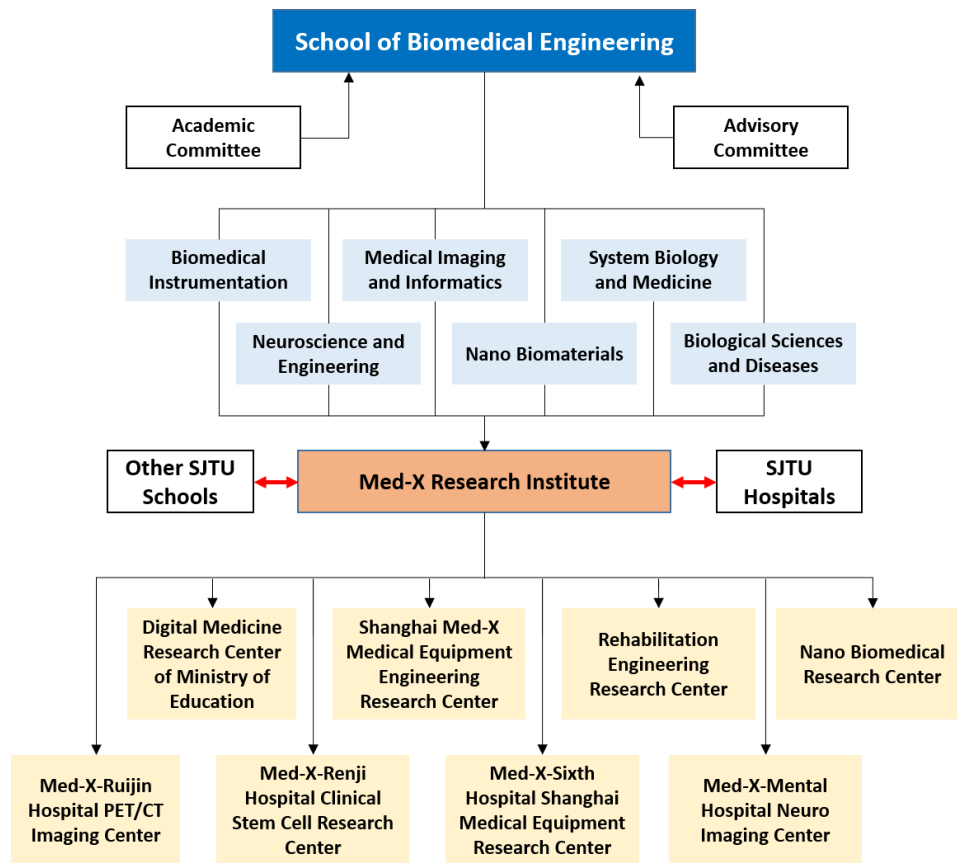


Fig. 4 Organization structure of Med-X Research Institute

Shenzhen Institutes of Advanced Technology (SIAT) of the Chinese Academy of Sciences (CAS)
SIAT was jointly established by CAS, the Shenzhen municipal government and the Chinese University of Hong Kong in February 2006. To meet the nation's needs in healthcare and manufacturing, SIAT focuses on emerging industries such as low-cost healthcare, service robots, electric vehicles, cloud computing, digital cities, nano-medicine, new energy and new materials. SIAT has also established long-term cooperation with many foreign academic and research institutions, including Stanford University (USA), Massachusetts Institute of Technology (MIT), NICTA (Australia), TRILabs (Canada), the University of Hamburg (Germany), the University of Southampton (UK) and many other institutions.

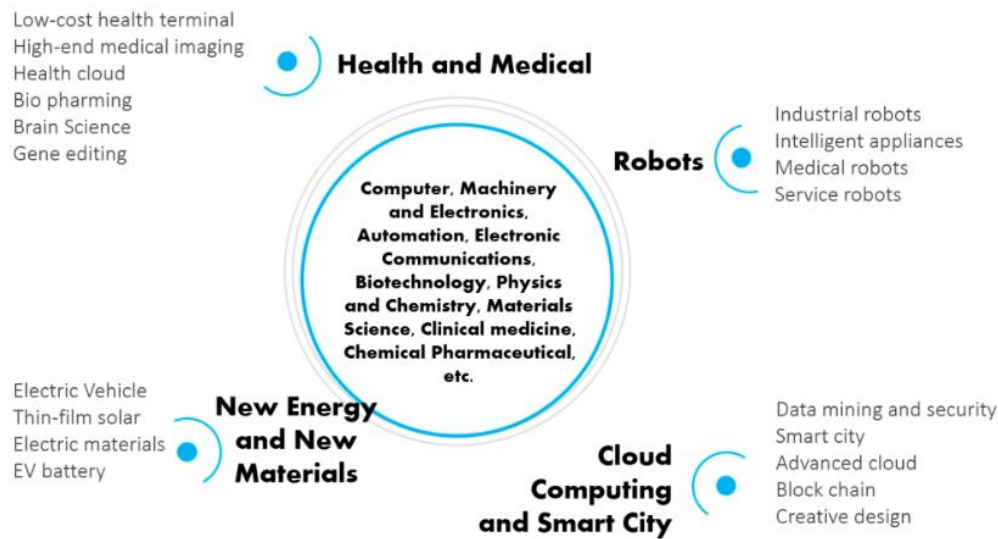


Fig. 5 The focused areas of Shenzhen Institutes of Advanced Technology

Shanghai Institute of Materia Medica, Chinese Academy of Science

Shanghai Institute of Materia Medica (SIMM), Chinese Academy of Sciences (CAS), has the longest history as a comprehensive research institution for drug discovery in China. Research priorities are given to treat major diseases, such as cancers, cardio-cerebrovascular diseases, neuropsychiatric diseases, metabolic diseases, autoimmune diseases, and infectious diseases. SIMM is leading a national project to use AI as the core technology for new drug development.

2.6.2 Industrial Key Stakeholders

Chinese Tech Giants

The Chinese Tech giants, e.g. Tencent and Alibaba, have begun to see the health care system's challenges as an opportunity to leverage their "anything, anytime, anywhere" consumer-focused approach to capture a new market with digital health care. While physicians, hospitals, and other providers may have more experience working within a heavily regulated environment and an ability to deliver specialized, high-acuity care, these tech companies benefit from a deep understanding of consumers, enormous financial resources, and the ability to innovate and scale their technology rapidly. This has positioned them well to meet the basic health care needs of a significant proportion of the population.

Tencent whose WeChat communication platform has more than 1 billion users, is pursuing a "Smart Hospital" strategy to enable patients to schedule appointments with specialists, conduct virtual visits, and access personal health information such as diagnostics, imaging reports, and prescriptions. Tencent is also making inroads into ambulatory care, building a network of primary care and ambulatory surgery centers in eight cities, as well as communication, payment, and referral services for providers and patients.

Alibaba users of the popular payment platform Alipay, known to the Chinese public as a fast and safe financial transaction platform, can schedule appointments. Alibaba then leverages its logistics capabilities to easily deliver those medications from partner pharmacies in less than 24 hours. Seeking to capture more of the value chain, Alibaba established its Tmall pharmacy division to distribute over-the-counter drugs and medical devices to consumers.



Ping An Technology

Ping An Technology, a subsidiary of Ping An Group uses AI, cloud and other cutting-edge technologies to develop and operate mission-critical platforms and services that support financial services, medical health, smart cities etc. Based on deep learning technologies, Ping An Technology built a prediction model using case reports from participating hospitals, historical data from regional health authorities and meteorological and environmental statistics to predict flu outbreaks ahead of time with accuracy rates of over 90% in cities of Chongqing and Shenzhen. The results were published recently in EBioMedicine with the title “Forecasting Influenza Activity Using Self-Adaptive AI Model and Multi-Source Data in Chongqing, China”.

Ping An Good Doctor, which is also under Ping An Group, is China’s largest health care platform with consultations, medical appointment services, certain health checks, has begun installing unstaffed, AI-enabled kiosks, called “One-Minute Clinics”, in communities and work sites around the county. Users sit in a small booth and talk with an “AI Doctor” about their symptoms and medical history; the virtual doctor then makes a diagnosis and treatment recommendations. If necessary, the patient can talk to a physician by video, and the kiosk’s smart medicine cabinet can dispense more than 100 different medications. In the first 2 months of operation, the one-stop clinics, which are open 24-7, has reportedly served 3 million consumers.



Fig. 6 Ping An Good Doctor’s One-Minute-Clinics are now installed in eight provinces across China.



3 HEALTH DATA

With the largest population in the world, China has a large amount of data in health sector. According to the statistics, by 2020, Chinese medical data will increase to 35ZB, which accounts for 20% of medical data in the world. However, the quality of medical data is still poor due to the system separation between different hospitals, even between different departments. In addition, the medical records in some primary hospitals and hospitals in small cities or rural areas are still based on hand-writing, which lowers the value of those medical data. How to structurize and standardize those medical data is still big issue in China. Government hopes by using new technologies in data collection, storage and analysis, that this data can become more valuable.

AI's inherent dependence on data is at odds with the government's goal of protecting sensitive medical data. Data sharing is essential to ensuring the wide and safe application of AI-driven medical products. Datasets used to train AI systems need to be drawn from a wide variety of hospitals and patients. For this reason, regulators have recently taken steps to improving China's currently underdeveloped and unstandardized electronic resource infrastructure. The NHC has issued policy documents to promote the use of electronic medical records across hospitals and assigned local regulators to assess how well they are being adopted.

However, under China's Cybersecurity Law and related implementation measures, much of the data generated in a medical context are classified as sensitive, potentially subjecting them to strict data localization requirements or security reviews. Initial healthcare-specific guidelines are requiring medical institutions to store patient information on secure servers within China and to apply for security evaluations if they wish to transfer it overseas.

China also lacks a robust regulatory framework for AI-powered software and devices. Much like in the United States and other parts of the world, many products in China are a long way from being commercialized. Yet, the lack of unified industry standards for risk classification and evaluation of medical AI is still causing significant delays in product registrations. Regulators are taking a distinctly conservative approach, with current medical device catalogs favoring the highest risk classification (Class III) for products or solutions as soon as they incorporate deep learning with explicit diagnosis functions. Many of the 50+ start-ups in China that have invested heavily in algorithm-driven diagnostic products may not survive due to the complexities and high costs of medical device registration. Increasingly, analysts suspect that as much as 90 percent of all Chinese AI start-ups could fail amid fierce competition, pressure to commercialize, and a wider economic slowdown.

To solve the problem, led by the NHC and the National Medical Product Administration (NMPA), healthcare regulators have been actively working on creating classification catalogs, clinical trial guidelines, and technical review documents specifically for medical AI. In February 2019, the Center for Medical Device Evaluation (CMDE) issued evaluation guidelines for medical devices using AI for clinical decision-making. In July 2019, led by CMDE from NMPA, Cooperation platform for AI medical device innovation was officially established, which consists of government, associations, medical institutions and universities. In this cooperation platform, several working groups and expert committees have been created with the specific task of creating further standards and guidelines for AI medical device approval.

In the cooperation platform there are 3 out of 10 working groups focusing on database, which shows that CMDE pays a lot of attention on clinical data as the key element for AI technology.

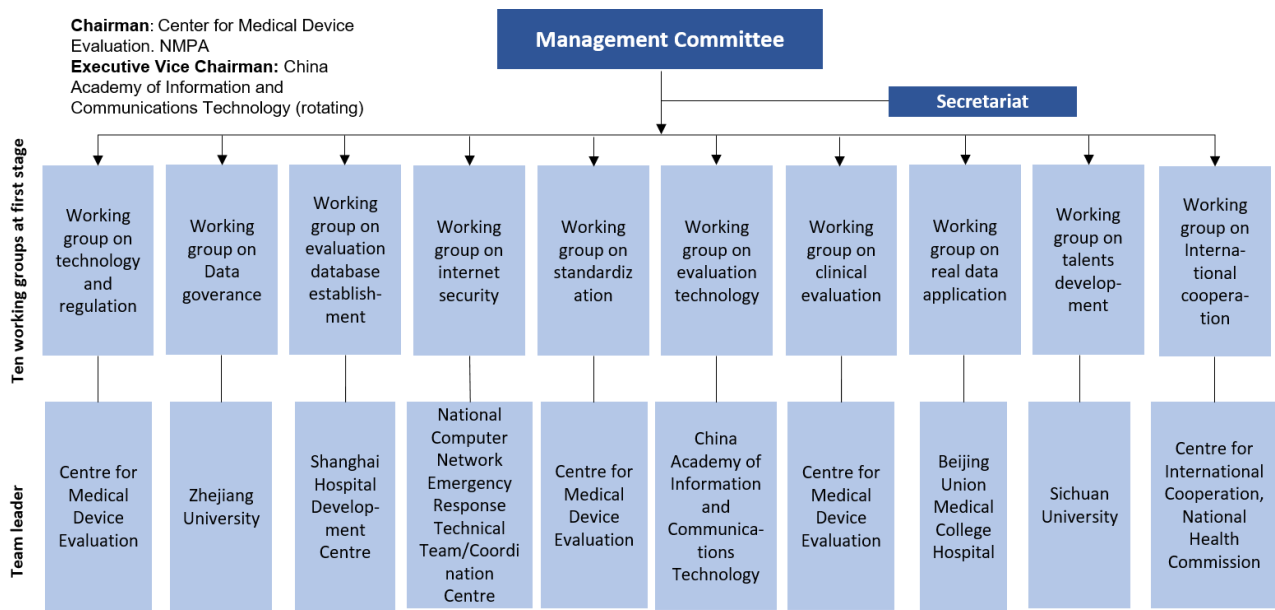


Fig. 7 Cooperation platform for AI medical device innovation.

Table 10 The key responsibilities of each working group in cooperation platform.

Working group	Key responsibilities
Working group on technology and regulation	Developing the regulatory policy for the full life cycle of AI medical device; using AI technology to achieve innovative regulatory methods for medical devices
Working group on data governance	using clinical data quality management as entry point to Investigate the process, method and requirement of data governance for AI healthcare medical device
Working group on evaluation database establishment	Establish evaluation database for medical devices approval by integrating clinical resources and utilizing the characteristics of AI medical device products
Working group on internet security	Investigate the technology for internet Security of AI medical devices based on application scenarios
Working group on standardization	Construction of standard system for technical requirement and assessment method for AI medical device
Working group on evaluation technology	Investigate the requirements for data quality and product evaluation methods of AI medical device
Working group on clinical evaluation	Develop the requirements for clinical evaluation of AI medical devices based on the intended use and application scenario
Working group on real data application	Based on the data in real world, develop the method and requirements for closed loop supervision AI medical device
Working group on talents development	Coordinate research and clinical resources to carry out non-profit training; strengthen the talents development in AI medical device evaluation, supervision and industry.
Working group on International cooperation	Coordinate the international cooperation in AI medical devices and medical device supervision, and increase the international influence



4 CONCLUSION AND STUDY TRIP 2020

The aging and growing populations, the prevalence of chronic diseases and exponential advances in innovative digital technologies have and will continually alter and transfer the way healthcare and eldercare are delivered. China's medical AI booms in recent years, which is very much aligned with the general aim of Chinese government, which is to become the world's leading AI innovation centre by 2030. The favourable policy environment, financial support, as well as the huge market size for AI healthcare development in China encourage more and more foreign companies to look for opportunities in China. Danish government also just released the 'Danish Strategy for AI' and healthcare is one of the prioritized areas in 2019. Denmark has excellent AI research community and strong institutions for turning research into business application. ICDK Shanghai will leverage the opportunity and established network to promote more Sino-Danish cooperation in AI healthcare and assist Danish AI healthcare companies to find business possibilities in China.

In order to achieve more Sino-Danish cooperation in AI healthcare, encouragement of open communication and better local understanding of Chinese AI healthcare ecosystem is the pre-requisite. ICDK Shanghai is planning to organize a fact-finding tour to China in 2020 for relevant Danish audiences and stakeholders from industry, academy and authorities. During the trip, we plan to visit and arrange in-depth discussion with Chinese leading AI healthcare companies, top-level researchers, authorities and other key stakeholders in order to gain insights into the Chinese regulatory, business and academic environment. For more information, feel free to contact us.



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