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Geographic Analysis of Neurosurgery Workforce in Korea

Hye Ran Park, M.D.,[1] Sukh Que Park, M.D. Ph.D.,[1] Jae Hyun Kim, M.D., Ph.D.,[2] Jae Chan Hwang, M.D.,[3] Gwang Soo Lee, M.D.,[1] Jae-Chil Chang, M.D., Ph.D.[1]

Departments of Neurosurgery,[1] Urology,[2] Soonchunhyang University Hospital Seoul, Seoul, Korea
Department of Neurosurgery,[3] Soonchunhyang University Hospital Gumi, Gumi, Korea

Objective : In respect of the health and safety of the public, universal access to health care is an issue of the greatest importance. The geographic distribution of doctors is one of the important factors contributing to access to health care. The aim of this study is to assess the imbalances in the geographic distribution of neurosurgeons across Korea.

Methods : Population data was obtained from the National Statistical Office. We classified geographic groups into 7 metropolitan cities, 78 non-metropolitan cities, and 77 rural areas. The number of doctors and neurosurgeons per 100000 populations in each county unit was calculated using the total number of doctors and neurosurgeons at the country level from 2009 to 2015. The density levels of neurosurgeon and doctor were calculated and depicted in maps.

Results : Between 2009 and 2015, the number of neurosurgeons increased from 2002 to 2557, and the ratio of neurosurgeons per 100000 populations increased from 4.02 to 4.96. The number of neurosurgeons per 100000 populations was highest in metropolitan cities and lowest in rural areas from 2009 to 2015. A comparison of the geographic distribution of neurosurgeons in 2009 and 2015 showed an increase in the regional gap. The neurosurgeon density was affected by country unit characteristics (p=0.000).

Conclusion : Distribution of neurosurgeons throughout Korea is uneven. Neurosurgeons are being increasingly concentrated in a limited number of metropolitan cities. This phenomenon will need to be accounted when planning for a supply of neurosurgeons, allocation of resources and manpower, and the provision of regional neurosurgical services.

Key Words : Geographic mapping · Hospital distribution systems · Neurosurgeons · Health manpower.

INTRODUCTION

Universal access to health care has become increasing restricted, even though it is set as one of the major objectives of the National Health System. Factors influencing the healthcare accessibility include health care system, ability to pay for medical expenses, regional distribution of doctors, socioeconomic status, inequity of examination, and waiting time to for surgery[13]. Of them, the uneven geographic distribution of doctors has been identified as a contributing factor to health inequities. Almost all Organization for Economic Cooperation and Development (OECD) countries face an uneven geographical distribution of doctors[16]. In order to maintain and improve the health of the people, healthcare manpower and

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• Address for reprints : **Jae-Chil Chang, M.D., Ph.D.**
Department of Neurosurgery, Soonchunhyang University Hospital Seoul, Soonchunhyang University College of Medicine, 59 Daesagwan-ro, Yongsan-gu, Seoul 04401, Korea
Tel : +82-2-709-9269, Fax : +82-2-792-5976, E-mail : j7chang@schmc.ac.kr

facilities should meet the social and economic conditions of local residents to balance demand and supply. Medical resources should be deployed to where all citizens can access them quickly and easily. Although the distribution problem of medical resources could be considered as an unimportant problem due to the development of traffic and roads, much of the neurosurgical area is often an interpersonal service that cannot be delayed. Spatial and temporal access is chiefly important because the lack of medical resources reduces the accessibility of residents' access to neurosurgical care. In particular, the accessibility of neurosurgeons in neurosurgical emergencies, such as trauma or vascular, is of utmost importance[12]. The aim of this study is to assess the actual geometrical distribution of neurosurgeons across Korea and to identify possible problem that may arise from such distribution trait.

MATERIALS AND METHODS

Neurosurgeon data

Data on the number of doctors and neurosurgeons in each country unit was obtained from records of the National Health Insurance Service, Ministry for Health, Welfare and Family Affairs. Neurosurgeon and doctor density was defined as the number of neurosurgeons and doctors, per 100000 individuals at county level, respectively. Population data was obtained from the Population Census Division of National Statistical Office.

Geographic classification

Municipalities consist of three types of geographic groups : metropolitan cities, non-metropolitan cities, and rural areas. We classified geographic groups according to the Korean Ministry of Security and Public Administration. Seven metropolitan cities include Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan, each with population size exceeding 1000000 inhabitants. Non-metropolitan cities (shi) were defined as other cities, with population size exceeding 50000 people. Rural areas include towns and villages (gun), with population size less than 50000 people. The current official county units are 163, including 7 metropolitan cities, 78 non-metropolitan cities, and 78 rural areas. We analyzed a total of 162 county units comprised of 7 metropolitan cities, 78 non-metropolitan cities, and 77 rural areas, reflecting the change of administrative district.

Healthcare environment data

Using publicly available data from the National Statistical Office, the trends in the four major emergent diseases in the neurosurgical field were analyzed : cerebral infarction, intracerebral hemorrhage, subarachnoid hemorrhage, and traumatic brain injury.

Statistical analysis

The number of doctors and neurosurgeons per 100000 populations in each county unit was calculated using a total number of doctors and neurosurgeons at the county level from 2009 to 2015. Maps were generated using X-Ray Map for Web GIS software (http://biz-gis.com/XRayMap; BIZ-GIS, Seoul, Korea). The level of neurosurgeon density was classified as 0 to 2, 2 to 4, 4 to 6 and greater than 6 neurosurgeons per 100000 populations in one map. The level of doctor density was classified as 0 to 80, 80 to 120, 120 to 160, 160 to 200, and greater than 200 doctors per 100000 populations in another map. Total production sum of each country unit and individual income data were obtained from the Survey Management Bureau of National Statistical Office.

RESULTS

General trends

Between 2009 and 2015, the number of doctors increased from 86761 to 95076, and the ratio of doctors per 100000 populations increased from 159 to 185. In the same period, the number of neurosurgeons increased from 2002 to 2557, and the ratio of neurosurgeons per 100000 populations increased from 4.02 to 4.96 (Table 1). Table 2 shows the change in neurosurgeon density according to administrative districts. The number of neurosurgeons per 100000 populations in 2009 was 4.50 in metropolitan cities, 3.94 in non-metropolitan cities, and 2.40 in rural area. In 2015, it was 5.57 in metropolitan cities, 4.70 in non-metropolitan cities and 2.93 in rural area, respectively. The trend toward urban areas continued throughout the entire period. The number of neurosurgeons per 100000 populations was highest in metropolitan cities and lowest in rural areas from 2009 to 2015. Fig. 1A demonstrates the trend of absolute number of doctors and neurosurgeons by

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Table 1. Ratio of doctors and neurosurgeons per 1000 population by location, 2009–2015

	2009		2010		2011		2012		2013		2014		2015	
	Doctor ratio	Neurosurgeon ratio	Doctor ratio	Neurosurgeon ratio	Doctor ratio	Neurosurgeon ratio	Doctor ratio	Neurosurgeon ratio	Doctor ratio	Neurosurgeon ratio	Doctor ratio	Neurosurgeon ratio	Doctor ratio	Neurosurgeon ratio
Seoul	2.27	0.0450	2.37	0.0462	2.42	0.0488	2.48	0.0519	2.67	0.0540	2.72	0.0548	2.77	0.0575
Busan	1.75	0.0421	1.83	0.0446	1.91	0.0473	1.96	0.0475	2.03	0.0499	2.09	0.0534	2.15	0.0544
Daegu	1.88	0.0514	1.90	0.0526	1.93	0.0554	2.00	0.0575	2.04	0.0576	2.08	0.0582	2.14	0.0615
Incheon	1.24	0.0350	1.23	0.0373	1.29	0.0386	1.31	0.0380	1.37	0.0396	1.44	0.0434	1.49	0.0441
Gwangju	1.86	0.0579	1.97	0.0626	2.04	0.0629	2.06	0.0667	2.11	0.0679	2.16	0.0657	2.24	0.0734
Daejeon	1.98	0.0505	1.98	0.0545	2.00	0.0534	2.09	0.0512	2.12	0.0515	2.16	0.0542	2.24	0.0579
Ulsan	1.19	0.0386	1.19	0.0391	1.25	0.0387	1.26	0.0392	1.30	0.0398	1.32	0.0386	1.39	0.0409
Sejong*							0.76	0.0442	0.79	0.0409	0.79	0.0384	0.75	0.0285
Gyeonggi	1.25	0.0307	1.27	0.0322	1.32	0.0343	1.35	0.0357	1.40	0.0386	1.42	0.0408	1.45	0.0410
Gangwon	1.47	0.0449	1.51	0.0471	1.50	0.0469	1.53	0.0474	1.56	0.0473	1.60	0.0512	1.63	0.0536
Chungbuk	1.30	0.0478	1.32	0.0484	1.35	0.0473	1.35	0.0485	1.39	0.0521	1.42	0.0488	1.46	0.0486
Chungnam	1.26	0.0329	1.27	0.0323	1.29	0.0343	1.32	0.0335	1.35	0.0347	1.38	0.0359	1.40	0.0380
Jeonbuk	1.64	0.0431	1.65	0.0455	1.67	0.0448	1.68	0.0443	1.75	0.0481	1.79	0.0492	1.86	0.0508
Jeonnam	1.37	0.0382	1.40	0.0407	1.42	0.0434	1.46	0.0429	1.50	0.0477	1.51	0.0504	1.54	0.0503
Gyeongbuk	1.13	0.0352	1.15	0.0372	1.18	0.0411	1.20	0.0404	1.25	0.0430	1.28	0.0433	1.27	0.0444
Gyeongnam	1.27	0.0431	1.30	0.0438	1.32	0.0444	1.35	0.0449	1.38	0.0450	1.43	0.0472	1.46	0.0484
Jeju	1.35	0.0409	1.41	0.0350	1.44	0.0399	1.48	0.0463	1.58	0.0522	1.58	0.0527	1.64	0.0512
Total	1.59	0.0402	1.63	0.0417	1.67	0.0435	1.70	0.0446	1.77	0.0467	1.81	0.0482	1.85	0.0496

*Sejong city was created as a special administrative distinct from parts of south and north Chungcheong provinces administrative district from 2009 to 2015. The area with more than 50 neurosurgeons was a metropolitan area, and there was no significant difference in absolute number of neurosurgeons between 2009 and 2015. Fig. 1B shows the trend of the neurosurgeon density per 100000 population classified by administrative district. Compared to 2009, the concentration into the metropolitan and non-metropolitan cities is further intensified in 2015. In particular, supply shortage was observed in Gangwon and Yeongnam regions, and the distribution within the same region was uneven according to administrative district units. Table 3 shows the number and relative proportions of neurosurgeons between administrative units. The gap of the value between metropolitan cities and rural areas was 1.88 times in 2009. Between 2009 and 2015, the value in metropolitan cities increased by 23.8%, while that in rural areas increased by 22.1%. The gap between metropolitan cities and rural areas was still 1.90 times in 2015. Repeated measurements of analysis of variance revealed that neurosurgeon den-

Table 2. Density of neurosurgeons according to country characteristics

Area	Neurosurgeon density*/No. of neurosurgeons						
	2009	2010	2011	2012	2013	2014	2015
Metropolitan cities	4.50/1037	4.68/1092	4.87/1136	5.03/1175	5.19/1212	5.33/1244	5.57/1299
Non-metropolitan cities	3.94/875	3.95/919	4.10/963	4.23/1003	4.49/1073	4.65/1126	4.70/1148
Rural	2.40/90	2.55/96	2.93/110	2.56/96	2.75/103	2.75/103	2.93/110
Total	4.02/2002	4.17/2107	4.35/2209	4.46/2274	4.67/2388	4.82/2473	4.96/2557

*Neurosurgeon density is defined as number of neurosurgeons/100000 populations

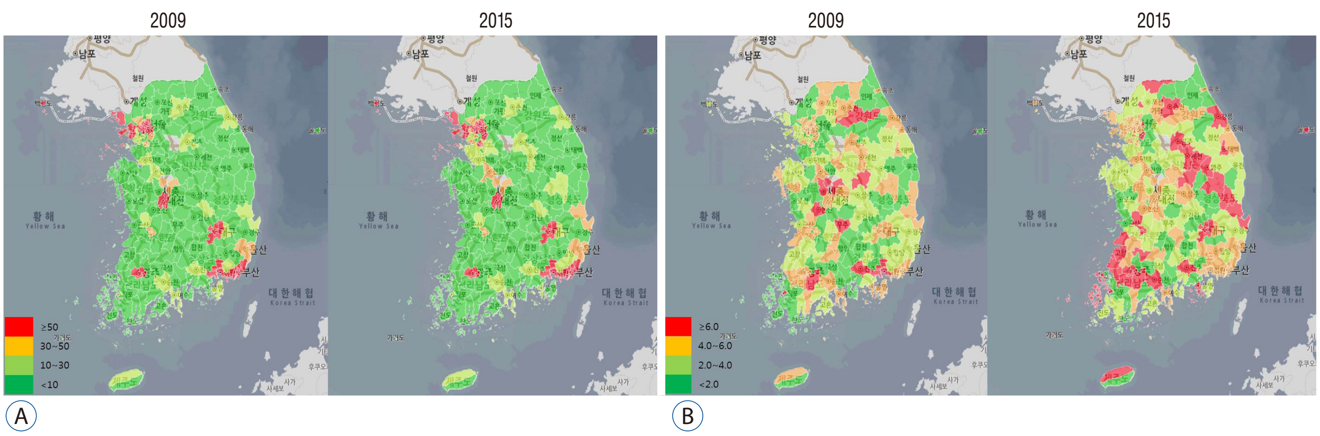

Fig. 1. Color map representing the geographic distribution of neurosurgeon number (A) and density (B) in 2009 and 2015.

Table 3. Relative value of neurosurgeon density according to country characteristics

Year	Difference of neurosurgeon density			Relative ratio of neurosurgeon density		
	Metropolitan/non-metropolitan cities	Metropolitan/rural	Non-metropolitan cities/rural	Metropolitan/non-metropolitan cities	Metropolitan/rural	Non-metropolitan cities/rural
2009	0.56	2.10	1.54	1.14	1.88	1.64
2010	0.73	2.13	1.4	1.18	1.84	1.55
2011	0.77	1.94	1.17	1.19	1.66	1.40
2012	0.80	2.47	1.67	1.19	1.96	1.65
2013	0.70	2.63	1.93	1.16	2.03	1.75
2014	0.68	2.58	1.9	1.15	1.94	1.69
2015	0.87	2.64	1.77	1.19	1.90	1.60

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sity was more affected by country unit characteristics (*p*=0.000) than year (*p*=0.834) (Table 4).

Regional distribution of the neurosurgeons

Fig. 2 reveals the neurosurgeon density by region. In Seoul-Gyeonggi province, as of 2015, only 4 of 34 regions were in short-supply, with less than 2 neurosurgeons per 100000 populations. Guri, Dongducheon, and Seongnam were in over-supply, with more than 6 neurosurgeons per 100000 populations. In Seoul, the number of neurosurgeons per 100000 populations increased rapidly from 4.5 in 2009 to 5.75 in 2015, and is expected to become in over-supply in the near future. In Gangwon area, 6 out of 18 areas were in short-supply, and there was no neurosurgeon in these areas. On the other hand, other 5 regions were in over-supply of neurosurgeon with more than 6. It is believed that the number of neu-

Table 4. Repeated measures ANOVA results of the relationship between country unit characteristics and year, and neurosurgeon density

Parameters	Type III sum of squares	Mean square	F	*p*-value
Country characteristics	732.572	366.286	66.476	0.000
Year	15.382	2.564	0.465	0.834
Error	6132.676	5.510		
Total	20501.136			
Corrected total	6935.858			

R squared=0.116 (adjusted R squared=0.100). ANOVA : analysis of variance

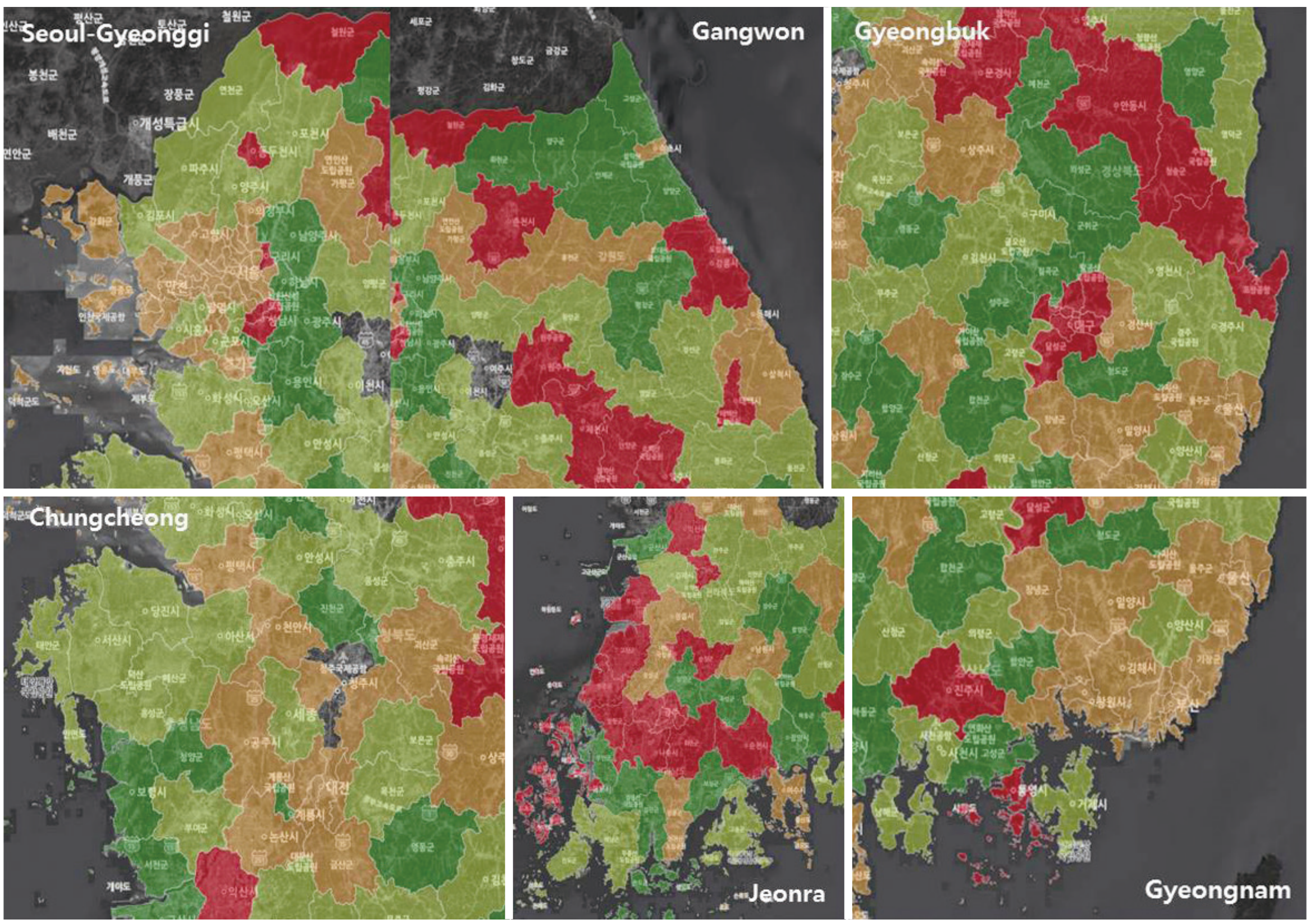

Fig. 2. Color map representing the neurosurgeon density in 2015 by region.

rosurgeons serving in military surveillance was reflected in these regions as over-supplied. In Chungcheong province, 7 out of 28 districts were in short-supply, and 2 cities were in over-supply with more than 6 neurosurgeons per 100000 populations. In Daegu-Gyeongbuk province, 7 of 24 areas were in short-supply, and there was no neurosurgeon in 6 of them. However, other 7 cities including Daegu and Pohang were in over-supply. The regional variation was large. In Busan-Gyeongnam area, 5 out of 20 areas were in short-supply, while 2 cities (Jinju and Tongyeong) were in over-supply of neurosurgeon. The remaining areas had relatively even distribution of neurosurgeons. In Jeonbuk, only one area was in short-supply, while 5 areas were in over-supply. In Jeonnam, 8 out of 23 districts were in short-supply, while other 8 areas were over-supplied, showing a regional variation. This uneven distribution of neurosurgeons seems to be influenced by the fact that the high-grade, big-sized hospitals that operate the neurosurgery department continue to be concentrated in urban area (Table 5).

Trends of neurosurgical diseases

To estimate the demand for emergency disease treatment in neurosurgical field, recent trends in insurance claims of cerebral infarction, traumatic brain injury, intracerebral hemorrhage, and subarachnoid hemorrhage were reviewed (Fig. 3). The actual number of patients treated with cerebral infarction increased from 85734 in 2009 to 95876 in 2015, and the cost of treatment increased from 43915 million won in 2009 to 79404 million won in 2015. The actual number of patients with traumatic brain injury increased from 46092 in 2009 to 48229 in 2012, and then decreased to 46073 in 2015. However, the cost of treatment for traumatic brain injury steadily increased from 11554 million won in 2009 to 19189 million won in 2015. The actual number of intracerebral hemorrhage increased from 18755 in 2009 to 21725 in 2015, and the cost of treatment also increased from 16931 million won to 29465 million won between 2009 and 2015. Subarachnoid hemorrhage also showed an increasing trend in the actual number of patients (8533 in 2009 and 9991 in 2015) and the cost of treatment (10138 million won in 2009 and 16077 million won in 2015). All of the 4 neurosurgical diseases increased in the number of actual patients and the medical expenses in the last 6 years.

Table 5. Geographical distribution of hospitals by size

	2009				2015			
	Tertiary general hospital	General hospital	Hospital	Clinic	Tertiary general hospital	General hospital	Hospital	Clinic
Seoul	17	42	232	7142	14	42	218	7802
Busan	4	22	200	2065	4	24	130	2198
Daegu	4	7	136	1460	4	8	114	1615
Incheon	2	12	85	1313	3	16	55	1444
Gwangju	2	17	66	826	2	20	75	893
Daejeon	2	6	68	964	1	9	38	1026
Ulsan	0	4	64	516	1	6	40	574
Sejong	-	-	-	-	0	0	1	100
Gyeonggi	5	48	383	5470	5	53	288	6159
Gangwon	2	14	58	660	1	14	49	717
Chungbuk	1	9	63	764	1	11	40	815
Chungnam	2	9	93	993	2	11	51	1024
Jeonbuk	2	12	124	1042	2	10	81	1107
Jeonnam	0	19	112	888	1	22	83	905
Gyeongbuk	0	18	146	1169	0	19	84	1226
Gyeongnam	1	24	198	1457	2	22	142	1522
Jeju	0	6	11	298	0	7	7	361
Total	44	269	2039	27027	43	294	1496	29488

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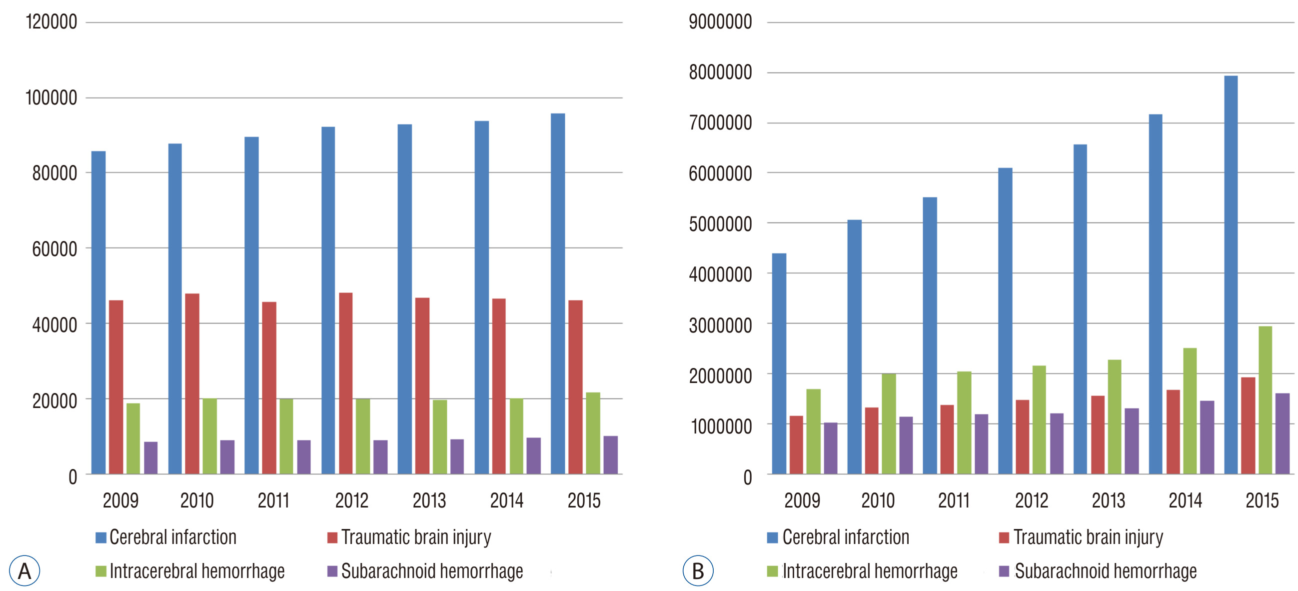

Fig. 3. Recent trends in the number of patients and the cost of treatment of cerebral infarction, traumatic brain injury, intracerebral hemorrhage, and subarachnoid hemorrhage. A : The number of patients treated, B : The cost of treatment (units : 10000 won).

DISCUSSION

The two most important factors in terms of accessibility of medical resources are that there should be a sufficient number of doctors and the doctors should be evenly distributed throughout the area. Doctor shortages in certain areas increase unmet medical demand by increasing the patients' travel and waiting time. Access to healthcare resources has some impact on local disease outcomes, because medical resources increase treatment opportunities for inhabitants. Municipal districts with a lot of medical supply per population show low total mortality, cancer mortality, and mortality due to cardiovascular diseases[18,19]. According to the report on the case of regional stroke centers and the difference in stroke mortality rates, published by the Stroke Society of Korea in 2015[10], about 60% of the stroke centers were concentrated in Seoul, Gyeonggi, and other metropolitan cities, while other areas including Ulsan, Gyeongbuk, and Chungnam have less than one. This shows serious regional disparities. The stroke mortality rate also showed an evident regional difference. When analyzed the average stroke mortality rates for the 3 years (2011–2013), the difference between the lowest and highest mortality rate region was 1.6 times.

For this reason, there are opinions that the number of medical students should be increased. Those who support this opinion argue that the regional imbalance of doctors is due to a lack of doctors. The number of doctors per 1000 people in Korea is 2.2, ranking 24 out of 33 OECD member countries (3.3 on average). The annual number of medical service cases per doctor in Korea is 6732, which is the highest among OECD countries with average of 2277 cases. However, the number of medical students stayed at 3058 per year for 9 years from 2007. In addition, the doctor shortage is intensifying in some departments including neurosurgery, and doctor demand would also increase as 80-hour workload per week for residents is mandatory. It is argued that it is difficult to obtain a doctor in the rural area because there is not enough doctor supply compared to demand[2].

The opinions from medical field are different. If we increase the number of doctors according to the prediction of the number of doctors without consideration of the decrease in the fertility rate, it would be an oversupply in 2030s. Rather than increasing the absolute number of doctors, it is more important to even out the regional distribution. In particular, neurosurgeon is difficult to open a hospital and perform primary healthcare services, because advanced medical equipment and medical system are required. For these reasons, there are some opinions that the construction and qualitative management of large-scale national hospital in rural area is very crucial.

The concentration of doctors in urban areas is a common phenomenon in OECD countries[16]. The reasons are that the professional services like operation are concentrated in urban areas and the doctors prefer to work in the cities rather than rural areas. However, Korea, along with Japan, has a relatively smaller difference in doctor density between urban and rural areas than other OECD countries.

Studies on the demand and geographical distribution of neurosurgeons were conducted at an interval of years in the United States and Europe, and the problem has been pointed out that neurosurgeons who are able to treat neurosurgical emergent diseases are increasingly concentrated in some large institutions[1,4-7,11,14]. However, in Korea, such studies have been led by government affiliated research institutes, and there has been no research or approach from the perspective of neurosurgeons. Other OECD countries have been involved in a number of policy interventions to resolve regional imbalances in doctors[16]. The first is financial incentives. Canada, the United Kingdom, and New Zealand governments pay extra to doctors working in rural areas. Additionally, Australia, Canada, and the United Kingdom support the doctors who start their career in rural areas by providing them the initial cost for opening or transferring from urban to rural areas[15]. Although these financial incentives have been successful increasing the number of doctors in rural areas to a certain extent, but it is unclear whether it is more cost-effective than education or regulatory policies. The second is the medical education policy. Australia operates a program that offers special admissions and scholarships to medical students from rural areas, which has been effective in inducing doctors to work in rural areas[3]. In addition, Australia, Canada, Greece, and the United Kingdom have inclusion of mandatory experience in rural areas in medical school education curriculum, allowing medical students to have experience in diverse environments and acquire necessary knowledge and skills for medical care in rural area[9]. Norway, Sweden, and New Zealand have established medical schools in rural areas, attracting more students from rural areas and providing more training experiences in rural areas[9]. The third is the regulatory policy. Australia and Austria are limiting the number of payments to doctors by region[8]. Germany and the United Kingdom restrict doctor practice in oversupplied areas, such as not issuing a license in areas where a set number of doctors proposed by the regional health plan is exceeded[17].

This study has some limitations. First, this research was carried out based on the administrative district. It is ambiguous whether the division of administrative district reflects the actual living area of the local inhabitants. In addition, as the development of traffic and roads, the measurements of medical accessibility is unclear as to the classification using administrative districts, and it was overlooked that the influence was different depending on the size of hospitals by region. Second, the qualitative level of individual neurosurgeons was not reflected in this study. Medical institutions with low economic levels are small-sized and difficult to invest in personnel and equipments. Therefore, there is a difference in the level of facilities provided and the quality of medical services provided to patients. Third, the distribution of sub-specialties was not reflected. Currently, most neurosurgeons specialize in detailed areas, and it will be further necessary to analyze the regional distribution of neurosurgeons with subspecialty.

CONCLUSION

The number of neurosurgeons in Korea is steadily increasing. However, the distribution of neurosurgeons remains uneven and continues to be concentrated in urban areas. This phenomenon affects the quality of treatment and prognosis of neurosurgical diseases in underprivileged patients. It is time to effectively arrange the appropriate supply of neurosurgeons, allocation of medical resources and personnel, and provision of neurosurgical services to remote areas. A monitoring system should be established for a proper supply of health care resources and resolution of regional disparities. Establishing the construction and qualitative management of large-scale national hospital in rural area could be another alternative. First of all, it is necessary to accurately understand total amount of neurosurgical demand and the distribution of neurosurgeons by region and by sub-specialty, in order to solve the inequality of spatial and temporal accessibility to neurosurgical care.

PATIENT CONSENT

The patient provided written informed consent for the publication and the use of their images.

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References

1. Bean JR : Neurosurgical emergency and trauma services: legal, regulatory, and socioeconomic barriers. **Clin Neurosurg 54 :** 149-152, 2007
2. Chung HS KJ, Park HK, Lee WJ, Han DU : Future need and supply of practicing doctors ini total and by speciality. **Yonsei Institute for Health and Welfare,** 2011.
3. Dunbabin JS, Levitt L : Rural origin and rural medical exposure: their impact on the rural and remote medical workforce in Australia. **Rural Remote Health 3 :** 212, 2003
4. Ecker RD, Levy EI, Hopkins LN : Workforce needs for endovascular neurosurgery. **Neurosurgery 59(5 Suppl 3) :** S271-S276; discussion S3-S13, 2006
5. Friedlich DL, Feustel PJ, Popp AJ : Workforce demand for neurosurgeons in the United States of America: a 13-year retrospective study. **J Neurosurg 90 :** 993-997, 1999
6. Hankinson TC, Bohman LE, Vanaman M, Egorova N, Mocco J, Orrico KO, et al. : Geographical neurosurgery workforce analysis from 1990 to 2005 improves our understanding of the role of market factors. **Clin Neurosurg 55 :** 145-149, 2008
7. Harbrecht BG, Smith JW, Franklin GA, Miller FB, Richardson JD : Decreasing regional neurosurgical workforce-a blueprint for disaster. **J Trauma 68 :** 1367-1372; discussion 1372-1374, 2010
8. Kamalakanthan A, Jackson S : Doctor supply in Australia: rural–urban imbalances and regulated supply. **Aust J Prim Health 15 :** 3-8, 2009
9. Laven G, Wilkinson D : Rural doctors and rural backgrounds: how strong is the evidence? A systematic review. **Aust J Rural Health 11 :** 277-284, 2003
10. Lee SJ, Park HK, Park TH, Lee KB, Bae HJ, Rha JH, et al. : Stroke system of care: a policy statement from the Korean Stroke Society. **J Korean Neurol Assoc 33 :** 226-228, 2015
11. Murphy J : Care of the patient with traumatic brain injury: urban versus rural challenges. **Adv Emerg Nurs J 26 :** 231-236, 2004
12. Oncel MY, Ozdemir R, Kahilogulları G, Yurttutan S, Erdeve O, Dilmen U : The effect of surgery time on prognosis in newborns with meningomyelocele. **J Korean Neurosurg Soc 51 :** 359-362, 2012
13. Organization for Economic Cooperation and Development : **Health at a glance 2013: OECD indicators.** Paris : OECD Publishing, 2013, pp63-67
14. Reulen HJ, Hide RA, Bettag M, Bodosi M, Cunha E Sa M : A report on neurosurgical workforce in the countries of the EU and associated states. Task force "Workforce planning", UEMS section of neurosurgery. **Acta Neurochir (Wien) 151 :** 715-721, 2009
15. Rourke J : Increasing the number of rural physicians. **CMAJ 178 :** 322-325, 2008
16. Simoens S, Hurst J : **The supply of physician services in OECD countries. OECD health working papers,** No. 21. Paris : OECD, 2006, pp38-49
17. Simonet D : Healthcare reforms and cost reduction strategies in Europe: the cases of Germany, UK, Switzerland, Italy and France. **Int J Health Care Qual Assur 23 :** 470-488, 2010
18. Walker R, Whiting D, Unwin N, Mugusi F, Swai M, Aris E, et al. : Stroke incidence in rural and urban Tanzania: a prospective, community-based study. **Lancet Neurol 9 :** 786-792, 2010
19. Woods R : Urban-rural mortality differentials: an unresolved debate. **Popul Dev Rev 29 :** 29-46, 2003