

Original Article  
Surgery



# Analysis of Pediatric Surgery Using the National Healthcare Insurance Service Database in Korea: How Many Pediatric Surgeons Do We Need in Korea?

Chaeyoun Oh ,<sup>1</sup> Sanghoon Lee ,<sup>2</sup> Hye Kyung Chang ,<sup>3</sup> Soo Min Ahn ,<sup>4</sup> Kyunghye Chae ,<sup>5</sup> Sujeong Kim ,<sup>5</sup> Sukil Kim ,<sup>5</sup> and Jeong-Meen Seo <sup>2</sup>

OPEN ACCESS

Received: Jan 12, 2021

Accepted: Mar 25, 2021

Address for Correspondence:

Jeong-Meen Seo, MD, PhD

Department of Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, 81 Irwon-ro, Gangnam-gu, Seoul 06351, Korea.

E-mail: jm0815.seo@samsung.com

© 2021 The Korean Academy of Medical Sciences.

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ORCID iDs

Chaeyoun Oh   
<https://orcid.org/0000-0001-9734-0869>  
Sanghoon Lee   
<https://orcid.org/0000-0002-5086-1461>  
Hye Kyung Chang   
<https://orcid.org/0000-0003-2537-7464>  
Soo Min Ahn   
<https://orcid.org/0000-0002-2854-5032>  
Kyunghye Chae   
<https://orcid.org/0000-0003-2030-0847>  
Sujeong Kim   
<https://orcid.org/0000-0001-9357-7105>  
Sukil Kim   
<https://orcid.org/0000-0001-9730-9845>  
Jeong-Meen Seo   
<https://orcid.org/0000-0002-5527-3976>

<sup>1</sup>Department of Pediatric Surgery, Korea University Ansan Hospital, Korea University College of Medicine, Seoul, Korea

<sup>2</sup>Department of Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

<sup>3</sup>Department of Pediatric Surgery, Kyung Hee University Hospital, Kyung Hee University College of Medicine, Seoul, Korea

<sup>4</sup>Department of Pediatric Surgery, Gangnam Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

<sup>5</sup>Department of Preventive Medicine, College of Medicine, The Catholic University of Korea, Seoul, Korea

## ABSTRACT

**Background:** In the past, general surgeons (GSs) without a pediatric surgical subspecialty often performed surgery on children and, even now, GSs are performing many pediatric surgeries. We aimed to investigate the involvement of pediatric surgeons (PSs) and GSs in pediatric surgery, compare the outcomes of surgery in the neonatal intensive care unit (NICU), and estimate the appropriate PS workforce in Korea.

**Methods:** We used surgical data from the National Health Insurance Service database that was collected from patients under the age of 19 years in hospitals nationwide from January 2002 to December 2017. In this database, we found 37 hospitals where PSs worked by using the index operation (congenital diaphragmatic hernia, esophageal atresia, hypertrophic pyloric stenosis, Hirschsprung's disease, abdominal wall defect, jejunoileal atresia, malrotation, anorectal malformation, and biliary atresia). It was assumed that the surgery in the 37 hospitals was performed by PS and that the surgery in other hospitals was performed by GS. Mortality was analyzed to compare the outcomes of acute abdominal surgery in the NICU. We estimated the number of PS currently needed in Korea for each situation under the assumption that PS would perform all operations for the index operation, main pediatric diseases (index operation + gastroesophageal reflux disease, choledochal cyst, inguinal hernia, and appendicitis), acute abdominal surgery in the NICU, and all pediatric surgeries. Additionally, we estimated the appropriate number of PS required for more advanced pediatric surgery in the future.

**Results:** The number of pediatric surgeries from 2002 to 2017 increased by 124%. Approximately 10.25% of the total pediatric surgeries were performed by PSs, and the percentage of the surgery performed by PSs increased from 8.32% in 2002 to 15.92% in 2017. The percentage of index operations performed by PSs annually was 62.44% in average. It was only 47.81% in 2002, and increased to 88.79% in 2017. During the last 5 years of the study

**Funding**

This research was supported by the Korean Association of Pediatric Surgeons (2019).

**Disclosure**

The authors have no potential conflicts of interest to disclose.

**Author Contributions**

Conceptualization: Oh C, Seo JM, Lee S, Chang HK, Ahn SM, Kim S<sup>1</sup>. Data curation: Oh C, Chae K, Kim S<sup>1</sup>, Kim S<sup>2</sup>. Formal analysis: Oh C, Seo JM, Chang HK, Ahn SM, Chae K, Kim S<sup>1</sup>. Investigation: Chae K, Kim S<sup>1</sup>, Kim S<sup>2</sup>. Methodology: Oh C, Lee S, Seo JM, Kim S<sup>1</sup>. Writing - original draft: Oh C. Writing - review & editing: Lee S, Seo JM. Kim S,<sup>1</sup> Sukil Kim; Kim S,<sup>2</sup> Sujeong Kim.

period, the average annual number of surgeries for main pediatric diseases was approximately 33,228. The ratio of the number of surgeries performed by PS vs. GS steadily increased in main pediatric diseases, however, the ratio of the number of surgery performed by PS for inguinal hernia and appendicitis remained low in the most recent years. The percentage of the number of acute abdominal surgery performed by PS in the NICU was 44% in 2002, but it had recently risen to 89.7%. After 30 days of birth, mortality was significantly lower in all groups that were operated on by PS, rather than GS, during the last 5 years. In 2019, 49 PSs who were under the age of 65 years were actively working in Korea. Assuming that all pediatric surgeries of the patients under the age of 19 years should be performed by PS, the minimum number of PS currently required was about 63 if they perform all of the index operations, the main pediatric surgery was about 209, the NICU operation was about 63, and the all pediatric surgeries was about 366. Additionally, it was determined that approximately 165 to 206 PS will be appropriate for Korea to implement more advanced pediatric surgery in the future.

**Conclusion:** The proportion of the pediatric surgery performed by PS rather than GS is increasing in Korea, but it is still widely performed by GS. PSs have better operative outcomes for acute abdominal surgery in the NICU than GSs. We believe that at least the index operation or the NICU operation should be performed by PS for better outcome, and that a minimum of 63 PSs are needed in Korea to do so. In addition, approximately 200 PSs will be required in Korea in order to manage main pediatric diseases and to achieve more advanced pediatric surgery in the future.

**Keywords:** Pediatric Surgery; Korea; Pediatric Surgeon; General Surgeon; Workforce

## INTRODUCTION

In 1984, 14 pediatric surgeons (PSs) established the Korean Association of Pediatric Surgeons (KAPS) and Korean PSs have since made steady progress. During the past 35 years, 155 PS and trainees have registered with the KAPS, and in 2019, 49 who were under the age of 65 years were actively working in Korea.<sup>1</sup> In 1991, for the first time in Korea, a national survey of chief pediatric surgical diseases was conducted with members of the KAPS.<sup>2</sup> Since then, national surveys of these diseases have been performed with KAPS members every year, and the members frequently communicate with each other through regular meetings and academic conferences.

In Korea, a surgeon who has trained in general surgery becomes qualified as a PS when he/she completes a fellowship in pediatric surgery at an institution accredited by the KAPS. In the past, general surgeons (GSs) without a pediatric surgical subspecialty have often performed surgery on children, and many pediatric surgeries are still being performed by GS. This is because the concept and policies of the pediatric surgical subspecialty are not well established, and there is no consensus on whether GS with an adult surgical subspecialty should treat pediatric patients. There are still some tertiary hospitals without PS in Korea. The involvement of GS in the care of pediatric surgical patients has also occurred for those with the main pediatric surgical diseases, such as congenital anomalies, and neonatal intensive care unit (NICU) patients. Several studies have reported that the outcomes of surgery for some main pediatric surgical diseases are better when the surgery is performed by PS than when performed by GS.<sup>3-9</sup>

During the development of surgery, interest in surgical subspecialists has increased, and since 2013, the Korean Surgical Society has promoted subspecialty certification. As a result,

the awareness of surgical subspecialists has gradually risen not only among surgeons but also among the public. As such, in the current study, we were interested in the degree of involvement of PS and GS in the treatment of pediatric surgical diseases in Korea and what the outcomes are.

Therefore, the purpose of our study, which used the National Health Insurance Service (NHIS) database, was to 1) investigate the involvement of PS and GS in pediatric surgery in Korea, 2) compare the outcome of surgery in a specific cohort by analyzing NICU patients, and 3) calculate the workload of the PS and estimate the appropriate PS workforce in Korea.

## METHODS

This study was a retrospective cohort study that used the NHIS database. The NHIS database contains all claims data for the population covered by the National Healthcare Insurance program and Medical Aid program in Korea. The data were given to the researchers after de-identification, following the request to use the data for research purposes.<sup>10</sup> The big data of the NHIS database used in this study included all health insurance subscribers from 2002 to 2017, and it was structured by combining the qualification database, treatment database, and clinic database. The qualification database included basic information about the participants, who were NHIS subscribers and Medicare recipients (but not foreigners), and it provided information about their sex, age, location, type of subscription, and socioeconomic variables, such as income rank, disability, death, and so on. The treatment database contained a statement, details of the treatment, the type of disease, and details of the surgical patient's prescription. The clinic database provided information about the clinics' status, facility, equipment, and personnel by type, establishment, and location (city, county, and district). The big data did not include a resident registration number in order to protect personal information, but a personal serial number was provided that could link the medical information and clinic information.

The primary outcome measured the following in the pediatric surgery that was performed from 2002 to 2017: 1) the percentage of surgeries performed by PS according to the patients' age and year, 2) the percentage of surgeries conducted by PS in terms of the index operation and surgical cases of main pediatric diseases, and 3) the mortality of patients who underwent acute abdominal surgery in the NICU. The secondary outcome was an estimate of the PS workforce that would be appropriate in Korea.

### Study population

We used the NHIS database to collect all surgical data from pediatric and adolescent patients (age < 19 years) in hospitals nationwide from January 2002 to December 2017. These data included the sex of the patient, the location of the operation, the age at the time of the operation, the diagnostic and surgical codes at the time of surgery, number of days in hospital, and so on. In addition, the patients who were admitted to the NICU were assessed in terms of body weight at birth and deaths within 30 days, 180 days, and 365 days of birth.

We selected 288 surgical codes for the pediatric surgery area from all codes for surgery in Korea's Health Insurance Review and Assessment Service (**Supplementary Table 1**). This classification was performed by 5 PS (Oh C, Chang HK, Lee S, Ahn SM, and Seo JM) who participated in this study. The NHIS provides data for the administrative districts of each

**Table 1.** Index operations

Disease	Prescription code	Operation
Congenital diaphragmatic hernia	O1600	Repair of diaphragm
	O1605	Excision of diaphragmatic tumor and reconstruction
	O1610	Repair of diaphragmatic hernia
	Q2352	Repair of hiatal hernia—Abdominal approach
Esophageal atresia	Q2411	Primary anastomosis
	Q2412	Excision of tracheoesophageal fistula
	Q2413	Primary anastomosis + excision of tracheoesophageal fistula
Hypertrophic pyloric stenosis	Q2561	Pyloroplasty
Hirschsprung's disease	Q2676	Myomectomy
	Q2687	Segmental colonic aganglionosis type
	Q2688	Total colonic aganglionosis type
Abdominal wall defect	Q2781	Repair of omphalocele or gastroschisis
Jejunoileal atresia	Q2831	Simple reconstruction
	Q2832	Complex reconstruction
Malrotation	Q2841	Operation of midgut malrotation—Ladd procedure
	Q2842	Operation of midgut malrotation—Bowel resection
Anorectal malformation	Q2981	Low type
	Q2982	High type—Posterior sagittal anoplasty (Pena's operation)
	Q2983	High type—Pena's operation and laparotomy
	Q2984	High type—Repair of cloacal anomaly
	Q2985	High type—Laparoscopically assisted anorectal pull-through
	Q3031	Operation of total cloacal anomaly
Biliary atresia	Q7371	Hepaticoenterostomy (Kasai operation)

city (Si), county (Gun), and district (Gu). However, it does not provide specific regional information in the districts (Gu). Therefore, the survey could not be conducted by matching the data of a specific hospital in a specific area. As such, we devised a way to identify a hospital that specializes in pediatric surgery. By selecting the index operation (**Table 1**), which is difficult to perform unless by a PS, the hospital with the PS was considered to have the highest index operation rate among the NHIS data. We surveyed the number of index operations performed in all hospitals nationwide from 2002 to 2017 using the NHIS data. From 2002 to 2017, the 37 hospitals where KAPS members actually worked and the top 37 hospitals with a large number of index operations were matched. The number of hospitals matched in the district (Gu) was identical to the number of hospitals where KAPS members worked in the district (Gu). The pediatric surgery performed in these 37 hospitals was considered to be performed by PS, and the pediatric surgery conducted in the other hospitals was considered to be performed by GS.

### NICU patients

We analyzed hospitalized NICU patients who underwent surgery for acute abdomen. Because patients admitted to the NICU are assigned a NICU admission fee code, we classified patients with this code as NICU patients. In this study, acute abdominal surgery in NICU patients was defined as a case of surgery for intestinal problems, such as necrotizing enterocolitis, spontaneous intestinal perforation, meconium-related ileus, or non-meconium-related ileus (**Table 2**). In order to compare the results of the patients' acute abdominal surgery, we examined their mortality within 30 days, 180 days, and 365 days of birth.

### Analysis of recent trends in pediatric surgery

To examine the recent trends in pediatric surgery, we further analyzed 13 main pediatric diseases, which are relatively common congenital anomalies and benign diseases, that occurred during the last 5 years of the study period.

**Table 2.** Acute abdominal surgery in neonatal intensive care unit patients

Prescription code	Operation
Q2440	Diagnostic exploratory laparotomy
Q2640	Enterotomy
Q2650	Resection of small intestine
Q2680	Intestinal anastomosis
Q2691	Operation for intestinal obstruction, including resection of intestine
Q2692	Operation for intestinal obstruction, entero-enterostomy
Q2693	Operation for intestinal obstruction, adhesiolysis
Q2710	Intestinal plication
Q2791	Enterostomy, tube
Q2792	Enterostomy, loop
Q2793	Enterostomy, end
Q2794	Enterostomy, double barrel
Q2795	Enterostomy, revision of ileostomy or colostomy
Q2810	Adhesiolysis

### Estimation of the PS workforce in Korea

It is not easy to identify the appropriate number of PS for any country. This is because various factors, such as the country's population model, medical environment, and economic condition, work in combination. We estimated the number of PS currently needed in Korea for each situation by assuming that PS would perform all operations in terms of the index operation, surgeries for main pediatric diseases, acute abdominal surgeries in the NICU, and all pediatric surgeries. We examined the number of PS in the Organisation for Economic Co-Operation and Development member countries and the countries surrounding Korea.<sup>11</sup> Furthermore, we looked at the gross domestic product per capita of each country surveyed. The gross domestic product per capita data were for 2019, and in US dollars, as reported by the World Bank. Based on this, we attempted to estimate the appropriate number of PS required in Korea in the future.

### Statistical analysis

The NICU patients' mortality after acute abdominal surgery was compared using the  $\chi^2$  test or Fisher's exact test. The Kaplan-Meier survival curve for after acute abdominal surgery, according to the case volume, was calculated and a log-rank test was performed. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA) and  $P < 0.05$  was considered significant.

### Ethics statement

The study protocol was approved by the Institutional Review Board of Samsung Medical Center (approval number 2018-11-113). Informed consent was waived because of the retrospective nature of the study.

## RESULTS

### Role of PS in pediatric surgery from 2002 to 2017

The total number of surgeries, which were conducted in Korea from 2002 to 2017 and analyzed using 288 pediatric surgical codes, was 3,721,554 and 232,597 were performed annually. The absolute number of pediatric surgeries increased by 124% from 2002 to 2017. Approximately 10.25% of the total number of pediatric surgeries was performed by PS. The percentage of surgeries performed by PS was approximately 8.32% in 2002, and it was

**Table 3.** Annual cases of pediatric surgery in Korea

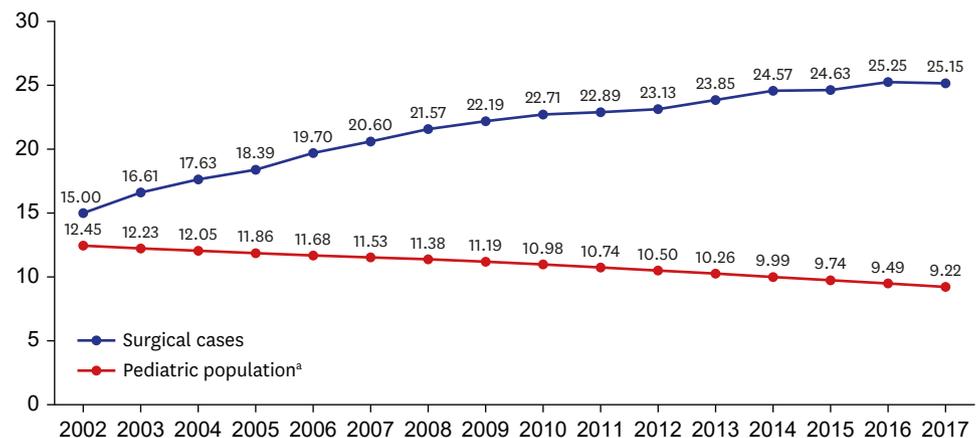
Years	Total	GS	PS	PS/total (%)
2002	186,793	171,250	15,543	8.32
2003	203,188	188,541	14,647	7.21
2004	212,397	196,288	16,109	7.58
2005	218,123	200,552	17,571	8.06
2006	230,044	209,693	20,351	8.85
2007	237,377	216,805	20,572	8.67
2008	245,341	224,608	20,733	8.45
2009	248,390	228,009	20,381	8.21
2010	249,378	226,599	22,779	9.13
2011	245,834	221,373	24,461	9.95
2012	242,941	215,633	27,308	11.24
2013	244,677	216,088	28,589	11.68
2014	245,528	217,098	28,430	11.58
2015	239,852	210,768	29,084	12.13
2016	239,669	201,834	37,835	15.79
2017	232,022	195,074	36,948	15.92
Sum	3,721,554	3,340,213	381,341	10.25

GS = general surgeon, PS = pediatric surgeon.

increased to approximately 15.92% in 2017 (Table 3). According to the Statistics Korea, the number of people under the age of 19 years in Korea steadily decreased from 12,450,123 in 2002 to 9,225,025 in 2017.<sup>12</sup> The number of pediatric surgeries for this population increased by approximately 168%, from 15 cases per 1,000 pediatric population in 2002 to 25.15 cases in 2017 (Fig. 1).

When pediatric surgery was analyzed by age, the percentage of surgeries conducted by PS was higher in younger patients and it decreased with age (Table 4). It was highest with patients aged 0 and 1 years, at 26.49% and 27.68%, respectively, and it was lowest with patients aged 13 and 14 years, at 4.89% and 4.73%, respectively.

A total of 11,568 index operations were performed during the study period of 16 years, with an annual average of 723. The annual average of the percentage of index operations performed by PS was approximately 62.44%, and it was approximately 47.81% in 2002; however, it was approximately 88.79% in 2017 (Table 5).



**Fig. 1.** Changes in surgical cases per 1,000 pediatric population in Korea.

<sup>a</sup>Million.

**Table 4.** Number of surgeries by age from 2002 to 2017

Age	Total	GS	PS	Proportion (%)	PS/total (%)
0	263,191	193,464	69,727	7.07	26.49
1	163,024	117,901	45,123	4.38	27.68
2	140,464	109,642	30,822	3.77	21.94
3	124,355	100,127	24,228	3.34	19.48
4	121,993	100,797	21,196	3.28	17.37
5	126,876	107,539	19,337	3.41	15.24
6	131,860	114,482	17,378	3.54	13.18
7	135,043	121,490	13,553	3.63	10.04
8	142,818	130,756	12,062	3.84	8.45
9	154,654	143,115	11,539	4.16	7.46
10	171,526	160,088	11,438	4.61	6.67
11	192,322	180,832	11,490	5.17	5.97
12	219,602	207,560	12,042	5.90	5.48
13	248,987	236,803	12,184	6.69	4.89
14	263,643	251,180	12,463	7.08	4.73
15	268,535	255,302	13,233	7.22	4.93
16	278,609	264,616	13,993	7.49	5.02
17	284,773	270,185	14,588	7.65	5.12
18	289,279	274,334	14,945	7.77	5.17
Sum	3,721,554	3,340,213	381,341	100	10.25

GS = general surgeon, PS = pediatric surgeon.

**Table 5.** Annual cases of index operations

Years	Total	GS	PS	PS/total (%)
2002	525	274	251	47.81
2003	598	344	254	42.47
2004	580	327	253	43.62
2005	495	274	221	44.65
2006	678	325	353	52.06
2007	715	341	374	52.31
2008	696	330	366	52.59
2009	772	375	397	51.42
2010	754	301	453	60.08
2011	790	316	474	60.00
2012	855	231	624	72.98
2013	845	253	592	70.06
2014	821	217	604	73.57
2015	857	258	599	69.89
2016	820	93	727	88.66
2017	767	86	681	88.79
Sum	11,568	4,345	7,223	62.44

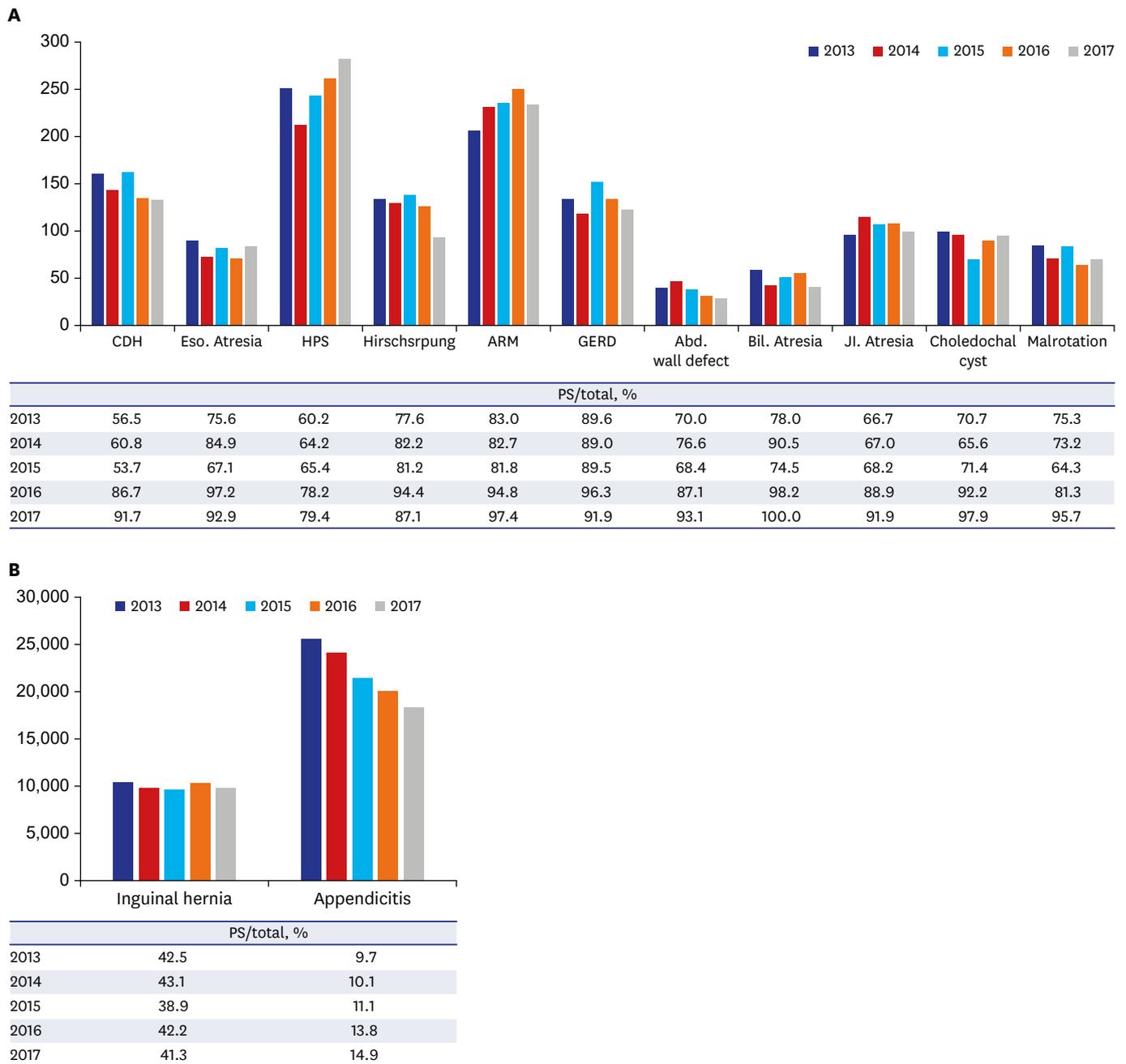
GS = general surgeon, PS = pediatric surgeon.

During the last 5 years of the study period, the number of surgeries conducted for main pediatric diseases decreased from 37,283 in 2013 to 29,464 in 2017, and the average annual number of surgeries for main pediatric diseases was approximately 33,228. The percentage of surgery performed by PS steadily increased, with 79.4% for hypertrophic pyloric stenosis and 100% for biliary atresia in 2017 (Fig. 2A). However, the proportions of surgery performed by PS for inguinal hernia and appendicitis remained low in the most recent years, with an annual average of approximately 41.6% and 11.9%, respectively (Fig. 2B).

### Comparison of the outcomes for acute abdominal surgery in the NICU between PS and GS

A total of 6,342 surgeries were conducted in NICU patients with acute abdomen for 16 years, and the average was approximately 396.4 cases per year. The occurrence of these operations

How Many Pediatric Surgeons Does Korea Need?



**Fig. 2.** Annual surgical cases of main pediatric disease from 2013 to 2017 (A), annual surgical cases of inguinal hernia and appendicitis (B). CDH = congenital diaphragmatic hernia, Eso. Atresia = esophageal atresia, HPS = hypertrophic pyloric stenosis, Hirschsprung = Hirschsprung's disease, ARM = anorectal malformation, GERD = gastroesophageal reflux disease, Abd. wall defect = abdominal wall defect, Bil. Atresia = biliary atresia, JI. Atresia = Jejunoileal atresia, PS = pediatric surgeon.

increased from 109 in 2002 to 524 in 2017. The percentage of surgery performed by PS was 44% in 2002, but it had recently risen to 89.7% in 2017 (Table 6). When comparing the mortality after acute abdominal surgery by PS and GS from 2002 to 2017, there was no statistically significant difference for all NICU patients, including babies with a birth weight of 2,500 g or more. However, for the 180-day mortality of patients with extremely low birth weight, there was a significant difference when it was performed by PS (31.7%) and GS

**Table 6.** Annual cases of acute abdominal surgery in the neonatal intensive care unit

Years	Total	GS	PS	PS/total (%)
2002	109	61	48	44.0
2003	165	116	49	29.7
2004	167	103	64	38.3
2005	159	80	79	49.7
2006	285	119	166	58.2
2007	367	170	197	53.7
2008	357	178	179	50.1
2009	378	176	202	53.4
2010	468	206	262	56.0
2011	483	186	297	61.5
2012	521	150	371	71.2
2013	523	140	383	73.2
2014	587	178	409	69.7
2015	575	170	405	70.4
2016	674	101	573	85.0
2017	524	54	470	89.7
Sum	6,342	2,188	4,154	65.5

GS = general surgeon, PS = pediatric surgeon.

(39.9%) ( $P = 0.029$ ). Additionally, in patients with a birth weight of less than 1,500 g, those who underwent surgery by PS had a significantly lower mortality within all follow-up periods (Table 7). We further examined this when limited to the last 5 years. The 30-day mortality was significantly lower in all birth weight groups who were operated on by PS rather than GS. Regarding the 180-day and 365-day mortality, although patients operated on by PS appeared to have a lower mortality rate than those operated on by GS, the difference was not statistically significant (Fig. 3). We calculated the Kaplan-Meier survival curve using this data, and found that there was a significant difference in survival between NICU patients who underwent surgery for acute abdomen by PS and GS (log-rank test:  $P < 0.001$ ) (Fig. 4).

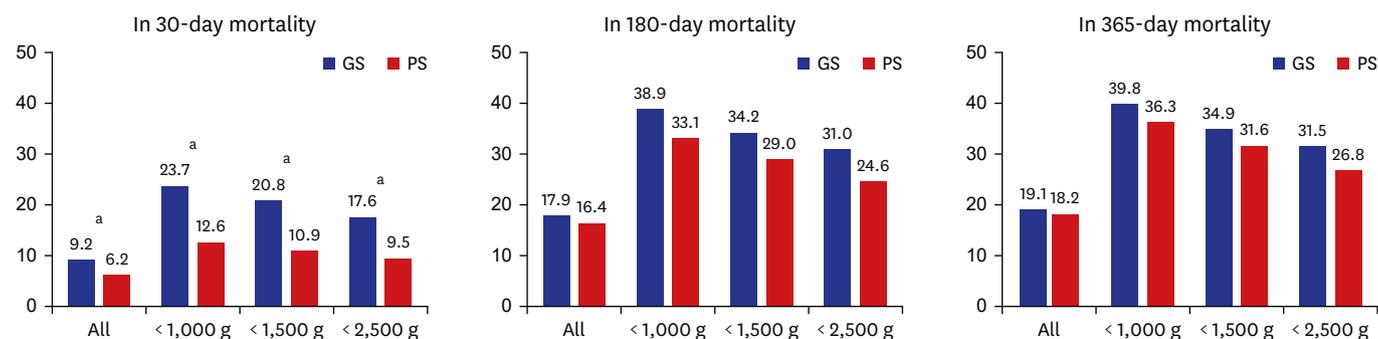
### Estimated PS workload and workforce

The index operations, surgeries for main pediatric diseases, acute abdominal surgeries in the NICU, and all pediatric surgeries of the 288 pediatric surgical codes in the last 5 years of the study period are summarized in Table 8. Forty-nine PS who were qualified by the KAPS were working in 37 hospitals in Korea. To estimate the recent annual workload of 1 PS, the

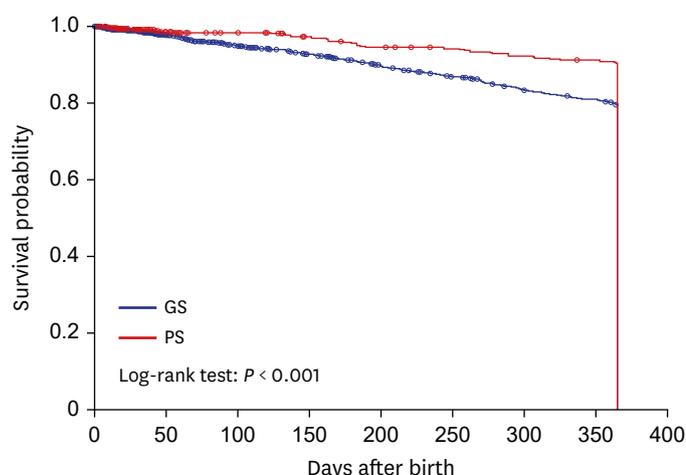
**Table 7.** Mortality comparison of acute abdominal surgery in neonatal intensive care units from 2002 to 2017

Details	No.	In 30-day mortality		In 180-day mortality		In 365-day mortality	
		No. (%)	<i>P</i> value	No. (%)	<i>P</i> value	No. (%)	<i>P</i> value
All NICU patients							
PS	2,933	147 (5)		417 (14.2)		477 (16.3)	
GS	1,626	87 (5.3)		230 (14.1)		256 (15.7)	
Total	4,559	234 (5.1)	0.620	647 (14.2)	0.946	733 (16.1)	0.648
< 1,000 g (extremely low birth weight)							
PS	483	61 (12.6)		153 (31.7)		170 (35.2)	
GS	233	41 (17.6)		93 (39.9)		96 (41.2)	
Total	716	102 (14.6)	0.748	246 (34.4)	0.029	266 (37.1)	0.119
< 1,500 g (extremely low + very low birth weight)							
PS	612	67 (10.9)		172 (28.1)		190 (31)	
GS	278	47 (16.9)		103 (37)		106 (38.1)	
Total	890	114 (12.8)	0.014	275 (30.9)	0.007	296 (33.2)	0.038
< 2,500 g (extremely low + very low + low birth weight)							
PS	879	77 (8.8)		206 (23.4)		230 (26.2)	
GS	490	56 (11.4)		130 (26.5)		136 (27.7)	
Total	1,369	133 (9.7)	0.110	336 (24.5)	0.202	366 (26.7)	0.524

NICU = neonatal intensive care unit, PS = pediatric surgeon, GS = general surgeon.



**Fig. 3.** Mortality comparison of acute abdominal surgery in the neonatal intensive care unit from 2013 to 2017. GS = general surgeon, PS = pediatric surgeon. <sup>a</sup>*P* < 0.05 between GS and PS.



**Fig. 4.** Kaplan-Meier survival curve after neonatal intensive care unit patients' acute abdominal surgery from 2013 to 2017. GS = general surgeon, PS = pediatric surgeon.

total number of each types of surgeries performed by PS in last 5 years of the study period was divided by the recent number of PS in Korea (49 PS); the number of the index operations was 13.1 per year, the number of surgeries for main pediatric diseases was 159.5 per year, and the number of neonatal acute abdominal surgeries was 9.1 per year, respectively. For all pediatric surgeries, it was estimated that 656.7 cases are performed annually by 1 PS.

Assuming that all of the surgeries in each situation described in **Table 8** that were performed by PS or GS should be performed only by PS with similar workload, the number of PS currently needed in Korea was estimated as follows: 1) index operations:  $49 \div 0.78 = 62.82$ , 2) main pediatric diseases:  $49 \div 0.235 = 208.51$ , 3) acute abdominal surgeries in the NICU:  $49 \div 0.776 = 63.14$ , and 4) all pediatric surgeries:  $49 \div 0.134 = 365.67$ . In other words, the minimum number of PS currently required to conduct at least index operation or neonatal acute abdominal operations in Korea is about 63.

In 2017, the number of PSs per million children under 15 years of age in Korea was 7.16 (**Table 9**). This was small compared to neighboring countries, such as China (7.9), Taiwan (19.8), and Japan (38.7). Of the 22 Organisation for Economic Co-Operation and Development member countries for which the number of PSs is known, only Colombia (4), Turkey (4.3), and Ireland

**Table 8.** Estimate of 1 Korean pediatric surgeon's 1-year workload based on the latest 5-year data

Details	Index operation	Main pediatric disease	Acute abdominal surgery in NICU	All pediatric surgery
Annual cases				
By PS + GS	822	33,228	577	240,350
By PS only	641 (78%)	7,814 (23.5%)	448 (77.6%)	32,177 (13.4%)
Estimated annual cases of one PS				
By PS + GS	16.8	678.1	11.8	4,905
By PS only	13.1	159.5	9.1	656.7

NICU = neonatal intensive care unit, PS = pediatric surgeon, GS = general surgeon.

**Table 9.** Number of pediatric surgeons per million children (under 15 years) and gross domestic product per capita

Country	Numbers	GDP (\$)	Country	Numbers	GDP (\$)
India	2.9	2,104	France <sup>a</sup>	19.8	40,494
Colombia <sup>a</sup>	4	6,432	United Kingdom <sup>a</sup>	30.1	42,300
Thailand	14.2	7,808	Canada <sup>a</sup>	14.1	46,195
Brazil	15.4	8,717	Germany <sup>a</sup>	24.1	46,259
Turkey <sup>a</sup>	4.3	9,042	Finland <sup>a</sup>	105.2	48,686
China	7.9	10,262	Austria <sup>a</sup>	54.8	50,277
Poland <sup>a</sup>	125.2	15,595	Sweden <sup>a</sup>	58.6	51,610
Czech Republic <sup>a</sup>	42.9	23,102	Netherlands <sup>a</sup>	12.4	52,448
Portugal <sup>a</sup>	44.7	23,145	Australia <sup>a</sup>	31	54,907
Taiwan	19.8	25,909	Denmark <sup>a</sup>	10.8	59,822
Spain <sup>a</sup>	46.6	29,614	United States <sup>a</sup>	20.5	65,118
Korea <sup>a</sup>	7.16	31,762	Norway <sup>a</sup>	15.8	75,420
Italy <sup>a</sup>	51.8	33,190	Ireland <sup>a</sup>	3.8	78,661
Japan <sup>a</sup>	38.7	40,247	Switzerland <sup>a</sup>	41.3	81,994

GDP = gross domestic product per capita.

<sup>a</sup>Organisation for Economic Co-operation and Development members except Belgium, Chile, Estonia, Greece, Hungary, Iceland, Israel, Latvia, Lithuania, Mexico, Luxembourg, New Zealand, Slovak Republic and Slovenia.

(3.8) have fewer PS than Korea.<sup>11</sup> Based on the gross domestic product per capita, this is very insufficient, even when compared to Spain (46.6) and Italy (51.8), which have similar gross domestic product per capita to Korea. Although having a high level of gross domestic product per capita alone does not mean that a country is medically advanced, it is true that many countries aim for a high gross domestic product per capita. In **Table 9**, among the countries with a higher gross domestic product per capita than Korea, Germany (24.1) and the United Kingdom (30.1) have median values of the number of PS per million children under 15 years of age. Based on this, it is believed that approximately 165 to 206 PS would be appropriate for Korea to implement more advanced pediatric surgery in the future.

## DISCUSSION

Raising all children as members of a healthy society is an important task for medical personnel. Therefore, the social role of experts who are responsible for the highly specialized field of surgical treatment for children has become important. Founded in 1985, the KAPS prides itself on being the world's best in terms of the skill of Korean PS. To date, it has employed strict requirements to manage the quality of PS (i.e., 1 year of fellowship training in hospitals accredited for domestic pediatric surgery training or 1 year of training in overseas hospitals accredited for pediatric surgery training, and cumulative pediatric surgeries of more than 500 cases, of which more than 50 are neonatal surgery). Although pediatric surgery is considered a division that requires a high level of skill, it is difficult to preserve the cost of surgery and patient management because of the low medical fee policy. Some hospitals do not want to have a pediatric surgery division because of the low profitability. As a result, there

are not many hospitals in which PS can work, and surgical residents cannot easily choose pediatric surgery divisions. This vicious cycle is repeated, and the number of PS in Korea is currently lacking. Because of the insufficient number of PS, GS become involved in pediatric surgery, which includes surgery for congenital anomalies and surgery for NICU patients that require advanced experience.

The patient's outcomes depend on various factors, and surgeons are very interested in improving the quality of treatment by analyzing these factors. Surgical subspecialty training for surgeons is often cited as a predictor of improving surgical outcomes.<sup>13</sup> In many studies, surgical subspecialty and sufficient experience in relevant cases have been reported to influence patient outcomes.<sup>14-16</sup> The surgery for main pediatric diseases and acute abdominal surgery in the NICU that were included in this study are not commonly encountered, even by young PS, and are very rare for most GS. Boo et al.<sup>9</sup> reported that the adjusted odds ratios of postoperative complications for GS were 2.9 times higher than for PS when performing surgery on NICU patients, including for acute abdominal surgery, esophageal atresia, and Hirschsprung's disease (95% confidence interval, 1.03–7.79). In the above study, it was reported that an infant's younger gestational age, lower birth weight, and more associated anomalies were not risk factors for postoperative complications; however, undergoing surgery by GS was a risk factor. In this study, which assessed acute abdominal surgery in the NICU, although the comorbidity of the patients could not be compared, the survival of patients who underwent surgery by PS was significantly better than for those whose surgery was performed by GS. A study of the surgical treatment of intussusception in children found that, although there were more severe situations, such as perforation, bowel ischemia, and sepsis (17.6% of PS vs. 9.3% of GS), the bowel resection was lower when the surgery was performed by PS (33% vs. 59.3%), and the odds of bowel resection were significantly lower for PS than GS (odds ratio, 0.20;  $P < 0.001$ ).<sup>7</sup> Langer et al.<sup>3</sup> reported that GS had a higher overall complication rate (4.18% vs. 2.58%) than PS when conducting pyloromyotomy for hypertrophic pyloric stenosis, and the incidence of duodenal perforation was reported to be 3.65 times more common in GS. In addition, studies of inguinal herniorrhaphy,<sup>8</sup> appendectomy,<sup>6</sup> biliary atresia,<sup>5</sup> and congenital diaphragmatic hernia<sup>4</sup> have also shown that PS have better outcomes than GS. Based on these studies, it is considered that surgery for main pediatric diseases should be performed by PS.

The new requirements for surgical resident training in pediatric surgery do not address training in the care of children, which is already part of the core residency education for all GS. In other words, pediatric surgery is already recognized as an independent division by surgeons, and this is widely known to the public. During the study period, the surgical ratio of PS for children up to the age of 7 years was more than 10%, and up to the age of 2 years, it was more than 20%. This is believed to be the point at which the importance of the pediatric surgical subspecialty emerges for the younger age group. From 2002 to 2017, the absolute number of pediatric surgeries increased by 124%, and considering the decrease in the pediatric population during the study period, the number of surgeries per 1,000 children increased by 168%. In all pediatric surgeries, percentage conducted by PS increased from 8.32% in 2002 to 15.92% in 2017. Excluding hypertrophic pyloric stenosis (79.4%) and Hirschsprung's disease (87.1%), more than 90% of the index operations were performed by PS in 2017. In addition, the percentage of neonatal acute abdominal surgery performed by PS steadily increased, reaching 89.7% in 2017. For appendicitis, which is one of the most common pediatric surgeries, the proportion of the surgery performed by PS was still small, but it had increased by approximately 154% during the last 5 years. However, the role of PS in

treating inguinal hernia did not change significantly in the last 5 years. As mentioned earlier, for inguinal hernia and appendicitis, surgery by PS had better outcomes than surgery by GS. Therefore, KAPS, PS and the government should come up with a way to increase the surgical ratio of PS for benign surgical cases, such as inguinal hernia or appendicitis

O'Neill et al.<sup>17</sup> noted that hiring a new PS would require 400 surgeries per year. A study conducted in the United States reported that 1 PS performed 421 surgeries in 1997.<sup>13</sup> In a Canadian study in 2010, the number of surgeries per PS per year was estimated to be 328.<sup>18</sup> In this study, we estimated that the number of surgeries per year per PS in Korea in the last 5 years of the study period was 656.7. However, the pediatric surgeries for 37 hospitals selected based on the index operation were calculated as being performed by pure PS, but in reality it will not be. This is because surgeries that are traditionally considered the domain of PS now often overlap with other surgical departments. This is particularly noticeable in neck and urogenital surgery. Studies conducted in the United States from 2005 to 2014 reported that otolaryngologists conducted approximately 60% of thyroglossal duct cyst excisions and brachial cleft excisions and approximately 50% of cervical lymph node excisions. It has also been found that approximately 30% of unilateral inguinal herniorrhaphy and approximately 85% of orchiopexy surgeries are implemented by urologists.<sup>19</sup> In addition to the above diseases, surgery for skin and soft tissue tumors (12.5%), central venous catheterization (20.8%), frenulotomy (4.4%), and hydrocele (3.3%), which accounted for a large proportion of pediatric surgeries in this study, overlapped with other departments. Therefore, the number of surgeries per year per PS in Korea will be less than 656.7.

We referred to several studies to evaluate the appropriate number of PS in the workforce in Korea. The American Pediatric Surgical Association estimated that the number of PS needed per 100,000 children aged 0 to 15 years in developed countries, such as the United States and some European countries, is 1.<sup>20</sup> In some developing countries, where children comprise almost half of the population, the number of PS required per 200,000 children aged 0 to 15 years is estimated to be 1.<sup>21</sup> In Korea, the number of children aged 0 to 15 years in 2017 was 6,844,221. If the aforementioned studies are taken into account when evaluating the number of PS needed in Korea, there should be 35–69 PS, but since Korea is closer to a developed country than a developing country, it leads to the conclusion that there should be at least 69.

We found that about 63 PS are required if they perform at least the index operation among the pediatric surgeries investigated in this study. When this study was conducted in 2019, 49 PS were working in 37 hospitals across the country, and only 1 PS was employed in 30 of these hospitals. In hospitals where there was only 1 PS, he/she was required to wait for an emergency; thus, the occupational burden of the PS is inevitably worse, and he/she may not be able to respond appropriately in an emergency. Ideally, 2 or more PS should be working in each hospital, and the number of PS should be more than the current minimum estimate.

A recently published study found that there must be at least 4 PS per million children under the age of 15 years to achieve a survival rate of more than 80% for surgically correctable pediatric diseases (e.g., gastroschisis, esophageal atresia, intestinal atresia, typhoid intestinal perforation, and neonatal bowel obstruction).<sup>11</sup> The number of PS per million children under 15 years of age in Korea is 7.16, which is higher than 4, but lower than in many countries in Asia and significantly lower than in Japan (38.7). To achieve more advanced pediatric surgery in the future, it is evident that more PS are needed, and the number of PS in advanced countries should be aimed for. However, over the past 17 years, the number of PS in

**Table 10.** Pediatric surgeon retirees and trainees in the last 17 years

Years	Retiree	Trainee	Variation
2004	2		-2
2005	1	2	+1
2006	1	2	+1
2007		1	+1
2008	4	1	-3
2009	4	3	-1
2010	1	3	+2
2011		2	+2
2012	4	1	-3
2013	2	2	0
2014	4	2	-2
2015	2	1	-1
2016		7	+7
2017	1	1	0
2018	2	6	+4
2019		2	+2
2020	4		-4
Sum	32	36	4

Korea has increased by just 0.235 per year (**Table 10**). The number of PS has sharply declined since the first generation of PS began to retire from 2004. In addition, a large number of second-generation PS who are currently active will retire in the 2020s. If the birth rate and pediatric patient revenue continue to drop, and hospitals stop hiring PS, a severe problem could occur within a decade.

The total fertility rate (TFR) of the Korea according to the Statistics Korea was 4.53 in 1970.<sup>12</sup> The TFR decreased to 2.82 in 1980, decreased to less than 2 from 1984 (TFR = 1.74), and decreased to less than 1.5 from 1998 (TFR = 1.464). In the 2010s, the TFR maintained around 1.2, but decreased to 1.052 in 2017, then 0.977 in 2018 and 0.918 in 2019. Due to the persistent decrease in TFR, the absolute number of neonatal and pediatric patients decreased. As a result, the medical income of doctors who treat children has decreased, which leads to a poor working environment, so that the recruitment of doctors who treat children has not been properly made, and this includes PS. Although TFR decreased, high-risk pregnancy such as premature labor and premature rupture of the amniotic membrane increased as the childbearing age increased, and congenital anomalies and neonatal diseases increased accordingly. This is proved by the annual number of surgeries for main pediatric disease and acute abdominal surgery of the NICU patients in the last five years in this study. Therefore, this author does not believe that the number of PS should decrease due to the decrease in TFR in Korea. In order to create a medical system that meets the healthy lives of children and adolescents required in the era of low birthrate, 1) prenatal counseling and management for mothers (or families) suspected of fetal anomaly, 2) government support for pediatric surgery and rehabilitation treatment expenses, etc., 3) establish a treatment system for pediatric trauma patients is needed. PS also need continuous qualification management, so attending academic conferences or workshops should be supervised by the KAPS so that they can learn new knowledge and surgical methods. Also, for young PS with little experience, the KAPS should support surgical practice, such as using animal models. As mentioned earlier when discussing the results of the estimated workload and workforce of the PS, it is believed that 165 to 206 PS will be needed in Korea when aiming for more advanced pediatric surgery. To achieve this, a better educational environment for pediatric surgery and improvement of the working conditions are required, and these cannot be postponed any longer.

The reliability of the NHIS data at the beginning of this study in 2002 and at the end in 2017 is considered to differ. This was particularly noticeable regarding the NICU patients. When analyzing the amount of NICU surgeries, the average number in the 5 years from 2002 was 117, but it was approximately 577 in the last 5 years. This change was not due to a surge in actual NICU patients. It was probably due to the fact that the number of patients increased from 2013, and that the NICU admission fee code was actively registered. This probably occurred because the NICU admission fee code has been actively registered since 2013, when the medical fee for NICU patients increased. Additionally, there may have been missing data in the old data, which could have occurred more frequently before the medical charts for each hospital were computerized. In order to minimize these errors and analyze recent trends in pediatric surgery, we further analyzed the surgery in the last 5 years.

In conclusion, pediatric surgery is not the same as surgery for adults. Pediatric surgery in Korea is increasing in proportion of PS, but it is still widely performed by GS. PS have better operative outcomes for acute abdominal surgery in the NICU than GS. It is desirable for PS to perform pediatric surgery, but the number of PS in Korea is insufficient. We believe that at least the index operations or NICU operation should be performed by PS, and that a minimum of 63 PS are needed to do so. Additionally, approximately 200 PS will be required in Korea to manage of main pediatric diseases and to achieve more advanced pediatric surgery in the future. The government should create a better educational environment and improve working conditions to foster an appropriate number of PS.

## SUPPLEMENTARY MATERIAL

### Supplementary Table 1

The 288 surgical codes for the pediatric surgery area

[Click here to view](#)

## REFERENCES

1. Hong J, Sim J. A single pediatric surgeon working in a single center: Was there a change in the pediatric surgeon's role following 25 years of service in Suwon City? *Adv Pediatr Surg* 2020;26(1):1-10.  
[CROSSREF](#)
2. Oh JT, Chang HK, Cho MJ, Cho YH, Choi SJ, Choi YM, et al. Sacrococcygeal teratoma: a survey by the Korean Association of Pediatric Surgeons in 2018. *Adv Pediatr Surg* 2019;25(2):35-43.  
[CROSSREF](#)
3. Langer JC, To T. Does pediatric surgical specialty training affect outcome after Ramstedt pyloromyotomy? A population-based study. *Pediatrics* 2004;113(5):1342-7.  
[PUBMED](#) | [CROSSREF](#)
4. Baird R, Eeson G, Safavi A, Puligandla P, Laberge JM, Skarsgard ED, et al. Institutional practice and outcome variation in the management of congenital diaphragmatic hernia and gastroschisis in Canada: a report from the Canadian Pediatric Surgery Network. *J Pediatr Surg* 2011;46(5):801-7.  
[PUBMED](#) | [CROSSREF](#)
5. McKiernan PJ, Baker AJ, Kelly DA. The frequency and outcome of biliary atresia in the UK and Ireland. *Lancet* 2000;355(9197):25-9.  
[PUBMED](#) | [CROSSREF](#)
6. da Silva PS, de Aguiar VE, Waisberg J. Pediatric surgeon vs general surgeon: Does subspecialty training affect the outcome of appendicitis? *Pediatr Int* 2014;56(2):248-53.  
[PUBMED](#) | [CROSSREF](#)

7. McAteer JP, Kwon S, LaRiviere CA, Oldham KT, Goldin AB. Pediatric specialist care is associated with a lower risk of bowel resection in children with intussusception: a population-based analysis. *J Am Coll Surg* 2013;217(2):226-232.e1-3.  
[PUBMED](#) | [CROSSREF](#)
8. Borenstein SH, To T, Wajja A, Langer JC. Effect of subspecialty training and volume on outcome after pediatric inguinal hernia repair. *J Pediatr Surg* 2005;40(1):75-80.  
[PUBMED](#) | [CROSSREF](#)
9. Boo YJ, Lee EH, Lee JS. Comparison of surgical outcomes among infants in neonatal intensive care units treated by pediatric surgeons versus general surgeons: the need for pediatric surgery specialists. *J Pediatr Surg* 2017;52(11):1715-7.  
[PUBMED](#) | [CROSSREF](#)
10. Lee J, Lee JS, Park SH, Shin SA, Kim K. Cohort profile: The National Health Insurance Service-National Sample Cohort (NHIS-NSC), South Korea. *Int J Epidemiol* 2017;46(2):e15.  
[PUBMED](#)
11. Hamad D, Yousef Y, Caminsky NG, Guadagno E, Tran VA, Laberge JM, et al. Defining the critical pediatric surgical workforce density for improving surgical outcomes: a global study. *J Pediatr Surg* 2020;55(3):493-512.  
[PUBMED](#) | [CROSSREF](#)
12. The Statistics Korea. Korean Statistical Information Service. <https://kosis.kr/search/search.do>. Updated 2020. Accessed December 31, 2020.
13. Birkmeyer JD, Dimick JB, Birkmeyer NJ. Measuring the quality of surgical care: structure, process, or outcomes? *J Am Coll Surg* 2004;198(4):626-32.  
[PUBMED](#) | [CROSSREF](#)
14. Archampong D, Borowski D, Wille-Jørgensen P, Iversen LH. Workload and surgeon's specialty for outcome after colorectal cancer surgery. *Cochrane Database Syst Rev* 2012;(3):CD005391.  
[PUBMED](#)
15. Chowdhury MM, Dagash H, Pierro A. A systematic review of the impact of volume of surgery and specialization on patient outcome. *Br J Surg* 2007;94(2):145-61.  
[PUBMED](#) | [CROSSREF](#)
16. Hillner BE, Smith TJ, Desch CE. Hospital and physician volume or specialization and outcomes in cancer treatment: importance in quality of cancer care. *J Clin Oncol* 2000;18(11):2327-40.  
[PUBMED](#) | [CROSSREF](#)
17. O'Neill JA Jr, Gautam S, Geiger JD, Ein SH, Holder TM, Bloss RS, et al. A longitudinal analysis of the pediatric surgeon workforce. *Ann Surg* 2000;232(3):442-53.  
[PUBMED](#) | [CROSSREF](#)
18. Emil S, Blair G, Langer JC, Miller G, Aspirot A, Brisseau G, et al. A survey-based assessment of the Canadian pediatric surgery workforce. *J Pediatr Surg* 2014;49(5):678-81.  
[PUBMED](#) | [CROSSREF](#)
19. Reich DA, Herbst KW, Campbell BT. The recent evolution of the breadth of practice for pediatric surgeons in the United States, 2005-2014. *Pediatr Surg Int* 2019;35(4):517-22.  
[PUBMED](#) | [CROSSREF](#)
20. O'Neill JA Jr, Vander Zwagg R. Update on the analysis of the need for pediatric surgeons in the United States. *J Pediatr Surg* 1980;15(6):918-24.  
[PUBMED](#) | [CROSSREF](#)
21. Chirdan LB, Ameh EA, Abantanga FA, Sidler D, Elhalaby EA. Challenges of training and delivery of pediatric surgical services in Africa. *J Pediatr Surg* 2010;45(3):610-8.  
[PUBMED](#) | [CROSSREF](#)