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Research Article

Association between nurse staffing levels and rotavirus infection in neonatal intensive care units: A retrospective observational study

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ABSTRACT

Objectives: To explore the relationship between nurse staffing levels and rotavirus infection in neonatal intensive care units.
Research Methodology: This study adopted a retrospective observational design with data from the Health Insurance Review and Assessment Service (2018) database in South Korea. Participants were 35,308 infants in neonatal intensive care units. Multiple logistic regression analyses were employed to examine the association between nurse staffing levels and rotavirus infection in neonatal intensive care units after adjusting for confounding variables such as patient and hospital-related characteristics.
Results: A total of 1,514 (4.3%) infants developed rotavirus infection. Among the confounding variables, infectious disease, and being admitted from January to March and in December significantly increased the risk of rotavirus infection, whereas low birth weight, cardiovascular disorders, neonatal jaundice, receiving breastmilk, central line insertion, and ventilator usage significantly decreased the risk. Neonatal intensive care units with a grade 5 nurse staffing level (compared with grades 1–4) had a higher risk of rotavirus infection.
Conclusions: The results suggest that neonatal intensive care units with higher (vs lower) nurse staffing levels are associated with lower rotavirus infection rates among infants. High-risk infants are extremely susceptible to hospital-acquired infections, and more intensive nursing care that differs from that provided to adult or paediatric patients is required. Therefore, nurse staffing levels with less than a 2:1 patient-to-nurse ratio are needed to control and prevent rotavirus infection in neonatal intensive care units.

Implications for clinical practice

- Nurse staffing levels with less than a 2:1 patient-to-nurse ratio might be effective in preventing rotavirus infection in neonatal intensive care unit infants.
- Infants provided with breastmilk had lower rates of rotavirus infection than those not provided with breastmilk; therefore, nurses should offer mothers information regarding the effective provision of breastmilk.

Introduction

Rotavirus is an important cause of gastroenteritis in infants worldwide, in both developed and developing countries. Common symptoms of rotavirus infection include severe diarrhoea and vomiting, which lead to dehydration, and contribute to morbidity and mortality among infants (Aliabadi et al., 2019; Muendo et al., 2018; Ojobor et al., 2020). Rotavirus is ubiquitous and is primarily transmitted by the faecal-oral route through either direct or indirect contact; transmission can also occur by contaminated water and respiratory droplets (Crawford et al., 2017). Although a rotavirus vaccine was first introduced in 2006

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globally, infants cannot be vaccinated until they are six weeks old (Cortese et al., 2009). Therefore, the highly contagious rotavirus can spread in new-borns and infants with weak immunities (Burke et al., 2020; Tsai et al., 2019). In South Korea, while the overall rate of rotavirus infection has decreased since vaccine administration began in 2008, the infection rate in infants has not decreased (Cho et al., 2020; Lee et al., 2019).

In addition, the Advisory Committee on Immunisation Practices cautions against administering the rotavirus vaccine to infants in hospital nurseries or neonatal intensive care units (NICUs) because of the potential risk of transmission of the live vaccine-strain virus (Cortese et al., 2009). Especially, infants in NICUs, typically admitted immediately after birth, are at high risk for hospital-acquired rotavirus infection (Burke et al., 2020; Tan et al., 2016). Rotavirus infection might easily spread to vulnerable infants owing to infective particles from the stools of infected infants and contact with contaminated persons or fomites (Kim et al., 2017; Tsai et al., 2019).

Nurse staffing levels (number of nurses to patients) are associated with hospital-acquired infections (Cimiotti et al., 2012). Previous studies show that lower nurse staffing levels were associated with an increased risk of hospital-acquired infections such as bloodstream, urinary tract, surgical site infections, and pneumonia (Cimiotti et al., 2012; Shang et al., 2019; Van et al., 2020). In Kim and Kim's study (2018), hospital-acquired infections in paediatric patients, such as gastrointestinal and respiratory infections, decreased as nurse staffing levels increased. Furthermore, most healthcare providers perceived the nursing shortage in NICUs as the main barrier to infection prevention and control (Salem and Youssef, 2017). There is substantial literature that suggests an association between nurse staffing levels and hospital-acquired infections (Cimiotti et al., 2012; Kim and Kim, 2018; Shang et al., 2019; Van et al., 2020); however, little is known about the association between nurse staffing levels and rotavirus infection.

Various risk factors associated with rotavirus infection have been reported. The prevalence was higher in infants aged $<$ 24 months compared with older infants (Kim et al., 2017; Ojobor et al., 2020). An underlying disease or malformation, prematurity or low birth weight, and a hospital-acquired infection other than rotavirus were also related to rotavirus infection in infants (Fidhow et al., 2017; Hwang and Kim, 2018; Kim et al., 2017). Invasive procedures and ventilator care might also increase the risk of hospital-acquired infections in NICUs (Andersson et al., 2019; Flidel-Rimon et al., 2019; Scamardo et al., 2020). Rotavirus infection is characterised by seasonal peaks, from December to March in South Korea (Choi et al., 2013; Lee et al., 2019). However, other studies suggested that breastmilk could protect against rotavirus infection (Muendo et al., 2018; Salim et al., 2014). Additionally, hospitals' location and health insurance status, indicating parents' socioeconomic status, could be related to hospital-acquired infections in hospitalised infants (Kim and Kim, 2018).

Although research has found significant effects of nurse staffing levels on patient health outcomes, most previous studies focused on adults (Musy et al., 2021; Shin et al., 2019). Since appropriate nurse staffing levels are crucial to providing quality nursing care and for patient safety, more data needs to be accumulated from various patient groups and nursing work units to provide reasonable guidelines for appropriate nurse staffing levels (Musy et al., 2021; Shin et al., 2019). However, evidence of the association between nurse staffing levels and hospital-acquired infections in infants is limited.

Consequently, we examined the association between nurse staffing levels and rotavirus infections in NICUs using national data from the Health Insurance Review and Assessment Service (HIRA). HIRA is the Korean organisation that sets the criteria for the application of medical claims covered by the national health insurance and evaluates the quality of healthcare services (HIRA, 2018, 2019). We adjusted for several confounding variables such as low birth weight, prematurity, hospital-acquired infections other than rotavirus (Fidhow et al., 2017; Hwang and Kim, 2018; Kim et al., 2017), underlying disease, admission season (Kim et al., 2017; Lee et al., 2019; Ojobor et al., 2020), central line insertion, ventilator status (Andersson et al., 2019; Flidel-Rimon et al., 2019; Scamardo et al., 2020), medical security, hospital location (Kim and Kim, 2018), and breastmilk provision (Muendo et al., 2018; Salim et al., 2014). All these variables have previously been reported as risk factors for rotavirus in NICUs or hospital-acquired infections.

Methods

Database

We used data from 2018 from the HIRA database, which contains electronic reimbursement claims data of inpatients and outpatients in South Korea. All medical institutions in South Korea must submit medical care fee claims for all patients via either electronic data interchange or electronic media to the HIRA. The database also contains demographic information of patients, such as age, sex, up to 30 diagnoses, all operations and procedures, care-provision details such as ICU stay and ventilator usage, breastfeeding history, and central line insertion. Diagnoses were coded using the International Classification of Diseases, 10th Revision (ICD-10), and procedures using the Korean national health insurance reimbursement claim code.

Ethics

This study was approved by the institutional review board of Asian Medical Center (no. 2019-0711).

Study design and population

We used a retrospective observational design. We selected all anonymised patients who used NICUs in 2018 through electronic reimbursement claims data.

Measures

Nurse staffing level

Nurse staffing level refers to the staffing grade of NICU nurses. There are five levels, determined by the ratio of beds to registered nurses in the NICU (HIRA, 2018): grade 1 ($<$ 0.75:1), grade 2 (0.75:1 to $<$ 1:1), grade 3 (1:1 to $<$ 1.5:1), grade 4 (1.5:1 to $<$ 2:1), and grade 5 ($\geq$ 2:1).

Risk factors related to rotavirus infection

We selected risk factors noted in previous studies (Andersson et al., 2019; Fidhow et al., 2017; Flidel-Rimon et al., 2019; Hwang and Kim, 2018; Kim et al., 2017; Kim and Kim, 2018; Lee et al., 2019; Muendo et al., 2018; Ojobor et al., 2020; Salim et al., 2014; Scamardo et al., 2020) and the HIRA database. Patients' characteristics such as age (continuous variable), sex, the type of health security as a proxy index of socioeconomic status (health insurance for higher socioeconomic status or medical aid for lower socioeconomic status), admitted month, and breastmilk provision were considered. An eligibility criterion for Korean medical aid is that the household income should be less than 40 % of the median household income in the country.

Considered clinical characteristics were birth weight; gestational period; other hospital-acquired infections including respiratory syncytial virus, methicillin resistant *Staphylococcus aureus*, vancomycin resistant enterococci, and carbapenem resistant *Acinetobacter baumannii* (ICD-10 codes: B97.4, J21.0, B95.6, U82.1, B96.81, U83.0, and U82.8); infectious diseases including sepsis, respiratory infection, acute gastroenteritis, and congenital infection (ICD-10 codes: P36.1, P36.4, P36.9, J00-J06, J20-J22, A09, A09.0, A09.9, J11.8, A02.0, P35, and P37); respiratory disorders including respiratory distress syndrome and bronchopulmonary dysplasia (ICD-10 codes: P22.0 and P27.1); gastrointestinal disorders including megacolon and necrotising enterocolitis (ICD-10 codes: Q43.1 and P77); cardiovascular disorders including patent ductus arteriosus, congenital

heart disease, pulmonary hypertension, and Down syndrome (ICD-10 codes: Q25.0, Q24, Q22.1–4, Q23.1–3, Q26.0, I27.0 I27.2, Q90, and Q90.0); neurological disorders including intraventricular haemorrhage, and hydrocephalus, epilepsy (ICD-10 codes: P91.7, P10.2, G40, G41, P91.7, Q03 Q03.8 Q03.9, Q05.0–8, and G91–9); neonatal jaundice (ICD-10 codes: P57, P58, and P59); breastmilk provision; central line insertion; and ventilator usage. We identified each patient's comorbidity with the outpatient and inpatient data derived from the HIRA database.

According to a previous study, hospital characteristics include location (Needleman et al., 2002). Location was classified into three categories: large metropolitan areas (Seoul), other metropolitan areas, and other areas. Highly rated medical institutions are concentrated in metropolitan areas in South Korea. There are many big hospitals with premium services, high-end equipment, and specialised medical staff in Seoul—the capital of South Korea (Yoo, 2011). Hospitals in Seoul receive higher grades concerning the healthcare service quality evaluation (HIRA, 2019) and HIRA's hospital quality evaluation (Suh, 2018).

Rotavirus infection

We defined rotavirus infection using the ICD-10 code (A08.0) to calculate the incidence rate. Rotavirus infection information was derived from the inpatient reimbursement claim data of HIRA using these criteria, which have been mapped with the disease code.

Statistical analyses

Data were analysed with SAS® 9.4 software (Cary, NC). Descriptive statistics such as means, standard deviations, frequencies, and proportions were calculated to determine patients' characteristics. We conducted chi-square tests (χ^2) for the differences in the infection rate according to patient- and hospital-related characteristics. Multiple logistic regression analyses were used to examine relationships between nurse staffing level and rotavirus infection after adjusting for the patient- and hospital-related characteristics that were significantly different in the univariate tests ($p < .05$). SAS PROC GLIMMIX was employed for multiple logistic regression with NICU as a random intercept effect. Variable selection was performed by the backward elimination method with $p = .15$. The gestational period was not included in the multiple logistic regression model because it is highly correlated with birth weight.

Results

Patient- and hospital-related characteristics

Table 1 shows the patient- and hospital-related characteristics. Among the 35,308 infants administered to NICUs in Korea in 2018, 1,514 (4.3 %) developed rotavirus infection. Their mean age was 20.3 days. A total of 11,183 (31.7 %) patients had low birth weight, 14,902 (42.2 %) had a gestational period of less than 37 weeks, and 14,142 (40.1 %) received breastmilk. Patients with other hospital-acquired infections or infectious diseases, totalled 524 (1.5 %), and 7,105 (20.1 %), respectively. Nearly-one-quarter (8,104; 23.0 %) of the hospitals had a grade 1 staffing level, and more than 12,772 (36.2 %) patients were admitted from December 1st to March 31st (Table 1).

Differences in the patient- and hospital-related characteristics by rotavirus infection

Univariate analyses revealed that patients with rotavirus infection were younger and had lower birth weight and gestational age ($p < .001$). The mean age of patients with rotavirus infection was 10.5 days, shorter than the 20.8 days reported for patients without rotavirus infection. Rotavirus infection babies had a lower proportion of lower birth weight (less than 2.5 kg) patients compared with rotavirus non-infection babies (10.4 % vs 32.6 %). Infectious babies had a lower proportion of patients with gestational periods of fewer than 37 weeks than non-infectious babies (13.9 % vs 43.4 %).

Infectious babies more frequently had a history of other hospital-acquired infections or infectious diseases than non-infectious babies ($p < .001$). Furthermore, rotavirus infection babies had a lower proportion of patients with respiratory disorders, gastrointestinal disorders, cardiovascular disorders, neurological disorders, neonatal jaundice, who were breastfed, and who experienced central line insertion or ventilator usage than rotavirus non-infection babies ($p < .05$). Infectious babies were more frequently admitted from December to March than

Table 1
Patient- and hospital-related characteristics.

Independent Variable	(N = 35,308) n (%)
Mean Age, day (SD)	20.3 (33.5)
Sex	
Male	19,645 (55.6)
Female	15,663 (44.4)
Type of medical security	
Health Insurance	34,884 (98.8)
Medical Aid	424(1.2)
Birth Weight	
~999 g (ELBW)	2257 (6.4)
1000 g ~ 1499 g(VLBW)	2114(6.0)
1500 g ~ 2499 g(LBW)	6812 (19.3)
Normal	24,125 (68.3)
Gestational Period	
< 28 weeks	1777 (5.0)
≤ 28 weeks ~ < 37 weeks	13,125 (37.2)
Normal	20406(57.8)
Other hospital acquired infection	
Yes	524 (1.5)
No	34784(98.5)
Infectious disease	
Yes	7105 (20.1)
No	28203(79.9)
Respiratory disorders	
Yes	7623 (21.6)
No	27686(78.4)
Gastrointestinal disorders	
Yes	825 (2.3)
No	34,483 (97.7)
Cardiovascular disorders	
Yes	5151 (14.6)
No	30,157 (85.4)
Neurological disorders	
Yes	779(2.2)
No	34529(97.8)
Neonatal jaundice	
Yes	19713(55.8)
No	15595(44.2)
Admission month	
January ~ March, December	12772(36.2)
April ~ November	22536(63.8)
Breastmilk provision	
Yes	14142(40.1)
No	21166(59.9)
Central line insertion	
Yes	4349(12.3)
No	30959(87.7)
Ventilator	
Yes	8213 (23.3)
No	27095(76.7)
Nurse staffing level (ratio of beds to registered nurse)	
Grade 1 (<0.75:1)	8104(23.0)
Grade 2 (0.75:1 to < 1:1)	18329(51.9)
Grade 3 (1:1 to < 1.5:1)	8356(23.7)
Grade 4 (1.5:1 to < 2:1)	35(0.1)
Grade 5 (≥2:1)	484(1.3)
Hospital location	
Large metropolitan area	11138(31.6)
Other metropolitan area	10604(30.0)
Other area	13566(38.4)
Rotavirus infection	
Yes	1514(4.3)
No	33794(95.7)

non-infectious babies (43.5 % vs 35.9 %, $p < .001$).

Rotavirus infection was most common in NICUs with a grade 5 nurse staffing level. Hospitals with a grade 5 nurse staffing level had a higher proportion of infectious babies than non-infectious babies (2.3 % vs 1.4 %, $p = .005$). Hospitals in large metropolitan areas (Seoul) had a lower proportion of infectious babies than non-infectious babies (19.8 % vs 32.1 %) whereas those in other metropolitan areas had a higher proportion of infectious babies than non-infectious babies (41.2 % vs 29.5 %, $p < .001$; Table 2).

Patient- and hospital-related characteristics associated with rotavirus infection by multiple logistic regression

Table 3 shows the adjusted odds ratios for rotavirus infection. Other infectious diseases and hospitalisation in the winter season (from December to March) were significantly associated with higher rotavirus infection risk. The risk of rotavirus infection in those with other infectious diseases was 1.21 (95 % CI 1.04–1.41) times higher than the group without other infectious diseases. Patients admitted in the winter season (January, February, March, and December) were 1.29 (95 % CI 1.14–1.46) times more likely to have rotavirus infection than those admitted in the non-winter season (from April to November). However, low birth weight, cardiovascular disorders, neonatal jaundice, breastmilk provision, central line insertion, and ventilator usage were significantly associated with lower risk. Patients under 999 g, 1,000 g–1499 g, and 1500 g–2499 g weight were 0.43 (95 % CI 0.24–0.78) times, 0.41 (95 % CI 0.25–0.67) times, and 0.32 (95 % CI 0.26–0.40) times less likely to have rotavirus infection, respectively, than those weighing more than 2,500 g. Patients fed with breastmilk were 0.66 (95 % CI 0.58–0.76) times less likely to have rotavirus infection than those who were not. Patients with cardiovascular disorders, neonatal jaundice, central line insertion, and ventilator usage were 0.78 (95 % CI 0.63–0.98) times, 0.76 (95 % CI 0.67–0.86) times, 0.71 (95 % CI 0.54–0.93) times, 0.46 (95 % CI 0.36–0.60) times less likely to have rotavirus infection, respectively, than those without these disorders and treatments. Grade 5 NICUs had an odds ratio of 3.11 (95 % CI 1.03–9.35) times compared with those with better grade hospitals (Table 3).

Discussion

Although rotavirus infection was not associated with each nurse staffing level sequentially, rotavirus infection in NICUs with a grade 5 level was higher than in NICUs with a grade 1 in univariate analysis. According to previous studies (Kumar et al., 2018; Tsai et al., 2019), rotavirus is often detected on environmental surfaces in NICUs, such as a computer keyboard/mouse and even on healthcare workers. Moreover, some neonates might be asymptomatic, making it difficult to prevent the risk of a rotavirus outbreak (Tan et al., 2016). Therefore, nurses' role in providing infection control and prevention in NICUs is crucial. However, workload or burnout owing to insufficient nurse staffing in NICUs hinders the provision of infection control and prevention (Cimiotti et al., 2012; Kumar et al., 2018; Salem and Youssef, 2017), especially since nurses must also coordinate with infants' parents. In South Korea, in 2017, four infants in a NICU at a university hospital died during the same period owing to hospital-acquired infections, highlighting the need for more nurses in NICUs (Chang, 2018). In multiple regression analysis, rotavirus infection in NICUs with a grade 5 nurse staffing level was higher than in NICUs with a grade 1–4 level. These results indicate that nurse staffing levels greater than a 2:1 patient-to-nurse ratio are significantly associated with increased rotavirus infection rates, but staffing less than 2:1 is not. Although the nurse staffing level in hospitals nationwide has improved over the last 20 years in South Korea, the nurse staffing level is still lower in NICUs compared with adult or paediatric ICUs (Chang, 2018; Hong and Cho, 2017). This study provides practical evidence that could promote the improvement of nurse staffing in NICUs. The standard minimum staffing levels with less than a 2:1

Table 2
Patient- and hospital-related characteristics by rotavirus infection.

Independent Variable	Infection baby (n = 1514) N (infection rate, %)	Not-infection baby (n = 33794) N (rate of no infection, %)	(N = 35,308) *p value*
Mean Age, day (SD)	10.5(16.2)	20.8(34.0)	<0.001
Sex			
Male	837(55.3)	18808(55.7)	0.776
Female	677(44.7)	14986(44.3)	
Type of medical security			
Health Insurance	1498(98.9)	33386(98.8)	0.599
Medical Aid	16(1.1)	408(1.2)	
Birth Weight			
~999 g(ELBW)	17(1.1)	2240(6.6)	<0.001
1000 g ~ 1499 g (VLBW)	22(1.4)	2092(6.2)	
1500 g ~ 2499 g(LBW)	119(7.9)	6693(19.8)	
Normal	1356(89.6)	22769(67.4)	
Gestational Period			
< 28 weeks	7(0.5)	1770(5.2)	<0.001
≤28 weeks~<37 weeks	203(13.4)	12922(38.2)	
Normal	1304(86.1)	19102(56.6)	
Other hospital acquired infection			
Yes	39(2.6)	485(1.4)	<0.001
No	1475(97.4)	33309(98.6)	
Infectious disease			
Yes	538(35.5)	6567(19.4)	<0.001
No	976(64.5)	27227(80.6)	
Respiratory disorders			
Yes	95(6.3)	7528(22.3)	<0.001
No	1419(93.7)	26266(77.7)	
Gastrointestinal disorders			
Yes	22(1.5)	803(2.4)	0.020
No	1492(98.5)	32991(97.6)	
Cardiovascular disorders			
Yes	135(8.9)	5016(14.8)	<0.001
No	1379(91.1)	28778(85.2)	
Neurological disorders			
Yes	17(1.1)	762(2.3)	0.003
No	1497(98.9)	33032(97.7)	
Neonatal jaundice			
Yes	747(49.3)	18966(56.1)	<0.001
No	767(50.7)	14828(43.9)	
Admission month			
January ~ March, December	658(43.5)	12114(35.9)	<0.001
April ~ November	856(56.5)	21680(64.1)	
Breastmilk provision			
Yes	403(26.6)	13739(40.7)	<0.001
No	1111(73.4)	20055(59.3)	
Central line insertion			
Yes	91(6.0)	4258(12.6)	<0.001
No	1423(94.0)	29536(87.4)	
Ventilator usage			
Yes	103(6.8)	8110(24.0)	<0.001
No	1411(93.2)	25684(76.0)	
Nurse staffing level (ratio of beds to registered nurse)			
Grade 1 (<0.75:1)	321(21.2)	7783(23.0)	0.005
Grade 2 (0.75:1 to <1:1)	783(51.7)	17546(51.9)	
Grade 3 (1:1 to <1.5:1)	375(24.8)	7981(23.6)	
Grade 4 (1.5:1 to <2:1)	0(0.0)	35(0.1)	
Grade 5 (≥2:1)	35(2.3)	449(1.4)	
Hospital location			
Large metropolitan area	300(19.8)	10838(32.1)	<0.001
Other metropolitan area	624(41.2)	9980(29.5)	
Other area	590(39.0)	12976(38.4)	

Table 3
Patient- and hospital-related characteristics associated with rotavirus infection by multiple logistic regression.

		(N = 35,308)	
Independent Variable	Adjusted Odds ratio	95 % confidence interval	
Age per a day	1.00	0.99	1.00
Birth Weight			
~999 g (ELBW)	0.43	0.24	0.78
1000 g ~ 1499 g (VLBW)	0.41	0.25	0.67
1500 g ~ 2499 g (LBW)	0.32	0.26	0.40
Normal	1.00		
Other hospital acquired infection	0.73	0.50	1.06
Infectious disease	1.21	1.04	1.41
Respiratory disorders	0.81	0.60	1.08
Cardiovascular disorders	0.78	0.63	0.98
Neonatal jaundice	0.76	0.67	0.86
Admission month			
January ~ March, December	1.29	1.14	1.46
April ~ November	1.00		
Breastmilk provision	0.66	0.58	0.76
Central line insertion	0.71	0.54	0.93
Ventilator	0.46	0.36	0.60
Nurse staffing level (ratio of beds to registered nurse)			
Grade 1 ~ 4 (<2:1)	1.00		
Grade 5 (≥2:1)	3.11	1.03	9.35

patient-to-nurse ratio are necessary to control and prevent rotavirus infection in NICUs.

Among the confounding variables, underlying disease, such as infectious disease, was associated with increased rotavirus infection among infants in NICUs, similar to a previous study (Kim et al., 2017). Meanwhile, infants with cardiovascular disorders or neonatal jaundice had a decreased risk of rotavirus infection. Although there has been literature reporting an association between rotavirus infection and the clinical severity of the disease, the findings have been inconsistent (Kim et al., 2017; Lee et al., 2019; Ojobor et al., 2020). Therefore, future studies regarding rotavirus infection need to include these diseases as confounding variables.

Contrary to a previous study (Fidhow et al., 2017), we showed that low birth weight was associated with a lower risk of infection. Most premature babies are born with low birth weight and might have severe conditions. Accordingly, these infants are mainly hospitalised in tertiary hospitals with nurse staffing level grades 1 or 2 (Hong and Cho, 2017). Furthermore, low birth weight infants with severe conditions admitted to NICUs receive more intensive care in isolated spaces than typically developing infants. In addition, the patient-to-nurse ratio is arranged according to the severity of infants in NICUs, and the time that parents can visit is also limited (Chang, 2018). Therefore, these factors may explain why these infants have a lower rate of rotavirus infection than their counterparts.

It is well known that rotavirus tends to spread in cold weather in South Korea (Choi et al., 2013; Lee et al., 2019), which is consistent with our results. Meanwhile, central line insertion or ventilator usage was associated with lower rotavirus infection in NICUs, contrary to previous studies (Andersson et al., 2019; Flidel-Rimon et al., 2019; Scamardo et al., 2020). Similar to low birth weight, high-risk infants with a central line or ventilator usage would receive more intensive care in NICUs, including hospital-acquired infection control, which could explain the lower rotavirus infection rates. In addition, previous studies (Andersson et al., 2019; Flidel-Rimon et al., 2019; Scamardo et al., 2020) did not adjust the nurse staffing levels as a confounding variable. The nurse staffing levels may also be a factor explaining the difference in the results of previous studies. Another explanation could be that neonates with central lines or ventilator usage would not receive enteral nutrition; thus, perhaps there could be a link between not receiving enteral nutrition and being protected against rotavirus.

Additionally, breastmilk provision in NICUs was associated with a decreased risk of rotavirus infection. Breastmilk has ample benefits for infants; for example, immunoglobin A reduces infants' risk of infection. Breastmilk also promotes infants' intestinal microbiome and drives growth. Breastmilk is further associated with decreased diarrheal disease among infants (Victora et al., 2016). Nevertheless, there are several barriers to breastfeeding in NICUs, including infants' weak sucking power and cumbersome monitors and ventilators that hinder breastfeeding. However, nurses can provide breastmilk to infants in NICUs via alternative feeding methods such as syringes or gavage tubes. Although this requires more time and effort for nurses, and the benefits are widespread, there were no additional costs for the nursing service in South Korea until 2018 (Korea Ministry of Health and Welfare, 2018). Stakeholders should aim to improve the breastmilk provision-related services that nurses provide in NICUs.

Nevertheless, a meta-analysis revealed that breast feeding was not associated with rotavirus infections among infants (Shen et al., 2018). The finding that breastmilk provision may protect infants against rotavirus infection could imply that the powdered milk prepared in hospitals may be a risk factor. In a previous study (Zerr et al., 2005), hospital workers' hand hygiene campaign decreased hospital-associated rotavirus infection rates in children. Hygiene while preparing food might make premature infants susceptible to rotavirus infection because this virus is transmitted by the faecal-oral route.

There was an inconsistent relationship between breastmilk provision and rotavirus infection in previous studies (Muendo et al., 2018; Salim et al., 2014; Shen et al., 2018). However, there were no relevant studies about the relationship between NICU infants' rotavirus and breastmilk provision. Although various unknown factors might have affected rotavirus infection rates in NICUs, the results of this study imply an association between breastmilk provision and rotavirus infections in NICU infants. To further our understanding, future studies need to compare rotavirus infection rates between infants provided with breastmilk compared with those given powdered milk in NICUs.

Conclusion

This study indicates that nurse staffing levels are associated with rotavirus infections in NICUs. Various factors among the confounding variables such as patient and hospital-related characteristics were also associated with rotavirus infection in this study. Future studies regarding the association between nurse staffing levels and rotavirus infection need to control for these confounding variables. High-risk infants in NICUs are extremely susceptible to hospital-acquired infections such as rotavirus and more intensive nursing care that differs from that provided to adult or paediatric patients is needed. Therefore, nurse staffing levels with less than a 2:1 patient-to-nurse ratio are needed to control and prevent rotavirus infection in NICUs. Specifically, this study found that breastmilk provision was associated with a decreased risk of rotavirus infection. Increasing the nurse staffing levels in NICUs could promote more effective services related to breastmilk provision, such as helping mothers produce milk; storing, freezing, defrosting, or warming the milk; and providing breastmilk to infants with alternative feeding methods. This may help decrease rotavirus infection in NICUs.

Ethical Statement

Ethical approval for this study was granted by the institutional review board of Asian Medical Center (no. 2019-0711).

CRediT authorship contribution statement

Chul-Gyu Kim: Methodology, Data curation. **Ji-Soo Kim:** Conceptualization, Writing – original draft, Writing – review & editing. **Kyun-Seop Bae:** Software, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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