HEALTHCARE AI

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METHODOLOGY

1. Dataset used for the report

The patent dataset was retrieved on 15 March 2019 and comprises worldwide patent applications relating to healthcare AI published in 2009-2018.

Relevant business information, market data, and national policies that are available from commercial databases or on the web are also used to support the findings of the report.

2. Counting the number of inventions

This report counts the number of inventions by the total number of unique patent families. Counting individual patent applications will result in double counting as each patent family may contain several patent publications if the applicant files the same invention for patent protection in multiple destinations. As a patent family is a group of patent applications relating to the same invention, analyses based on counting one invention per unique patent family can reflect innovation activity more accurately.

3. Formulation of search strings

To ensure optimal recall and accuracy of the data sets retrieved, the search strings used in this study were formulated by incorporating keywords (and their variants), as well as relevant patent classification codes and indexes, e.g. International Patent Classification (IPC) and Cooperative Patent Classification (CPC).

4. Grouping of technology domains

Grouping of individual patent documents into the respective technology domains was carried out based on patent classifications codes, text-mining and semantic analysis of the patent specifications in particular claims, titles, abstracts, as well as a manual review of the individual patent applications.

5. Growth rate calculation

Annual growth rate refers to the average annual growth and was derived by using the best-fit exponential line method for the set of data, $y = a*e^{bx}$, where b is the growth rate.

CONTENTS

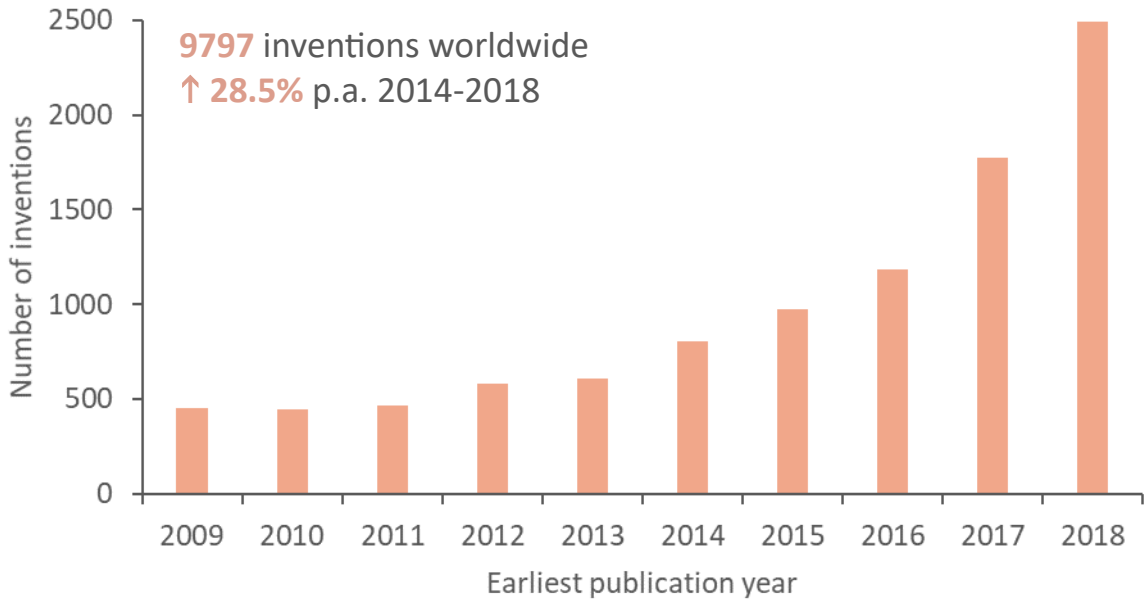
INTRODUCTION

While artificial intelligence (AI) has found its way into many industries and has been making a strong impact in improving productivity and efficiency, it is only beginning its penetration into the healthcare industry.[1] With advanced AI algorithms and copious amount of under-utilised health data to tap into, AI is set to revolutionise the healthcare sector, resulting in improved patient outcomes and massive cost reduction.[2]

While challenges, such as data privacy, regulatory approval, public acceptance and the 'black box' conundrum, abound for the quest towards an AI-empowered healthcare industry, the promise of AI remains huge. Robotics-assisted surgery, virtual nursing assistants, and personalised medicine are just some of the many possibilities healthcare AI can offer.

Given the immense potential of applying AI to the healthcare sector, it is important to understand the different forms of healthcare AI innovations that both healthcare givers and receivers can expect in the coming years. This report looks at worldwide patent applications relating to healthcare AI published in 2009-2018 with a particular focus on the domains of (a) Imaging & diagnostics; (b) AI-empowered apparatus; (c) Remote monitoring; and (d) Hospital workflow. This report also assesses the state of development in the application of AI in healthcare, and highlights the key players of the respective domains.

A FAST GROWING FIELD WITH HIGH INNOVATION INTEREST



The role of AI is rapidly increasing in the healthcare industry, given the attractiveness of AI deployment in healthcare to augment the operations of healthcare personnel. It is forecast that the healthcare AI market will reach USD 6.6 billion by 2021, a whopping 11 times of the USD 600 million in 2014, at a robust compound annual growth rate (CAGR) of 40%.[2]

A corresponding trend is also observed in the related innovation activity. After a stable number of publications of ~500 inventions annually in 2009-2013, interest in healthcare AI has exploded in recent years with fast annual growth of 28.5% over the period of 2014-2018. Given the industry's optimism on the potential growth of the healthcare AI market, healthcare AI-related patent filings are expected to continue its exponential growth in the coming years.

The anticipated infiltration of new healthcare AI products into the healthcare market signals an era of exciting times for the industry. It will thus be critical for the healthcare industry to keep itself up-to-date with the latest developments in healthcare AI technology, so as to better prepare itself for appropriate and timely deployment of the latest technology. Personnel looking into healthcare facility planning and design would need to evaluate the usefulness of deploying AI-powered technologies into facilities and services. With the inevitable advent of AI-powered products, human-machine collaboration in a healthcare context would require healthcare professionals to upgrade their skills and undergo training to better integrate technology to augment their work, improving efficiency and productivity.

U.S. AND CHINA ARE THE PREFERRED MARKETS FOR PATENT PROTECTION

Market of protection	Publication year										Total
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
U.S.	228	229	328	349	395	420	571	679	781	1019	4999
China	67	97	160	203	227	289	407	509	885	1469	4313
Japan	79	66	135	169	179	180	196	245	316	356	1921
Europe	24	98	126	141	155	170	205	264	311	424	1918
Korea	17	32	51	63	74	104	136	146	199	275	1097

Already considered one of the leading countries to adopt AI technologies across the gamut of healthcare technologies,[3] the U.S. has been the market of choice for protection. It has received ~5 thousand healthcare AI inventions, many of which were filed by leading industry players, including Siemens (366 inventions), Philips (195 inventions), Samsung (191 inventions), Fujifilm (128 inventions), and IBM (119 inventions). Canon, after its acquisition of Toshiba Medical Systems in 2016,[4] also views the U.S. as an important market, and boasts a portfolio of close to 190 inventions.

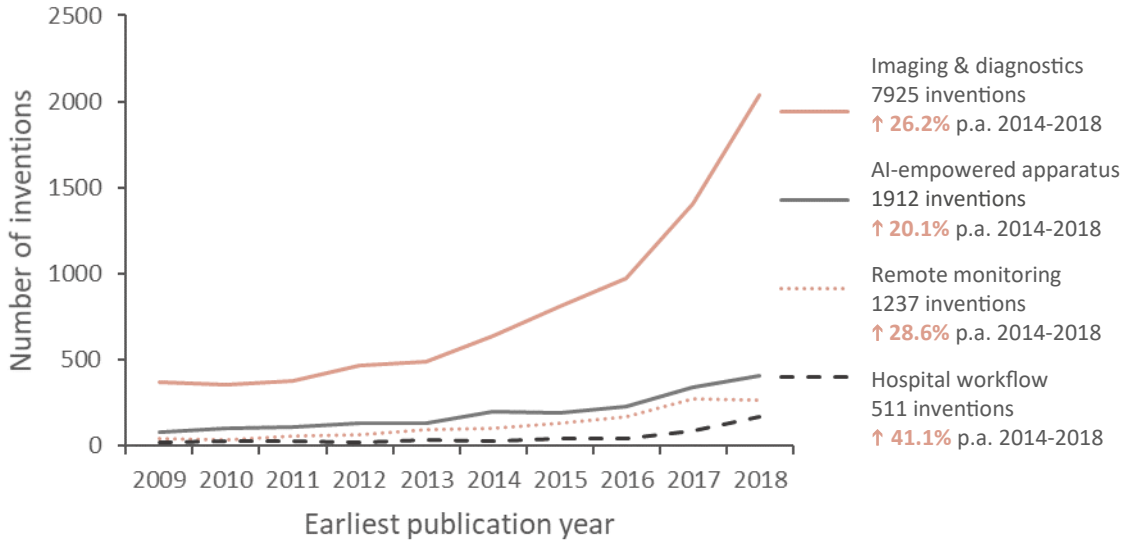
China is the up-and-coming market which has seen fervent filing activities in recent years that grew at a strong 40% per annum from 2014-2018. During this recent growth phase, the number of China filings in 2017-2018 exceeded those of the U.S. in the same period. While 65% of patent applications were contributed by its domestic players, established global players such as Philips, Siemens, and Samsung, have also raised their stakes and are seeking more patent protection, with ~75% of their combined China portfolio filed in 2014-2018.

The strong push towards healthcare AI in China can be attributed to the imbalance of local healthcare demand and supply, particularly the low ratio of healthcare professionals to care receivers,[5,6] which is set to decline further in the coming decades given the aging population in China. The tangible advantages brought about by AI in healthcare applications, together with the immense interest in patent protection in China, will propel China to be the leading market for healthcare AI protection in the coming years.

FILING TRENDS IN VARIOUS HEALTHCARE AI DOMAINS

There have been varying degrees of innovation interest in the four identified domains of healthcare AI, i.e. (a) imaging & diagnostics; (b) AI-empowered apparatus; (c) remote monitoring; and (d) hospital workflow. While imaging and diagnostics has been the main driver of healthcare AI growth, innovation activities in the other domains, including AI-empowered apparatus, remote monitoring, and hospital workflow are gaining traction in recent years. In general, all aspects of healthcare AI are expected to grow, and products resulting from innovation in these areas will likely surface in the market in the near future.

A predominant area of healthcare that employs the use of AI is imaging and diagnostics, with almost 8 out of 10 healthcare AI inventions focused around this aspect. The difficulty faced by healthcare professionals in deciphering medical images and extrapolating irregularities to a specific medical outcome has been the main motivating factor in the industry's search for a more systematic and efficient way of performing image diagnostics. Advancements in computer vision techniques thus play an important role in helping to solve the conundrum in such paradigms. As such, the observed innovation interest in this domain is not surprising. In particular, AI-assisted diagnosis of abnormalities has been demonstrated to be reliable, with potentially higher accuracy than the advice provided by experienced healthcare professionals.[7,8,9]



More notably, it is the synergistic effect of augmenting healthcare professionals' expertise with AI output[10] that is giving the industry the confidence that embedding AI into diagnostics solutions will be the way forward. In appreciating the benefits of AI embedment in imaging and diagnostics solutions, the U.S. Food and Drug Administration (FDA) has initiated fast-tracking programs for expediting regulatory approval of imaging and diagnostics products which incorporate AI, to reduce the time needed for them to go to market.[11] These initiatives have provided further impetus to the sector, and also led to high interest in equity funding, particularly in 2018.[11] Given the strong market demand and investment in this area, innovation growth is expected, and products embedded with AI are poised to not only support healthcare workers in their daily work, but also improve efficiency in hospitals and clinics by assisting clinical decision support in the decades to come.

FILING TRENDS IN VARIOUS HEALTHCARE AI DOMAINS (CONT.)

Despite AI-empowered hospital workflow presenting itself as the smallest focus area with a total of 511 inventions, interest here is gaining fast, with an annual growth of 41.1% in the recent five years. With increasing global healthcare demand due to an aging and growing population, coupled with the pervasiveness of chronic diseases and disorders[12], there exists a need to relieve healthcare professionals from administrative and logistical tasks[13]. The fast development of AI and machine learning capabilities thus hold the key to relieving healthcare professionals from mundane tasks, through administrative workflow assistance such as physician scheduling, and AI-powered automation of routine menial tasks, including clinical documentation and prescribing medications.[14,15,16] With a potential USD 18 billion in industry savings annually,[15] the AI-powered hospital workflow market is expected to maintain its relevance to the industry, with further innovation growth expected into the next decade.

TOP APPLICANTS IN VARIOUS AI HEALTHCARE DOMAINS

Rank	Remote monitoring	AI-empowered apparatus	Imaging & diagnostics	Hospital workflow
1	IBM (29)*	Siemens (78)	Siemens (400)	IBM (24)
2	Philips (27)	Philips (39)	Philips (222)	Philips (13)
3	Samsung (20)	Cochlear (21)	Samsung (206)	Nuance Communications (12)
4	Affectiva (15)	Samsung (19)	Fujifilm (157)	Cerner (11)
5	Fujitsu (14)	Brainlab (18)	Toshiba (130)	General Electric (9)
6	Microsoft (12)	LMECA (16)	Canon (107)	Siemens (6)
7	Cerner (11)	Chongqing University (15)	IBM (86)	Canon (5)
8	Blast Motion (10)	Tianjin University (14)	General Electric (80)	Foshan Rongxintong Enterprise Consultation Services (4)
9	General Electric (9)	Intuitive Surgical (14)	Shanghai United Imaging Healthcare (53)	Parkland Center For Clinical Innovation (4)
10	Xerox (9)	Sony (14)	Fujitsu (45)	Brainlab (3)

*Numbers in parentheses represent the number of published inventions

A deeper analysis of the leading players in the healthcare AI space revealed mainly commercial entities. This suggests that even though healthcare AI is in its early phase of adoption, industry players are already actively looking into translating basic AI/ machine learning technologies into solutions for various aspects of healthcare.

Specifically, this is led by Siemens and Philips—the two most established players in healthcare solutions—who are top players in the imaging & diagnostics domain with sizable portfolios. Siemens and Philips have began to introduce products relating to AI-powered imaging & diagnostics, including AI-assisted CT, MRI, and X-ray imaging solutions, that allow precise and accurate identification and diagnosis of lesions and abnormalities.[17,18,19] Additionally, Samsung[20,21], Fujifilm[22,23], and Canon[24] have also recently showcased AI-powered imaging solutions in their pipelines that are expected to hit the market soon. Given the substantial portfolio sizes of the top players, increasing imaging and diagnostics products and solutions can be expected in the near future.

Among the lead players, Philips stands out prominently and is consistently ranked within the top two spots in all domains. In addition to imaging & diagnostics, Philips' product portfolio also includes AI-powered wellness monitoring, AI-empowered medical apparatus, and health care data management. HealthSuite Insights, CareSage and IntelliSpace Console are some of Philip's platforms which cater to the various aspects of healthcare, ranging from data collection and creation, predictive diagnosis and treatment, to timely and efficient clinical decision support.[25] The comprehensive profile held by Philips makes it one of the few AI healthcare service providers with solutions across various segments of healthcare, and therefore an ideal commercial partner for holistic healthcare solutions.

INCREASING INNOVATION ACTIVITIES IN THE DEVELOPMENT OF INTEGRATED SOLUTIONS

	Remote monitoring	AI-empowered apparatus	Imaging & diagnostics	Hospital workflow
Remote monitoring	1230	155	707	54
AI-empowered apparatus	155	1914	852	33
Diagnostics & imaging	707	852	7966	110
Hospital workflow	54	33	110	510

As multiple facets of healthcare solutions need to come together for a holistic healthcare experience, for example, data/image collection and diagnostics, and robot-assisted treatment and care, it is useful to understand the state of innovations involving the integration of different healthcare facets within a single innovative solution.

Analysis of the co-occurrence of different healthcare aspects within a single invention revealed that a high proportion of inventions were related to incorporating AI-assisted imaging & diagnostics in medical apparatus, and for the use of remote monitoring.

6 out of 10 remote monitoring inventions involved imaging and diagnostics. These inventions relate to the monitoring of patient condition or compliance, while including a diagnostic function to remotely assess if a patient requires intervention. The increasing pervasiveness of devices like mobile phones and wearables, and their integration into cloud networks, has allowed instantaneous collection of health-related or vital signs data, and has enabled AI-based systems to monitor and accord timely and accurate advice or intervention.[26] Early detection and intervention of health-related problems or behaviours can also help reduce potential complications in the future.[27] Together with the potential benefits of cost savings and more useful and targeted consultation work for healthcare providers, this sector is expected to be an important facet of healthcare which will grow further in the coming decade.

Building on the maturity of computer vision techniques, almost half of AI-empowered apparatus are integrated with imaging and diagnostics capabilities. These inventions are systems where medical imaging equipment and diagnosis applications are integrated to provide a more streamlined solution, where an AI-assisted diagnosis can be obtained upon performing diagnostic imaging. The major players in this area are Siemens, Philips, Toshiba, and Fujifilm, who have been offering traditional medical imaging solutions. These companies have incorporated AI into such imaging-cum-diagnostic medical equipment to improve efficiency and productivity.[28,29,30,31] Brainlab, another prominent player in hardware and software solutions for radiation therapy and neurosurgery, is also incorporating AI in its surgical and radiotherapy devices to better determine patient characteristics for more accurate positioning and treatment.

CONCLUSION

The benefits of healthcare AI have propelled the industry's interest in pursuing AI-assisted innovations and solutions. While U.S. is currently the main market for healthcare AI, the China market is up-and-coming, and developing fast. The imaging and diagnostics domain has been relatively well-explored, and increasing market release of related products can be expected in the coming years. On the other hand, the other three domains—AI-empowered apparatus, remote monitoring, and hospital workflow—still remain in the development stage, and is gaining fast traction amongst industry players. In addition, there is also a shift towards integrated solutions, which will not only enable streamlined solutions, but also improve productivity and patient care services. With the imminent deployment and adoption of AI in healthcare, an understanding of the latest AI-assisted healthcare solutions would allow healthcare professionals to provide appropriate solutions in a timely manner, leading to better management of healthcare resources and systems, and allowing its recipients to obtain the required care seamlessly and efficiently.

REFERENCES

1. Health IT Analytics, “Challenges of developing and deploying AI in healthcare”, [Online]. Available: https://healthitanalytics.com/news/challenges-of-developing-and-deploying-ai-in-healthcare
2. Accenture, “Artificial Intelligence” Healthcare’s new Nervous System”, [Online]. Available: https://www.accenture.com/_acnmedia/PDF-49/Accenture-Health-Artificial-Intelligence.pdf#zoom=50
3. Healthcare Finance, “Healthcare AI market expected to surge from $2.1 to 36.1 billion by 2025”, [Online]. Available: https://www.healthcarefinancenews.com/news/healthcare-ai-market-expected-surge-21-361-billion-2025
4. Canon, “Canon Inc. to acquire Toshiba Medical Systems Corporation shares and make it a subsidiary”, [Online]. Available: https://global.canon/en/news/2016/20161219.html
5. The Business Times, “China's doctor shortage prompts rush for AI healthcare”, [Online]. Available: https://www.businesstimes.com.sg/technology/chinas-doctor-shortage-prompts-rush-for-ai-healthcare
6. World economic forum, “AI can solve China’s doctor shortage. Here’s how”, [Online]. Available: https://www.weforum.org/agenda/2018/09/ai-can-solve-china-s-doctor-shortage-here-s-how/
7. Medical News Today, “Artificial intelligence better than humans at spotting lung cancer”, [Online]. Available: https://www.medicalnewstoday.com/articles/325223.php
8. Medica Magazine, “AI: diagnosis of skin lesions is superior to humans”, [Online]. Available: https://www.medica-tradefair.com/en/News/News_from_the_Editors/AI:_diagnosis_of_skin_lesions_is_superior_to_humans
9. StarOnline, “AI defeats elite doctors in diagnosis competition”, [Online]. Available: https://www.thestar.com.my/tech/tech-news/2018/07/02/ai-defeats-elite-doctors-in-diagnosis-competition/#Q1tcZo5EOeoMPI06.99
10. Healthcare-in-Europe.com, “Artificial intelligence diagnoses with high accuracy”, [Online]. Available: https://healthcare-in-europe.com/en/news/artificial-intelligence-diagnoses-with-high-accuracy.html
11. CBInsights, “The AI industry series: top healthcare AI trends to watch”, [Online]. Available: https://www.cbinsights.com/research/report/ai-trends-healthcare/#diy
12. Deloitte, “2019 Global health care outlook”, [Online]. Available: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/gx-lshc-hc-outlook-2019.pdf
13. Harvard business review, “10 promising AI applications in health care”, [Online]. Available: https://hbr.org/2018/05/10-promising-ai-applications-in-health-care
14. Venturebeat, “The 3 most valuable applications of AI in health care”, [Online]. Available: https://venturebeat.com/2018/04/22/the-3-most-valuable-applications-of-ai-in-health-care/
15. Harvard business review, “10 promising AI applications in health care”, [Online]. Available: https://hbr.org/2018/05/10-promising-ai-applications-in-health-care
16. Deliotte, “The hospital of the future How digital technologies can change hospital globally”, [Online]. Available: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/us-lshc-hospital-of-the-future.pdf
17. Siemens Healthineers, “Siemens Healthineers introduces AI-Rad Companion Chest CT as first application based on its new AI-Rad Companion platform”, [Online]. Available: https://www.siemens-healthineers.com/press-room/press-releases/pr-20181125043shs.html

REFERENCES (CONT.)

18. Siemens Healthineers, “Mammography reading software from Siemens Healthineers with AI-based decision support for faster results”, [Online]. Available: https://www.siemens-healthineers.com/en-sg/press-room/press-releases/pr-20181125045shs.html
19. Analytics India Magazine, “Philips Healthcare launches new line of AI-powered imaging devices”, [Online]. Available: https://www.analyticsindiamag.com/philips-healthcare-launches-new-line-of-ai-powered-imaging-devices/
20. Samsung Newsroom, “Samsung showcases AI-based medical technologies at European Congress of Radiology 2019”, [Online]. Available: https://news.samsung.com/global/samsung-showcases-ai-based-medical-technologies-at-european-congress-of-radiology-2019
21. Samsung Newsroom, “Samsung Brings Together Medical Imaging and AI for Radiologists at RSNA 2018”, [Online], Available: https://news.samsung.com/global/samsung-brings-together-medical-imaging-and-ai-for-radiologists-at-rsna-2018
22. Cision PR Newswire, “Fujifilm showcases enterprise imaging portfolio and AI initiative at HIMSS 2018”, [Online]. Available: https://www.prnewswire.com/news-releases/fujifilm-showcases-enterprise-imaging-portfolio-and-ai-initiative-at-himss-2018-300606831.html
23. Cision PR Newswire, “Fujifilm showcases artificial intelligence initiative and advances AI education at RSNA 2018”, [Online]. Available: https://www.prnewswire.com/news-releases/fujifilm-showcases-artificial-intelligence-initiative-and-advances-ai-education-at-rsna-2018-300750655.html
24. AuntMinnie.com, “Canon debuts MRI and vascular systems and AI for CT at RSNA”, [Online]. Available: https://www.auntminnie.com/index.aspx?sec=rca&sub=rsna_2018&pag=dis&ItemID=123746
25. Thenextweb.com, “7 surprising companies where you can work on cutting-edge AI technology”, [Online]. Available: https://thenextweb.com/artificial-intelligence/2018/07/05/companies-work-ai-technology
26. Deloitte, “How digital technology is transforming health and social care”, [Online]. Available: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/life-sciences-health-care/deloitte-uk-connected-health.pdf
27. Clinical research news, “Remote patient care: the future of remote monitoring and diagnostics”, [Online]. Available: http://www.clinicalinformaticsnews.com/2017/2/7/remote-patient-care-the-future-of-remote-monitoring-and-diagnostics.aspx
28. Siemens Healthineers, “AI-Pathway Companion from Siemens Healthineers supports decisions along the clinical pathway, with artificial intelligence”, [Online]. Available: https://www.siemens-healthineers.com/press-room/press-releases/pr-20181125047shs.html
29. Siemens Healthineers, “Medical imaging in the age of artificial intelligence”, [Online]. Available: https://static.healthcare.siemens.com/siemens_hwem-hwem_ssxa_websites-context-root/wcm/idc/groups/public/@global/documents/download/mda3/mzy4/~edisp/white-paper_artificial-intelligence-in-medical-imaging-04384573.pdf
30. Philips news center, “Philips launches AI platform for healthcare”, [Online]. Available: https://www.philips.com/a-w/about/news/archive/standard/news/press/2018/20180301-philips-launches-ai-platform-for-healthcare.html
31. Fujifilm, “The feature of medical imaging led by Fujifilm with AI technology”, [Online]. Available http://reili.fujifilm.com/en/

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