AI Technology Application in Medical Care of NSCLC Based on Patent Trend Analysis

Cheng-Wen Lee[1] and Shu Hui Chen[2]

Abstract
The patent trend analysis provides sound knowledge about the possibility of exploring potential innovation/R&D and gives an insight into which countries and companies are mostly investing in artificial intelligence (AI) technologies involved with Non-Small Cell Lung Cancer (NSCLC) medical care. By comparing patent indicators changes of two decades from 2001 to 2020, the most active countries and companies are identified to provide perceptions of global patent variations. In line with this, we apply a comprehensive software INNOVUE to analyze the patent trend based on the Worldwide Patent Office database. According to previous research, 315 patents are selected as the appropriate patent analysis data. The analysis result is a series of trend maps that show the trend of patent development from the early stage to current changes, evaluate government's/company's concern and motivation on AI technology applied medical care of NSCLC, and indicate who plays the main role in the world regarding the application of AI combined with NSCLC medical treatment.

JEL classification numbers: C80, D81, E27
Keywords: Patent trend analysis, Artificial intelligence technologies, NSCLC

[1] Department of International Business, Chung Yuan Christian University, Taoyuan City, Taiwan.
[2] Ph.D Program in Business, College of Business, Chung Yuan Christian University, Taoyuan City, Taiwan.

1. Introduction

With the increasingly fierce global technological competition, organizations from all over the world have carried out patent strategy research. The core of analysis patent trend is to processing, and transform this information into competitive intelligence with overall and predictive functions. This paper aim to focuses on the lately most popular discussion topic of AI technology application in the highest fatality disease NSCLC.

About Lung cancer there are many vital facts we should pay attention. Over two million cases of lung cancer are diagnosed annually, according to the World Health Organization (WHO), non-small cell lung cancer (NSCLC) accounts for the majority of all lung cancer cases. According to Zappa and Mousa (2016), lung cancer has a poor prognosis as over half of people diagnosed with lung cancer die within one year of diagnosis. The 5-year survival rate is less than 18%.

Oncologists consider lung cancer is most challenged by a huge and rapidly expanding knowledge base. Oncologists who are experts in a specialized field cannot master all available knowledge. Doctors at the primary level are requested to task with tackling numerous tumor types. Also, the distribution of medical resources is not balanced. Medical specialist knows the growth of massive genetic and clinical databases need accelerate high speed of lung cancer treatment advances and cut down the cycle time for modified lung cancer treatment guidelines.

Matching patients to the most effective therapy currently require specimen-based assays. In addition to tissue-based biopsies being an invasive procedure, malignant tumors can be heterogeneous and the biopsied tissue used for testing may not be reflective of the entire tumor. Thus, artificial technology could assist medication care by their effective date progression and imaging identifying massive information. During the diagnosis process, tumors can mutate during a course of therapy, rendering the initial treatment ineffective.

Recently, artificial intelligence (AI) has been demonstrating remarkable success in medical care and analysis owing to the rapid progress of “deep learning” algorithms, which have shown increasing power to solve complex, real-world problems in computer vison and image analysis (Wang et al., 2019). Lung cancer is a serious health problem and the leading cause of cancer death worldwide, due to its high incidence and mortality. According to World Health Organization (WHO) statistic there is about 80% to 85% of lung cancers are none small cell lung cancer (NSCLC). NSCLC is the common existing with a locally advanced or metastatic disease (Kashf et al., 2018).

2. Literature Review

2.1 The current NSCLC medical treatment

Most NSCLC can be grouped into 3 main categories: Squamous Cell Carcinoma, Adenocarcinoma and LargeCell Carcinoma histo-subtypes. They are sorted by the type of lung cell the cancer began in and by how the cells appear under a microscope. They have slight differences among them. But they incline to have the same view (prognosis) and are commonly treated in similar way. The three main treatments in current NSCLC medical care are as follows:

(1) Surgery: Patients who have stage I, II, and III, typically NSCLC treatment would have surgery to remove the tumor if the tumor is found to be respectable and the patient is able to tolerate the surgery. To determine if the tumor is respectable, imaging studies and biopsies are decided by physician’s profession to complete as well as an evaluation of patient factors to lead the patient’s operability.

(2) Chemotherapy: Approximately 40% of newly diagnosed lung cancer patients are stage IV. The specific combination of chemotherapy depends on types and frequencies of toxic effects and doctors should be decided on an individual basis. However, overall median survival for patients was approximately 8–10 months.
(3) Radiotherapy: Uses high-energy beams to damage DNA within cancer cells, thereby destroying neoplastic cells. This therapy can help eliminate or control tumors at specific sites. This therapy may benefit patients with NSCLC that is localized to the chest and who are not candidates for surgical resection.

Besides histological, clinical and demographic information, a wide range of data ranging from genomics, proteomics, immunohistochemistry and imaging must be integrated by physicians when developing personalized treatment plans for patients which can be challenging and lead to unfavorable outcomes. Furthermore, there are a number of factors that limit timely access to these tests, including high cost and late availability in the patient care continuum (Rabbani et al., 2018). Accordingly, above reasons could make "time" saving became a critical issue for NSCLC patients. Early diagnosis and even gene analysis and image learning could provide great support for medication care and might lead better survival rate. Compared with shallow learning methods, artificial intelligence technology has multiple advantages in analyzing pathology images, power in recognizing complex objects, including simplification of feature definition, time-saving through parallel computation, and suitability for transfer learning. Thus, we do consider there is an urgent need for AI technology applied in NSCLC medical care.

2.2 AI technology application

Artificial intelligence (AI) aims to mimic human cognitive functions. It is bringing a paradigm shift to healthcare, powered by growing availability of healthcare data and rapid progress of diagnosis and analytics techniques (Jiang et al., 2017). AI has been well-known as the area of computer science dedicated to producing programs capable of refined, intelligent, computations like to those that the human brain regularly makes. It contains approaches, tools and systems dedicated to simulate human procedures of logical and inductive knowledge acquisition, reasoning of brain doings for resolving problems (Kashf et al., 2018). It is believed it is the future of the medical treatment, also the survival hope for NSCLC patients.

2.3 Urgent needs and further AI technology development

In current clinical practice, cancer diagnosis begins when a patient presents with a suspicious lesion on screening or signs and symptoms considered consistent with a diagnosis of lung cancer. Imaging modalities used to evaluate the presence and extent of cancer include computed tomography (CT), single-photon emission computed tomography (SPECT), magnetic resonance imaging (MRI) and 18Ffluorodeoxyglucose positron emission tomography-computed tomography (18F-FDG PET-CT) (Rabbani et al., 2018).

Liu (2020) claims that AI has been shown to be able to help clinicians make more accurate judgments and decisions in many ways. In an attempt to increase the information obtained from medical images and assist radiologists, new approaches that use machine learning methods to detect and diagnose lung nodules could detect and diagnose tumors as small as 3 mm. The strengths of AI are well suited to overcome the challenge posed by the current generation of targeted and immunotherapies, which can produce a clear clinical benefit (Bi et al., 2019).

New technology is new urgently needed for not only medication care and treatment but

also detection at the early stages of NSCLC. It has been involved in the screening of lung cancer, the classification of histological cancer, judge of benign and malignant degree of pulmonary nodules, to differentiate of histological subtypes, identified of genomics, the judgment of the effectiveness of treatment. To be more precise, what distinguishes AI technology from traditional technologies in health care is the ability to gather data, process it and give a well-defined output to the end-user.

3. Research Methodology

With the assistance of the software INNOVUE, a patent search strategy was quickly drawn up. In the artificial intelligence technology part according to 7 main patent authorities as USPTO, WIPO, EUIPO, CNIPA, JPO, KIPO, TIPO, to search AI patent statistics. This examination allows us to identify possible international based on patent indicators that permit rigorous cross-country comparisons of innovation performances at national and sectional levels based on Rabbani et al. (2018). Their research is to clarify the role of artificial intelligence in the care of patients with non-small cell lung cancer. From their research we conclude 10 keywords that are used to investigate in the fields of subject matter, abstract, and scope of patent application. Also, followed by the research that the scope of medical considerations is considered diverse, from measurement, monitoring, medical care, diagnosis, machine learning, deep learning, treatment, medical materials, we matched with 10 International Patents Classification (IPC) to cross related applications in the medical field for supplementary search and analyze related patents from 1986 to 2021. To ensure data consistency and relevance across the collection, only patents containing the following ten keywords in their title, or content were retrieved. Ten key words including NSCLC/Artificial intelligence/Machine learning/Neural network/Logic programming/Expert system/Lung cancer/big data/ oncology engineering/Deep learning.

Table 1 International Patents Classification from 1986 to 2021

IPC code	Description
G01N:	Investigating or analyzing materials by determining their chemical or physical properties
C12Q:	Measuring or testing processes involving enzymes or microorganisms, compositions or test papers there for; processes of preparing such compositions;
A61K:	Preparations for medical, dental or toilet purposes absorbent pads or surgical articles a61l; soap compositions c11d)
G16H:	Information and communication technology specially adapted for specific application fields.
C07K:	Peptides, genetic engineering processes for obtaining peptides c12n 15/00)
G06N:	Computer systems based on specific computational models.
G06F:	Electric digital data processing.
G06T:	Image data processing or generation, in general.
C12N:	Microorganisms or enzymes; compositions there propagating, preserving, or maintaining microorganisms; mutation or genetic engineering; culture
A01N:	Preservation of bodies of humans or animals or plants or parts there of biocides.

Source: https://www.uspto.gov/web/patents/classification/ 20210630

By applying the INNOVUE software system, based on patent announce year from 1986 to 2020, there are 462 related with AI technology apply for NSCLC patents are found. Manually checked and deducted, Patent whose concepts of AI are not consistent with the proposed definition related with NSCLC were then excluded along with patents which despite having keywords appearing in contents or subject heading did not investigate with NSCLC. Thus, the result in 315 patents are filtered for relevance by analyzing the content and skimming the content.

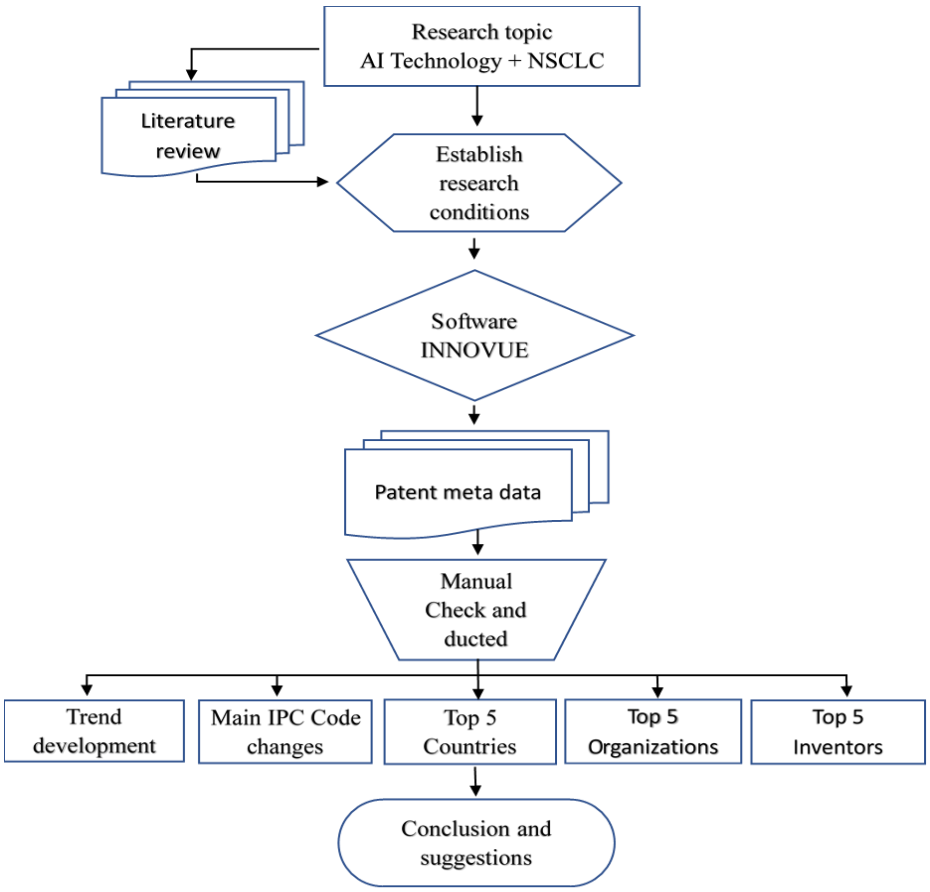


Figure 1 Methodology structure.

4. Data and Result Discussion

4.1 The increasing trend of patent development

As shown in Figure 2, AI technology apply in NSCLS related patent were firstly announced in 1986. Since then, the numbers of related patents were slowly progressed in the following 15 years. After 2001, it seems start revel some concentration in this research field. Until 2019, the patent number start dramatically growth two times and more than previous year from 16 in 2018 compare with number of 36 patent announced in 2019. In 2020, the growth remains rapid increases to 54 patents were announced. From this trend development, AI technology application in the medical care of NSCLC is obviously progress in an optimistic pattern.

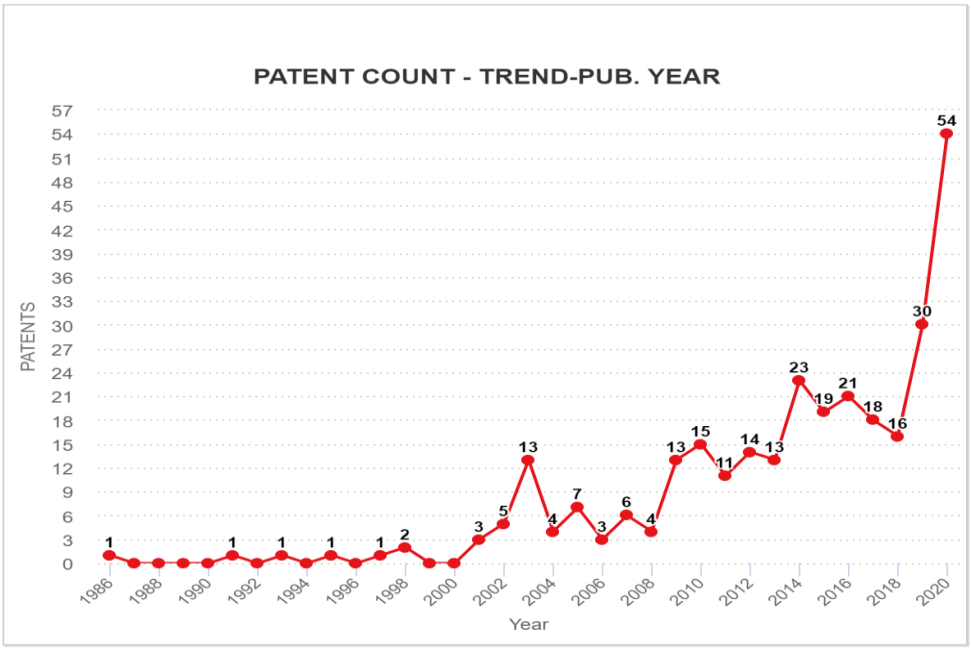


Figure 2 AI technology applied in NSCLS patents from 1986 to 2020

Consequently, Figure 3 shows that the trend of AI technology application in NSCLC development have changed in every 10 years. From 1986 to 2001, there were passively growths in the early stage. Not much patent was announced during the first period. The year after 2001, it seems the progressing pattern has significant increased. More researchers has involved in this field, the notion of AI technology applied in NSCLC treatment finally gather intention of it deserved. Therefore, in this paper we compare two decades observation to analysis the patent development.

First decade is defined as year 2001 to 2010. During this ten years, there were 73 patents were published. As can be seen in diagram (3), the steady increasing patent number represent a growth AI technology have submit an application in NSCLC medical treatment. The next decade 2011 to 2020, there were 219 patents were published, the number of patent be published have spectacularly increased. The increasing pattern shows there is noticeable need for AI technology applied for NSCLC treatment.

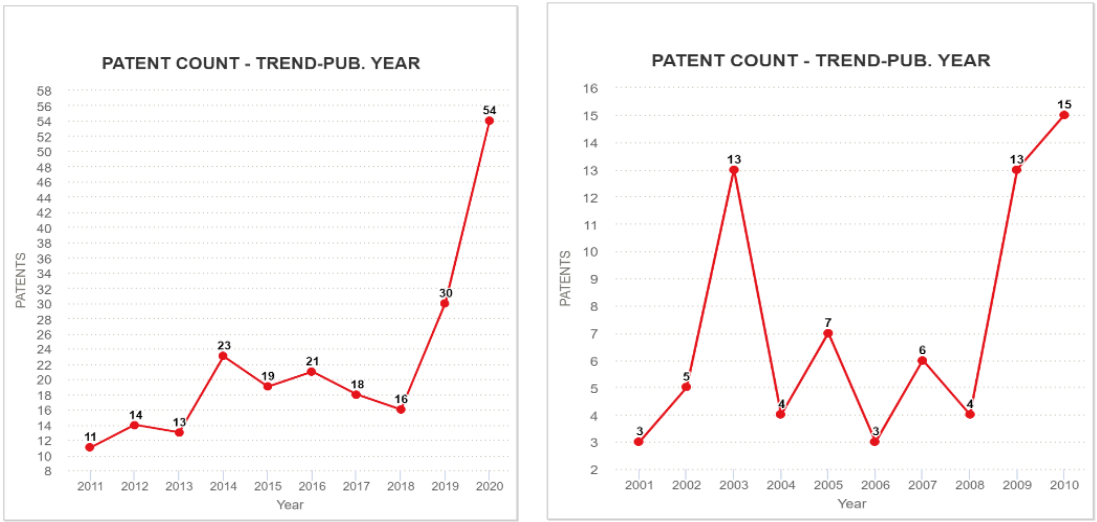
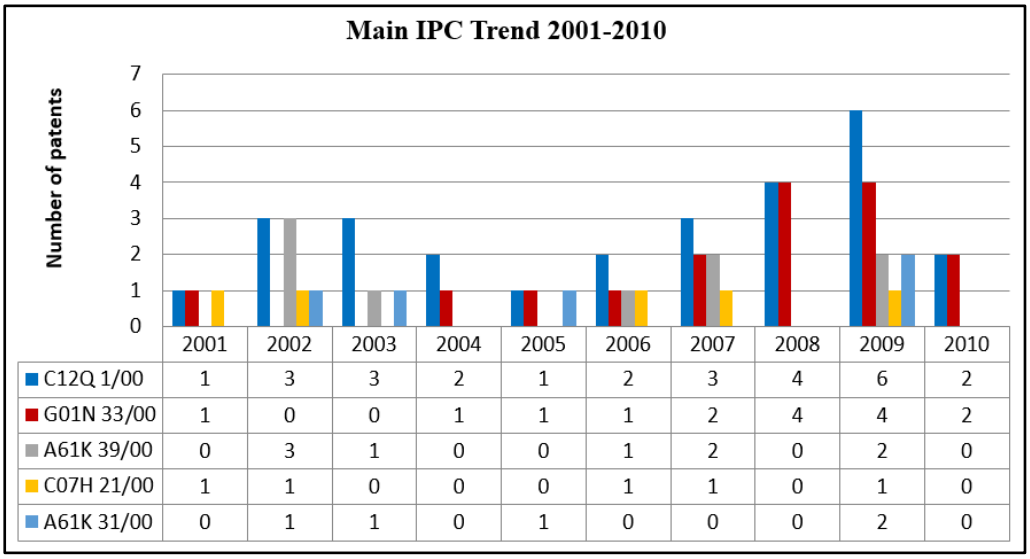


Figure 3 Comparing two decades from 2001 to 2010 and 2011 to 2020.

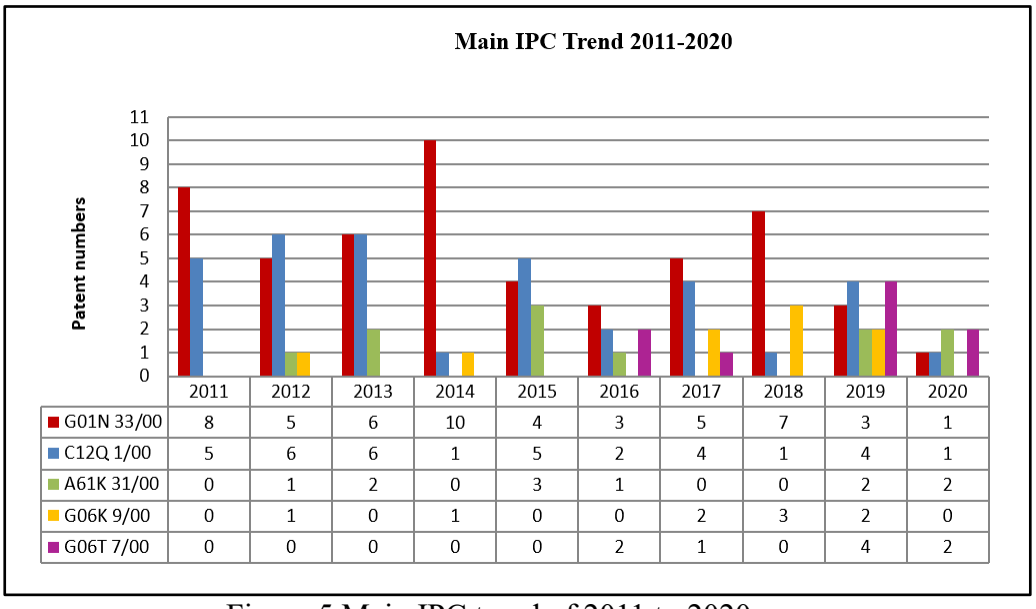
4.2 Main IPC analysis

The IPC system is used by more than 100 different patent offices around the world each classification code has its own particular description and reveals the technical contents of a patent. From Figure 4 and Figure 5, we can observe that for the previous ten years, the C12Q 1/00 attract the most interest and in the next decade it fails to second position of the top five main patent. Contrarily, G01N 33/00 previously were second priority position and become most popular in the following decade. The other patent changes ware A61K 39/00 have swapped by A61 31/00, G06K 9/00 and G06T 7/00 patent distribution replaced C07H 21/00 and A61K 31/00.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
C12Q 1/00	1	3	3	2	1	2	3	4	6	2
G01N 33/00	1	0	0	1	1	1	2	4	4	2
A61K 39/00	0	3	1	0	0	1	2	0	2	0
C07H 21/00	1	1	0	0	0	1	1	0	1	0
A61K 31/00	0	1	1	0	1	0	0	0	2	0

Figure 4 Main IPC trend of 2001 to 2010



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
G01N 33/00	8	5	6	10	4	3	5	7	3	1
C12Q 1/00	5	6	6	1	5	2	4	1	4	1
A61K 31/00	0	1	2	0	3	1	0	0	2	2
G06K 9/00	0	1	0	1	0	0	2	3	2	0
G06T 7/00	0	0	0	0	0	2	1	0	4	2

Figure 5 Main IPC trend of 2011 to 2020.

Table 2 The main IPC code of AI technology applied in NSCLS from 2001 to 2020

Main IPC	Descriptions
G01N 33/00	Investigating or analyzing materials by specific methods not covered by groups G01N 1/00-G01N 31/00
C12Q 1/00	Measuring or testing processes involving enzymes, nucleic acids or microorganisms ; Compositions therefore ; Processes of preparing such compositions
A61K 31/00	Medicinal preparations containing organic active ingredients
A61K 39/00	Medicinal preparations containing antigens or antibodies
G06K 9/00	Methods or arrangements for reading or recognizing printed or written characters or for recognizing patterns, e.g. fingerprints
G06T 7/00	Image analysis
A61K 31/00	Medicinal preparations containing organic active ingredients
C07H 21/00	Compounds containing two or more mononucleotide units having separate phosphate or polyphosphate groups linked by saccharine radicals of nucleoside groups, e.g. nucleic acids

Source: https://www.uspto.gov/web/patents/classification/ 20210630

Generally, it shows measuring or testing processes involving enzymes, nucleic acids or microorganisms and investigating or analyzing materials by specific methods are crucial at the previous stage of patent innovation and they remain the major AI technology treatment for the NSCLC. Medicinal preparations containing antigens or antibodies were changed to organic active ingredients. Methods for arrangement reading or recognizing patterns and image analysis are now become increasing important lately. Deep-learning models that quantitatively track changes in lesions over time may help clinicians tailor treatment plans for individual patients and help stratify patients into different risk groups for clinical trials. Wang et al. (2019) claim that artificial intelligence, especially deep learning, has shown great potential in tumor region identification, prognosis prediction, tumor microenvironment characterization, and metastasis detection by apply pathology image analysis tasks.

4.3 Main players/countries

As we know the patent innovation could be very finance and human power consuming, without government or corporation finance support the patent published could be a mission impossible. As Raghupathi and Raghupathi (2019) declare that countries governments play a key role by they can attain a level of endogenous innovation using multifaceted incentives for science and technology indicators.

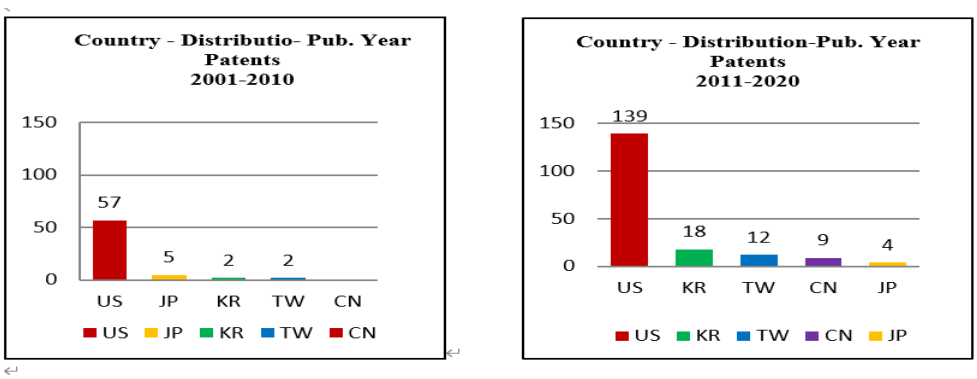


Figure 6 Patents of AI technology applied in NSCLS from 2001 to 2010 vs. 2011-2020

From 2001 to 2010, the top five research countries were ranking order as US, Japan, Korea, Taiwan and China. According to Abadi et al. (2020), from the beginning of 2008 to the end of 2018, more than 123,500 AI-related patents were granted by the USPTO. The United States had the highest number of AI-related patents (87,244), followed by Japan (9,787) and Korea (4,798). Not surprisingly the USPTO have been the most patent application country in the world even in the modern technology development of the AI. Despite from the US, the other top four countries are all from Asia. After 2010, although the countries ranking has slightly changed, except from the US, the AI technology related with NSCLC patent still devote interested within Asia countries. From 2010 to 2020, Korea has become the second large source of the patent distribution country. Japan has failed to the fifth order, while Taiwan and China are ranked as the third and fourth main published countries. From the current trend development, we can conclude that the NSCLC medical care apply AI technology force in Asia cannot be underestimated. However, the major development resource still remains in the US.

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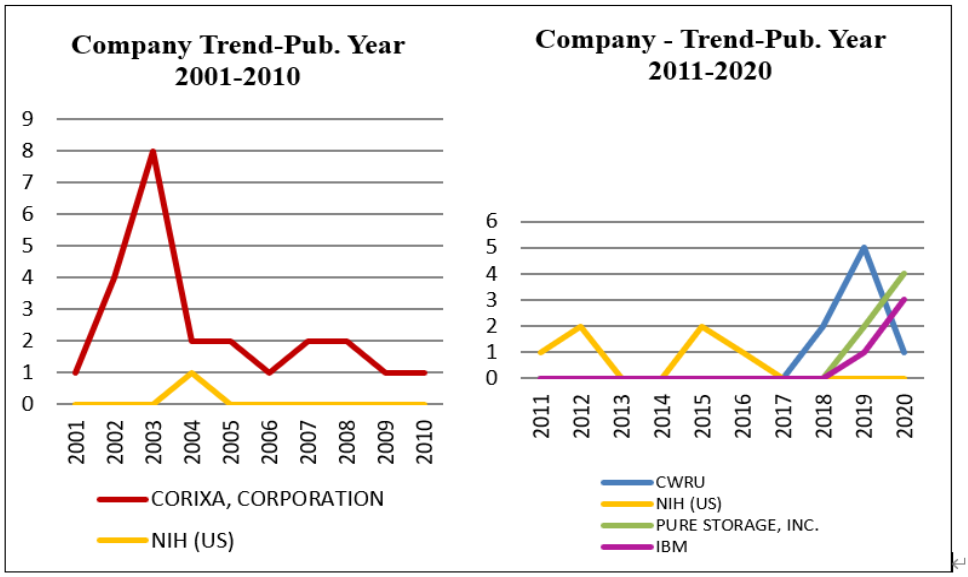

Figure 7 Patents published by companies during 2001 to 2010 vs. 2011 to 2020.

From diagram (8) we can perceive at the commencement CORIXA Corporation was dominating the AI technology development application of NSCLC medication treatment in year 2001-2010, they were the pioneer of the related research. The company was not alone National Institutes of Health (NIH) also have started published related patent although their research progress is remained less impressive. As can be seen the CORIXA Corporation does not have much influence in 2011 to 2020. Followed by online news, CORIXA was merged by GlaxoSmithKline (GSK) at March of 2006. This explains the reason why the used supremacy leader is no longer exists. Instead, Case Western Reserve University (CWRU), IBM, Pure Storage published patents shows aggressive progress, while the NIH remains moderate interest in the research field.

According to Chen and Chang (2010), market value of companies are highly related with their R&D-related capabilities, thus they should increase relative patent position and raise patent citations to further enhance their market value. In this software of INNOVIEW, the setting parameters formula of relative R&D capabilities are shown in Table 3. R&D capabilities formula: Xi = (5pc + 2oc + 1sc + 1ic + 0cc + -1py + 0ay), M = MAX(Xi), Relative R&D capabilities = Xi / M.

Table 3 R&D-related capabilities

Parameter Items	Default Value:
Patents (pc)	5
Other Citings (oc)	2
Self-Citings (sc)	1
Inventor Count (ic)	1
Country Count (cc)	0
Patent Age (py)	-1
Activity Year (ay)	0

Table 4 R&D-related capabilities of the top companies 2001-2010 and 2011-2020

Year	Company	Patents	Others Citings	Self-citings	Inventor Count	Country Count	Patent Age	Activity Year	Relative R&D capabilities
2001 - 2010	CORIXA	18	0	4	29	1	18	7	100%
	NIH (US)	4	0	0	19	1	14	3	24%
2011 - 2020	IBM	7	0	1	19	1	3	3	100%
	CWRU	8	0	0	11	1	4	4	90%
	Pure Storage	6	0	6	5	1	3	2	73%
	NIH (US)	3	0	0	11	1	7	2	37%

As can be seem in diagram (9), these top companies do not cite from others and seldom cite by themselves except Pure Storage Inc. CWRU have highest amount of 8 published patents while they were actively joining the research field for only 4 years. IBM are considered have highest relative R&D capabilities according to their potential research power of 19 inventors and activity year were only three. Pure storage have lately jointed the related research, have done a notable performance. From Table 4, the number of inventors explains the potential of the R&D research capabilities. It is worth to take close observation for their future development. The NIH has constantly remained active in the research of AI technology that related with NSCLC medical care. However, from the two decades of observation, they did not consider AI technology of NSCLC medical application research as the key object.

As shown in Table 5, the top 5 inventors are all work for CORIXA Corporation. Tongtong Wang -- the main inventor, has very productive patent inventory rate. From the table we can observe there were 30% patents were innovated by her and her team. Robert A Henderson was ranked as second dynamic patent innovator. His patents innovation companies are matching with Tongtong Wang. So as other innovators, we might able to assume that it is very likely they were worked as one single research team. Unfortunately, these very productive five innovators seem lost their support and become less productive after 2010. As the CORIXA Corporation merged by GSK, the top five innovators were also no longer exist in the research field.

Table 5 Top 5 inventors of 2001 to 2010

From Year 2001-2010				From Year 2011-2020			
Inventor	Company	Patents	Total Patents	**Inventor**	Company	Patents	Total Patents
Tongtong Wang	CORIXA, Corporation	14	**17**	**Anant Madabhushi**	CWRU	8	**8**
	Robert A. Henderson	1					
	Teresa M. Foy	1					
	Tongtong Wang	1					
Robert A. Henderson	CORIXA, Corporation	12	**15**	**Vamsidhar Velcheti**	CWRU	8	**8**
	Robert A. Henderson	1					
	Teresa M. Foy	1					
	Tongtong Wang	1					
Yoshihiro Watanabe	CORIXA Corporation	10	**10**	**Brian Gold**	PURE Storage, Inc.	6	**6**
Chaitanya S. Bangur	CORIXA Corporation	7	**7**	**Emily Watkins**	PURE Storage, Inc.	6	**6**
Gary R. Fanger	CORIXA Corporation	7	**7**	**Igor Ostrovsky**	PURE Storage, Inc.	6	**6**
Total	---	56	**56**	**Total**	---	34	**34**

From Table 5, we can learn that, unlike previous decade, innovator works for different organizations, in second following ten years, innovators usually only work for one particular company. The top two inventors (Anant Madabhushi and Vansidhar Velcheti) work for CWRU, they work together for the same 8 patents. It seems the result indicates that the two inventors are the explanation research advantages of the CWRU. Schmid and Fajebe (2019) specify that university patents have a particularly deep and wide impact on subsequent technological change. They suggesting policies which attempt to use universities as engines for advancing technological innovation may hold promise then corporations. It seems particular true, from the number of patents CWRU published.

The rest top three innovators are all work for the 6 patents of Pure Storage Inc. Their research performances are also incredibly impressive. Surprisingly, we do not found IBM innovators have ranked as the top five, their 19 innovator still remain very powerful argument that IBM have relatively preceding research power. Within three years, IBM has published 7 patents that related with AI technology of NSCLC medication treatment. It is very promising future research power that has attracted public attention. As noticed the IBM began its effort to bring Watson into the health care industry in 2011. Since then, the company has made nearly 50 announcements about partnerships that were intended to develop new AI-enabled tools for medicine.

To sum up, the company support is relatively important to innovators. As the CORIXIA Corporation merged by GSK, top researchers like Tongtong Wang and Robert A. Henderson does not productive as previous decade. They even don't have published any relative patent after 2010. This is obviously considered as a lost for NSCLC patients for innovators have no longer supported by company like CORIXIA Corporation, consequently they lost their productivity of related patent innovation. Although there are few outstanding researchers like Anant Madabhushi and Vamsidhar Velcheti, the prosperous patent publishing in the related field have gone with the CORIXIA Corporation.

5. Conclusions

This paper applies keywords searching technique by the use of the patent search software INNOVUE. Based on previous research, we identify 10 related keywords and

10 related IPC code to cross search patent data from 1986 to 2021, which have shown in the patents that in the title, abstract, content and related technical fields. By consideration of the patent trend development, we comparing year 2001 to 2010 with 2011 to 2020, to identify the patent trend changes in the two decades. Furthered by analyzes the trend development and forecast the future progress of AI application in medical development. This paper provides suggestion for government that willing try to assist their country in AI healthcare expansion and investors who intended to have insight for future trends related research of AI technology of NSCLC treatment.

From numerous anticipations, we look forward to AI technology could assist current medication care system and provide NSCLC patients better survival rate. From the patent trend analysis, this paper tries to analysis from the patent development of AI technology, which have been apply in NSCLC medical care, visual the patent future. The study presents insights on the phenomenon of international patent develop in AI technology application in NSCLC medication treatment. This research by comparing two decades of patent development, we indicate at national level, this study calls on policy makers to design appropriate policies. The analysis of IPC code and company R&D capabilities allows for effective and optimum resource allocation and talent distribution.

This study concludes: (1) First of all trend development, the number of paten Al technology have implied in NSCLC medical treatment is increasing from 2001 to 2020. (2) Most patent of AI technology applied in NSCLC medical treatment have published in the US, nevertheless, East Asia countries become second big source of the related patent publication. For the trend development, we conclude that at early-stage diagnosis and testing is still considered as the priority of the NSCLC treatment. However, at the lately years, the image analysis is considered increasing important in current medication stage. (3) In this research we can conclude that in the near future, the researchers can pay a close observation to CWRU, IBM and Pure Storage, their development in the related research could be very promising. From their patent published number concern, inventors could consider them as productive investment object. Top innovators are no longer making research for many companies instead they work together for get better quality of patent published.

The findings of this research result highlight concerted efforts in pushing AI technology to clinical usage and impact in future direction of NSCLC care. For patients benefit concern, we do not hope the patent develop individually. Instead, countries, companies and innovators can corporate with each other to fight with patients and create better chance for future patients. Although the idea seems controvert with the patent innovation, however, in the medication related research should put patients benefit for the priority concern. This study is sincerely convinced with high-speed technology development, the boundary might be break in the near future.

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