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# Improved Regional Disparities in Neonatal Care by Government-led Policies in Korea

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## ABSTRACT

**Background:** Although the number of high-risk neonates has increased in Korea, hospitals were reluctant to open or maintain neonatal intensive care unit (NICU) due to the low medical cost. Consequently, there were regional disparities in facilities, equipment, and neonatal health outcomes. For these reasons, the Korean government began to invest in neonatal care during the last decade. We identified the status of NICUs in Korea and assessed changes after the government-driven policies.

**Methods:** We surveyed 87 of 89 hospitals that operated NICUs in 2015. The questionnaire assessed the number of NICU beds, admission and mortality rates of very low birthweight infants (VLBWIs), personnel status, equipment and facilities, and available multidisciplinary approach. Current data was compared with the previous studies and changes in the status and function of the nationwide NICU from 2009 and 2011.

**Results:** During the last 7 years, there was an increase of 462 NICU beds, which met the required number estimated by the number of births and covered about 90% of regional VLBWI births. Status of facilities and equipment improved in all regions in Korea but there were still regional differences in multidisciplinary approach and human resources. The difference in odds ratios for mortality of VLBWI between regions decreased compared to 2009.

**Conclusion:** There was improvement in regional disparities of neonatal care and mortality of premature babies with the government investment in Korea. Further supports are required for human resources and referral system.

**Keywords:** Newborn; Policy; Korea

## INTRODUCTION

Since the last decades, the fertility rate of Korea is the lowest in the world and it was 1.24 per 1,000 fertile women in 2015.<sup>1</sup> However, the number of high-risk neonates has increased in Korea. The number of infants whose birthweight was under 2,500 g increased from 18,532 (2.6% of total births) in 1993 to 25,183 in 2015 (5.7%).<sup>2</sup> The increase in births of children who are preterm and with low birthweight arises from the increased maternal age and infertility, consequent assisted reproductive technology and multiple births.<sup>3</sup> However, hospitals were reluctant to open or maintain neonatal intensive care unit (NICU) because of operating deficit, estimating 500 to 700 deficits in NICU beds nationwide in 2006.

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This deficit was more prominent in non-capital areas and it created a regional disparity in neonatal care.<sup>4</sup>

For these reasons, from 2008, the Ministry of Health and Welfare in Korea initiated a project supporting NICUs in areas other than Seoul, the capital city of Korea. Two to ten hospitals were selected every year and initiative funds to expand NICU beds and facilities were granted, followed by funds for subsequent operating expenses annually. By 2015, about 56 million USD were provided to 42 hospitals nationwide.<sup>5</sup> Moreover, in 2013, the government doubled the NICU admission fee to compensate for the low medical cost that was found to be the main cause of deficit.<sup>6</sup> These efforts drove the NICU-operating hospitals to add more beds or to upgrade existing facilities in both capital and non-capital areas in Korea.

Several studies reported that improvement in neonatal outcomes was achieved by a policy-based approach by the government. In Japan, an increased number of perinatal care centers driven by the government contributed to a recent reduction in the neonatal mortality rate, which reduced the median travel time and regional disparity of accessibility.<sup>7</sup> In the United States, antenatal transfer system of high-risk mothers and regionalization of NICUs were associated with better neonatal outcomes.<sup>8,9</sup> In Korea, the regional disparity in resources for neonatal intensive care was attributed to inequality in mortality of very low birthweight infants (VLBWIs).<sup>10</sup>

The first object of our study was to identify the current state of NICUs in Korea and assess changes compared to previous studies after government-driven subsidy policies. The second aim was to identify regional disparity in NICU facilities, human resources, and mortality of VLBWIs, and estimate improvement in the disparity.

**METHODS**

The survey was conducted with 105 registered hospitals with the Health Insurance Review and Assessment (HIRA) service in 2015. Questionnaires were sent via mail and e-mail to the chiefs of the NICUs in the hospitals. The questionnaires assessed the number of NICU beds, the rates of admission and mortality of VLBWI (death before discharge), personnel status, equipment and facilities, availability of special treatment (extracorporeal membrane oxygenation [ECMO], dialysis, and therapeutic hypothermia), and available multidisciplinary approach in 2015. Questionnaire items were modified based on previous studies in 2010 and 2012.<sup>10-12</sup> Current data was compared with the previous studies and changes in the status and function of NICUs nationwide from 2009 (personnel status, facilities, and equipment) or 2011 (equipment and collaboration) to 2015 were estimated. Each item was described according to the regions in absolute terms as well as per bed or per birth.

Number of beds was assessed in the seven metropolitan cities (Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan) and nine administrative provinces (Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju) in Korea and they were grouped into five regions (1, Seoul; 2, Incheon and Gyeonggi province; 3, Chungcheong and Gangwon provinces; 4, Gyeongsang province; and 5, Jeolla province) to compare with previous study.<sup>10</sup> Regions 1 and 2 are capital areas and 3 to 5 are non-capital areas. Level of care was graded with a scoring system that was used in the previous study.<sup>10</sup> One point was awarded for each of the following nine items: availability of total parenteral

nutrition, general pediatric surgery, pediatric thoracic surgery, nitric oxide therapy, ECMO therapy, dialysis treatment, echocardiography, other ultrasounds, and capability of blood gas analysis within the unit. A hospital with a score of 1–5 was assigned as level 1, 6–7 points as level 2, and 8–9 points as level 3. Therefore, hospitals with higher scores indicate higher level of neonatal intensive care.

In Korea, all parents must register their child's birth within one month at the administrative agency located near their residence, and we used the data from the Statistics Korea to estimate the number of births in each region.<sup>13</sup> To estimate the number of NICU beds needed in the hospital, duration of hospitalization by stratified birthweight was referred from previous study and multiplied by the actual number of births according to birthweight. The sum of figures then divided by 365 days.<sup>11,12,14</sup> We calculated the regional coverage of premature births in hospitals by comparing the number of registered births in Statistics Korea and the number of births reported by hospitals. Birth and mortality were reviewed and compared with those from 2009, according to the level of NICUs and regions defined above.

### Statistical analysis

The logistic regression analysis was used to identify the risk of mortality among level of units and areas. All analyses were performed using the STATA software (version 12.1; StataCorp, College Station, TX, USA), *P* values of < 0.05 were considered statistically significant, and odds ratios (ORs) with 95% confidence intervals (CIs) were reported to describe the strengths of the associations.

### Ethics statement

As this study was not a human subject research, ethical review was waived by the Institutional Review Board at the Seoul National University Hospital.

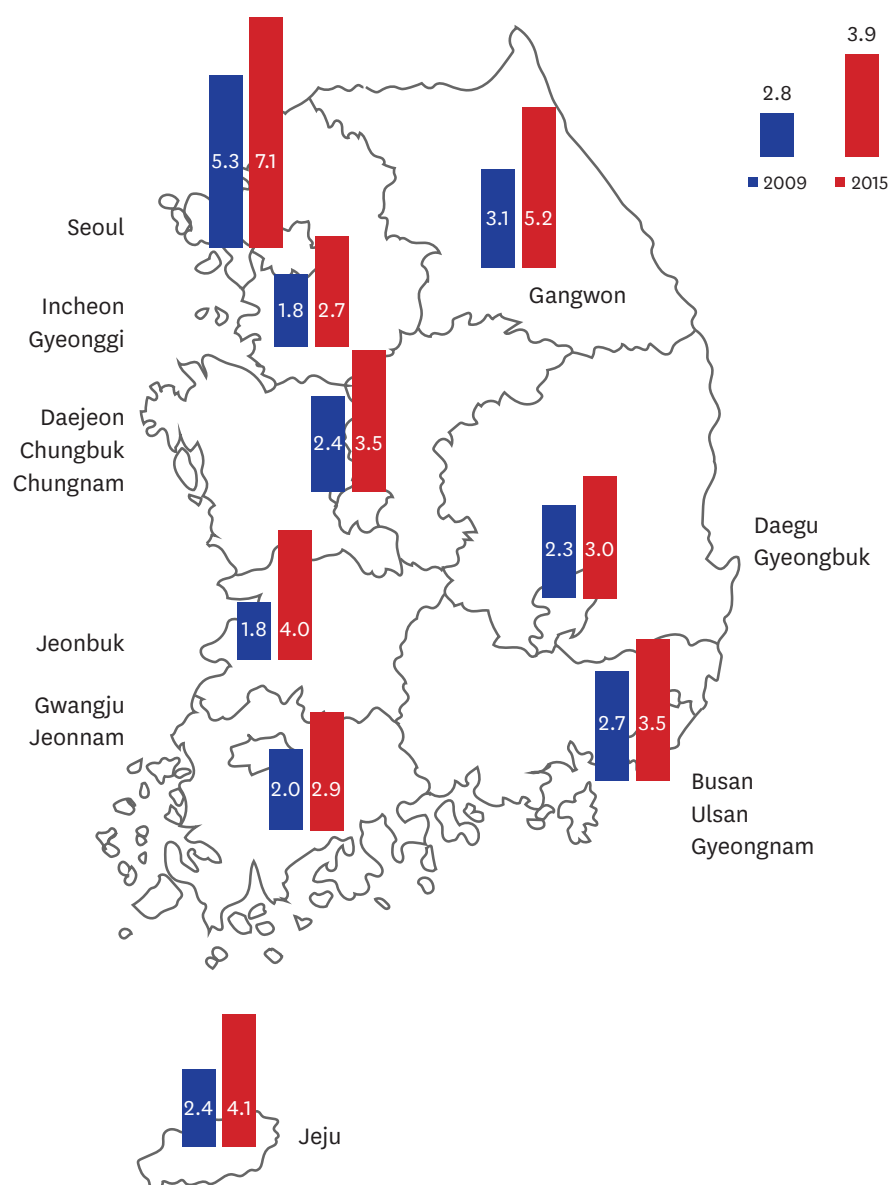
## RESULTS

Among 105 hospitals registered with the HIRA, 89 actually operated NICUs. Of these, 87 hospitals responded to the questionnaire and the retrieval rate was 97.8%. One of the two hospitals that refused to participate in the survey had only three NICU beds in Gyeonggi province. However, the other hospital was one of the two hospitals in Jeju province, and so we excluded the area from the analysis.

Even though the number of hospitals that run a NICU decreased from 91 in 2009 to 89 in 2015, there was significant increase in the total number of NICU beds. There were 1,714 NICU beds across the country in 2015 whereas there were 1,252 of these in 2009. This increase occurred in all provinces and it is estimated that there were 3.9 beds per 1,000 births (**Fig. 1**). Of 462 increased beds, 124 (26.8%) beds were in Seoul and 338 (73.2%) were distributed in the other cities and provinces. The average facility area of NICUs has increased from 272.4 ± 220.9 m<sup>2</sup> in 2011 to 348.2 ± 224.0 m<sup>2</sup> in 2015.<sup>11</sup>

### Required number of NICU beds and coverage of regional VLBWI births

The number of patients who were admitted to NICUs in 2015 was 34,714. The number of patients was multiplied with the average hospital days stratified by birthweight and the sum of the figure was divided by 365 days to obtain the average number of patients per day.<sup>14</sup> As a result, an average of 1,710 patients are receiving inpatient treatment in NICU each



**Fig. 1.** Comparison of changes in the distribution of NICU beds in Korea between 2009 and 2015 (number per 1,000 births).

NICU = neonatal intensive care unit.

day, which implied that there were 3.9 beds per 1,000 births and 67.7 beds per 1,000 low birthweight infants. This estimation was close to the current number of total NICU beds as described above (Table 1). In consideration of reserved beds equivalent to 10% of total beds for emergency deliveries or transfer from other hospitals, additional 169 beds are still required nationwide (4.3 per 1,000 births).<sup>11,12</sup> Most metropolitan cities except Incheon and Ulsan have enough or excessive beds. Other provinces still had insufficient beds. Hospitals in most metropolitan cities covered more than 100% of births of VLBWI in the city, whereas, hospitals in provinces except Jeonbuk covered less than 80%. Even the coverage in Gyeongbuk and Jeonnam was 4% and 20%, respectively. However, including the surrounding areas, hospitals in all regions covered about or more than 90% of VLBWI births (Table 2).

**Table 1.** Current and required number of NICU beds according to regions in Korea, 2015

City or province	No. of births in 2015 <sup>a</sup>	No. of NICU beds	No. of NICU beds per 1,000 births	Estimated No. of beds required			
				3.9 beds/1,000 births		4.3 beds/1,000 births <sup>b</sup>	
				Required	Surplus	Required	Surplus
Seoul <sup>c</sup>	83,005	590	7.1	324	266	357	233
Busan <sup>c</sup>	26,645	136	5.1	104	32	115	21
Daegu <sup>c</sup>	19,438	109	5.6	76	33	84	25
Incheon <sup>c</sup>	25,491	71	2.8	99	-28	110	-39
Gwangju <sup>c</sup>	12,441	68	5.5	49	19	53	15
Daejeon <sup>c</sup>	13,774	88	6.4	54	34	59	29
Ulsan <sup>c</sup>	11,732	25	2.1	46	-21	50	-25
Gyeonggi	113,495	308	2.7	443	-135	488	-180
Gangwon	10,929	57	5.2	43	14	47	10
Chungbuk	13,563	25	1.8	53	-28	58	-33
Chungnam	21,312	55	2.6	83	-28	92	-37
Jeonbuk	14,087	57	4.0	55	2	61	-4
Jeonnam	15,061	11	0.7	59	-48	65	-54
Gyeongbuk	22,310	16	0.7	87	-71	96	-80
Gyeongnam	29,537	77	2.6	115	-38	127	-50
Jeju	5,600	23	4.1	22	1	24	-1
Total	438,420	1,716	3.9	1,710	6	1,885	-169

NICU = neonatal intensive care unit.

<sup>a</sup>Birth registry data from Statistics Korea; <sup>b</sup>Considering 10% of reserved bed; <sup>c</sup>Metropolitan cities.**Table 2.** Coverage of very low birth weight infants by regional NICUs in Korea, 2015

City or province	Births in the regional hospitals	Registered births in the region <sup>a</sup>	Coverage (%)	5 regions <sup>b</sup>	Births in the regional hospitals	Registered births in the region	Coverage (%)	3 regions <sup>c</sup>	Births in the regional hospitals	Registered births in the region	Coverage (%)
Seoul <sup>d</sup>	994	539	184	1	994	539	184	1	2,000	1,909	105
Incheon <sup>d</sup>	127	189	67	2	679	957	71				
Gyeonggi	552	768	72								
Gangwon	67	90	74	3	327	413	79				
Chungbuk	37	87	43								
Daejeon <sup>d</sup>	133	92	145								
Chungnam	90	144	63								
Daegu <sup>d</sup>	298	165	181	4	771	839	92	2	771	839	92
Gyeongbuk	7	166	4								
Busan <sup>d</sup>	278	214	130								
Ulsan <sup>d</sup>	66	76	87								
Gyeongnam	122	218	56								
Jeonbuk	70	76	92	5	219	246	89	3	219	246	89
Gwangju <sup>d</sup>	132	83	159								
Jeonnam	17	87	20								

NICU = neonatal intensive care unit.

<sup>a</sup>Birth registry data from Statistics Korea; <sup>b</sup>Tying up the surrounding area geographically, 1: Seoul, 2: Incheon and Gyeonggi province, 3: Chungcheong and Gangwon provinces, 4: Gyeongsang province, and 5: Jeolla province; <sup>c</sup>Tying up the surrounding area geographically, 1: Seoul, Incheon and Gyeonggi province, Chungcheong, and Gangwon provinces, 2: Gyeongsang province, and 3: Jeolla province; <sup>d</sup>Metropolitan cities.

## Facilities and equipment

Compared with 2009, the number of invasive ventilators increased by 3.7 per 10,000 births (Table 3). The increase was most pronounced in Gyeongsang and Jeolla province, by 6.1 and 4.5 per 10,000 births, respectively. The number of hospitals capable providing treatment for inhaled nitric oxide (iNO) for pulmonary hypertension increased especially in the capital area and Gyeongsang province. It is still available only in 60% of NICUs in Korea. Additionally, ultrasound and amplitude-integrated electroencephalogram (aEEG) became more available. Therapeutic hypothermia system became equipped in about half of NICUs in Korea.

**Table 3.** Changes in equipment, multidisciplinary approach, and workforce of neonatal care according to the regions

Characteristic	Year	Region <sup>a</sup>					Total
		1	2	3	4	5	
No. of ventilator	2009	228	129	68	128	43	596
	2015	239	163	92	196	59	749
Ventilator/10,000 births	2009	25.4	9.3	11.5	11.8	9.7	13.6
	2015	28.8	11.7	15.4	17.9	14.2	17.3
No. of iNO available hospitals	2009	14	7	7	10	1	39
	2015	18	10	8	14	2	52
iNO available hospitals (%)	2009	47	33	78	48	13	44
	2015	64	45	80	74	25	60
No. of cardiologists available hospitals	2009	27	16	9	17	6	75
	2015	21	14	8	16	6	65
Cardiologists available hospitals (%)	2009	90	80	100	81	75	84
	2015	75	67	80	84	75	76
No. of in-NICU US available hospitals	2011	20	12	7	10	5	54
	2015	19	13	7	15	8	62
In-NICU US available hospitals (%)	2011	71	57	78	50	71	64
	2015	68	62	70	79	100	72
No. of aEEG available hospitals	2011	2	3	2	1	1	9
	2015	11	10	7	10	6	44
aEEG available hospitals (%)	2011	7	14	22	5	14	11
	2015	39	48	70	53	75	51
No. of hypothermia therapy available hospitals	2011	6	2	2	1	0	11
	2015	12	11	6	8	4	41
Hypothermia therapy available hospitals (%)	2011	21	10	22	5	0	13
	2015	43	50	60	42	50	48
No. of PDA operation available hospitals	2011	21	14	8	16	5	64
	2015	21	14	8	14	5	62
PDA operation available hospitals (%)	2011	75	67	89	80	71	72
	2015	75	64	80	74	63	71
No. of NEC/SIP operation available hospitals	2011	20	11	8	15	5	59
	2015	18	14	7	15	5	59
NEC/SIP operation available hospitals (%)	2011	71	52	89	75	71	66
	2015	64	64	70	79	63	68
No. of EVD operation available hospitals	2011	19	15	9	16	5	64
	2015	20	16	7	13	5	61
EVD operation available hospitals (%)	2011	68	71	100	80	71	72
	2015	71	73	70	68	63	70
No. of neonatologists	2009	40	17	11	20	6	94
	2015	58	23	13	25	11	130
Neonatologists/10,000 births	2009	4.5	1.2	1.9	1.8	1.4	2.1
	2015	7.0	1.7	2.2	2.3	2.6	3.0
Neonatologists/a bed	2009	0.08	0.07	0.07	0.07	0.07	0.08
	2015	0.10	0.06	0.06	0.07	0.08	0.08
No. of NICU nurses	2009	511	261	131	318	83	1,304
	2015	654	375	236	385	123	1,773
NICU nurses/10,000 births	2009	57.0	18.9	22.1	29.4	18.7	29.7
	2015	78.8	27.0	39.6	35.1	29.6	41.0
NICU nurses/a bed	2009	1.07	1.03	0.89	1.15	0.98	1.05
	2015	1.11	0.99	1.05	1.06	0.90	1.05

iNO = inhaled nitric oxide, PDA = patent ductus arteriosus, NEC = necrotizing enterocolitis, SIP = spontaneous intestinal perforation, EVD = extraventricular drainage, aEEG = amplitude-integrated electroencephalogram, NICU = neonatal intensive care unit.

<sup>a</sup>1: Seoul, 2: Incheon and Gyeonggi province, 3: Chungcheong and Gangwon province, 4: Gyeongsang province, and 5: Jeolla province.

### Multidisciplinary approach

Multidisciplinary approach is essential in neonatal intensive care because there could be nutritional, medical, and surgical problems concurrently. However, support from departments other than neonatology did not significantly improve. Proportion of hospitals with pediatric cardiologists or emergency operations such as closure of patent ductus

**Table 4.** Births and risk of death in very low birth weight infants by level of care and regions in Korea

Year	Characteristic	Level <sup>a</sup>			Region <sup>b</sup>					Total
		1	2	3	1	2	3	4	5	
2009	Hospital	47 (53.4)	29 (33.0)	12 (13.6)	30 (33.7)	21 (23.6)	9 (10.1)	21 (23.6)	8 (9.0)	89
	Birth	510 (19.7)	1,310 (50.7)	764 (29.6)	1,054 (40.8)	461 (17.8)	286 (11.1)	565 (21.9)	197 (7.6)	2,563
	Mortality rate	16.3	16.6	9.0	10.9	13.2	19.9	16.3	21.3	14.3
	OR (95% CI)	2.0 (1.4–2.8)	2.0 (1.5–2.7)	1.0 (Ref.)	1.0 (Ref.)	1.3 (0.9–1.7)	2.0 (1.4–2.8)	1.6 (1.2–2.1)	2.2 (1.5–3.3)	
2015	Hospital	33 (38.8)	30 (35.3)	22 (25.9)	28 (32.2)	21 (24.1)	10 (11.5)	19 (21.8)	8 (9.2)	86
	Birth	399 (13.3)	1,040 (34.8)	1,549 (51.2)	994 (33.2)	679 (22.7)	327 (10.9)	771 (25.8)	219 (7.3)	2,990
	Mortality rate	9.5	12.5	10.8	10.7	11.9	10.4	12.8	7.3	11.2
	OR (95% CI)	0.9 (0.6–1.3)	1.5 (1.2–1.9)	1.0 (Ref.)	1.0 (Ref.)	1.3 (0.9–1.7)	1.1 (0.7–1.6)	1.4 (1.0–1.8)	0.7 (0.4–1.3)	

Values are presented as number (%).

OR = odds ratio, CI = confidence interval.

<sup>a</sup>See Method for definition; <sup>b</sup>1: Seoul, 2: Incheon and Gyeonggi province, 3: Chungcheong and Gangwon province, 4: Gyeongsang province, and 5: Jeolla province.

arteriosus (PDA), or extraventricular drainage (EVD) decreased (**Table 3**). Regardless of this, the proportion of hospitals capable of surgical treatment in necrotizing enterocolitis or spontaneous intestinal perforation (66% to 68%) and retinopathy of prematurity (69% to 74%) slightly increased between 2009 and 2015 (**Table 3**).

### Human resources

The total number of neonatologists who were accredited by the Korean Society of Neonatology increased during the last 6 years from 94 to 130, corresponding to 0.08 neonatologists per bed both in 2009 and in 2015 (**Table 3**). However, in Incheon and Gyeonggi province and Gangwon and Chungcheong province, the number of neonatologists did not meet the increase in NICU beds. The number of nurses nationwide was the same, 1.05 per bed. By regions, the ratio increased in Seoul and Chungcheong and Gangwon province but in the other provinces it noticeably decreased.

### Births and mortality of VLBWI

Births of VLBWIs increased from 2,563 in 2009 to 2,990 in 2015. In 2009, half of them were born in level 2 NICU but in 2015, level 3 NICU covered half of the births (**Table 4**). The proportion of births of VLBWIs decreased in Seoul and increased in Incheon and Gyeonggi province and Gyeongsang province. The overall mortality decreased from 14.3% to 11.2% with a marked decrease in the risk of mortality in regions other than Seoul. The risk of mortality was significantly higher in regions other than Seoul (OR, 1.6 to 2.2) in 2009, which was attenuated and became comparable to Seoul area in 2015. Mortality rates of VLBWIs in level 1 and 2 NICUs in 2015 were lower than those in 2009, while the mortality rate increased in level 3 NICUs (9.0% to 10.8%) in 2015.

## DISCUSSION

In the present study, the status of neonatal intensive care of Korea in 2015 was investigated and compared with the status in 2009 and 2011 to evaluate the function of NICUs. The results showed that the absolute numbers of NICU beds, facilities, and manpower increased during last six years and disparity in the mortality of VLBWI improved. However, the increase in human resources did not meet the increase in the number of beds and multidisciplinary supports especially in surgical departments were not enhanced.

During the study period, the government fostered improvements in national neonatal intensive care system in two ways. First, it increased medical expenses for neonatal intensive care such



as administration fee and cost for medical facilities. In the past, running an NICU in a hospital inevitably caused a loss to the hospital in Korea because of low medical fee. This increase was mostly covered by national insurance, thus minimizing financial burden of individual patients. Second, they selected regional NICUs outside Seoul and directly supported them financially to build more beds and facilities. The former effort contributed to an increase in the number of NICU beds and facilities in Seoul where direct support projects were not applied. Outside Seoul, the increase in the number of beds mostly resulted from the latter effort by government. Consequently, the survey data showed that the total number of beds met the estimated number of beds required in 2015. This capability is comparable to that of the United States.<sup>15</sup> Even though there is an imbalance between metropolitan cities and provinces, hospitals in metropolitan cities usually cover surrounding areas and the imbalance was found to be alleviated in a regional analysis of neighboring districts, which could usually reach in 1–2 hours by car (**Table 2**). Such a phenomenon might be due to a relatively small land area in Korea. Because the NICU should always have beds for emergency patients, we assumed that 10% of reserved beds and an additional 169 beds are required nationwide. It is necessary to supply additional beds in the region where there is an overall shortage currently.

Even though many equipment and beds had been supplemented over the past six years, some equipment is disproportionately distributed. Equipment for emergency treatment (iNO, machines for therapeutic hypothermia) should be appropriately supplied in every region. Number of neonatologists and nurses increased in proportion to supplemented beds but there was still disparity between cities and provinces. The number of neonatologists per 10,000 births in Seoul was comparable to that in the United States and more than some Commonwealth countries but the numbers in other cities or provinces were lower than in other countries.<sup>15</sup> Although the number of nurses per beds was same in 2009 and 2015, the relevance of current attendance of nursing staff should be reconsidered. Nurses usually work in three shifts in Korea; one nurse has to take care of more than three infants concurrently, which could affect the quality of care and safety of patients in NICUs.<sup>16</sup> In region 2 and 5, the proportion was even lower in 2015. The status of human resources in NICUs has improved but it is still insufficient.

In contrast to the improvement in facilities, equipment, and neonatal staffs, supports from other specialists decreased. The number of hospitals where pediatric cardiologists or emergency operations were available diminished in most areas. Low medical fee for pediatric population, especially in surgical intervention, is an obstacle when it comes to hiring adequate numbers of pediatric surgeon. Of neonatal deaths, 20% were related to surgical conditions, which could be managed by pediatric surgeons more than general surgeons. Thus, there is an urgent need to improve reimbursement of health care costs for pediatric surgical patients.<sup>17,18</sup>

Compared to 2009, level 3 NICUs increased from 12 to 22 and level 1 decreased from 47 to 33, and level 2 were similar (29 and 30) (**Table 4**). Births of VLBWIs decreased in level 1 and 2 NICUs but markedly increased in level 3 NICUs as the number of level 3 units increased. Regional redistribution of preterm births also occurred, which presented with less number of births in Seoul and more births in Gyeonggi and Incheon province and Gyeongsang provinces. Overall mortality rate of VLBWIs decreased nationally, led by reduced mortality rates in regions other than Seoul or level 1 and 2 NICUs. The regional disparity was alleviated after the recent efforts by the government.<sup>10</sup>

There are some limitations in the present study. First, data from Statistics Korea were not directly taken from hospitals, but were reported by the parents. However, the data are



believed to be exact because these reports were medically certified by obstetricians and the civil servants review them on the website. Second, we could not access clinical data, such as morbidities and congenital anomalies in each hospital and this made it impossible to adjust for severity factors, for the mortality rate. Additional studies are required to grade NICUs with severity for the further assessment of their needs regarding on facilities and human resources accordingly. Despite these limitations, we investigated 97.8% of NICUs in Korea and could assess the status of neonatal care in the country. Moreover, with previous studies and reports, we tracked changes in facilities and human resources by regions, and found improvement in neonatal mortality rates and disparity between regions.<sup>11,12</sup>

The Korean government invested in neonatal care to overcome low fertility rate and increasing number of high-risk infants during the last decade. Due to the support policies, there has been proliferation and improvement in NICU and its facilities throughout the country. These changes were accompanied by improvement in preterm infant care and regional disparity. Notwithstanding these improvements, there is still a shortage of human resources and multidisciplinary supports for high-risk infants. Further efforts for improving working conditions and readjusting medical fee might be required to supply medical staffs stably in NICUs and to provide multidisciplinary approach for high-risk infants. In terms of replacing reserved beds, it would be better to not only cautiously increase the number of beds according to the regional births, but also enhance the level of care such as facilities and medical staffs capable of surgical care simultaneously. Moreover, for regionalization, making official classification of NICUs with the required facilities and medical staffs is necessary, and then referral system of high-risk mothers and neonates between different levels of NICU should be founded.<sup>19</sup> Since 2014, the government started “The integrated center for high-risk pregnant women and neonates program” and these centers are expected to play the main role of high level NICUs in each region.<sup>20</sup> Through these efforts, we expect the provision of qualified perinatal care anywhere in Korea, and further improvement in perinatal health outcomes.

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## REFERENCES

1. Fertility rate. [http://www.index.go.kr/potal/main/EachDtlPageDetail.do?idx\\_cd=1428](http://www.index.go.kr/potal/main/EachDtlPageDetail.do?idx_cd=1428). Updated 2016. Accessed May 24, 2017.
2. Trend of birth rate. [http://kosis.kr/statisticsList/statisticsList\\_01List.jsp?vwcd=MT\\_ZTITLE&parentId=A#SubCont](http://kosis.kr/statisticsList/statisticsList_01List.jsp?vwcd=MT_ZTITLE&parentId=A#SubCont). Updated 2016. Accessed October 1, 2016.
3. Moon JY, Hahn WH, Shim KS, Chang JY, Bae CW. Changes of maternal age distribution in live births and incidence of low birth weight infants in advanced maternal age group in Korea. *Korean J Perinatol* 2011;22(1):30-6.
4. Shin S, Park J, Namgung R, Park M, Son D, Lee J. *Establishment of an Effective Healthcare System for High Risk Newborn Infants*. Seoul, Korea: Korea Health Promotion Foundation, Management Center for Health Promotion; 2006.
5. Announcement of regional neonatal care center selection. [http://www.mohw.go.kr/front\\_new/al/sal0101vw.jsp?PAR\\_MENU\\_ID=04&MENU\\_ID=040101&CONT\\_SEQ=331285&page=1](http://www.mohw.go.kr/front_new/al/sal0101vw.jsp?PAR_MENU_ID=04&MENU_ID=040101&CONT_SEQ=331285&page=1). Updated 2016. Accessed May 25, 2017.
6. Notice for list of insured and uninsured items and revision of relative value score. [http://m.hira.or.kr/cms/notice/1316305\\_13992.html](http://m.hira.or.kr/cms/notice/1316305_13992.html). Updated 2013. Accessed May 25, 2017.
7. Aoshima K, Kawaguchi H, Kawahara K. Neonatal mortality rate reduction by improving geographic accessibility to perinatal care centers in Japan. *J Med Dent Sci* 2011;58(2):29-40.  
[PUBMED](#)
8. Holmstrom ST, Phibbs CS. Regionalization and mortality in neonatal intensive care. *Pediatr Clin North Am* 2009;56(3):617-30.  
[PUBMED](#) | [CROSSREF](#)
9. Thompson LA, Goodman DC. Regionalized perinatal care: an evidence-based intervention in development. In: Handler A, Kennelly J, Peacock N, editors. *Reducing Racial/Ethnic Disparities in Reproductive and Perinatal Outcomes*. New York, NY: Springer; 2011, 429-55.

10. Shim JW, Kim MJ, Kim EK, Park HK, Song ES, Lee SM, et al. The impact of neonatal care resources on regional variation in neonatal mortality among very low birthweight infants in Korea. *Paediatr Perinat Epidemiol* 2013;27(2):216-25.  
[PUBMED](#) | [CROSSREF](#)
11. Kim HS, Kim EA, Choi BM, Choi CW, Shim SY, Jung JM. *Evaluation of Performance and Efficiency in Operation of Neonatal Intensive Care Unit*. Seoul, Korea: Ministry of Health and Welfare; 2012.
12. Chang Y. *The Survey on the Actual Conditions of Neonatal Intensive Care Units and Analysis of Survival Rate of High-risk Newborn Infants*. Seoul, Korea: Korea Health Promotion Institute; 2010.
13. Number of births in the Republic of Korea. [http://kosis.kr/statisticsList/statisticsList\\_01List.jsp?vwcd=MT\\_ZTITLE&parentId=A#SubCont](http://kosis.kr/statisticsList/statisticsList_01List.jsp?vwcd=MT_ZTITLE&parentId=A#SubCont). Updated 2015. Accessed May 30, 2017.
14. Bae CW, Kim KS, Kim BI, Shin SM, Lee SL, Lim BK, et al. Patient distribution and hospital admission costs in neonatal intensive care units: collective study of 7 hospitals in Korea during 2006. *J Korean Soc Neonatol* 2009;16(1):25-35.
15. Thompson LA, Goodman DC, Little GA. Is more neonatal intensive care always better? Insights from a cross-national comparison of reproductive care. *Pediatrics* 2002;109(6):1036-43.  
[PUBMED](#) | [CROSSREF](#)
16. Rogowski JA, Staiger DO, Patrick TE, Horbar JD, Kenny MJ, Lake ET. Nurse staffing in neonatal intensive care units in the United States. *Res Nurs Health* 2015;38(5):333-41.  
[PUBMED](#) | [CROSSREF](#)
17. 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](#)
18. Han SJ. High-risk maternal and newborn integrated care centers: status and issues on aspect of pediatric surgery. *Korean J Perinatol* 2014;25(2):68-74.  
[CROSSREF](#)
19. Bae CW. Bench-marking of Japanese perinatal center system for improving maternal and neonatal outcome in Korea. *Korean J Perinatol* 2010;21(2):129-39.
20. Lee G. *Establishment of Health Care Delivery System between the Integrated Center for High-risk Pregnant Women and Neonates and the Maternity Care in the Underserved Area*. Cheongju, Korea: Ministry of Health and Welfare; 2015.