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The Effects of Improvement in Environmental Condition on Hand Washing Compliance and Nosocomial Infection Rate in the Intensive Care Unit

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Object: The purpose of this study is to identify the effects of improvement in environmental condition on hand washing compliance and the incidences of overall and site-specific nosocomial infection in neurosurgical patients in the intensive care unit (ICU) and to determine the risk factors of nosocomial infection.

Method: The design of facilities in the ICU was changed. Then nurses' hand washing compliance and the incidence of nosocomial infection in all neurosurgical, patients hospitalized for more than 48 hours in ICU, were investigated from July 1, 2003 to June 30, 2004 (second survey). Hand washing compliance and overall and site-specific nosocomial infection rates during that period were compared with the results of the first survey, which was conducted from April 1, 2002 to March 31, 2003.

Results: The rate of hand washing compliance increased from 25.65% to 47.90%. The overall nosocomial infection rates during the first and second survey were 42.51% and 28.80% ($p=0.02$) respectively. Risk factors associated with the incidence of nosocomial pneumonia were the length of hospital day, Glasgow Coma Scale (GCS) score, the use of ventilator and the presence of tracheostomy, and those associated with the incidence of nosocomial urinary tract infections were the duration of urinary catheter, the presence of diabetes mellitus and female gender.

Conclusion: These results showed that the improvement in environmental condition was an important factor in increasing hand washing compliance and in decreasing the incidence of nosocomial infection.

Key Words: Environmental condition · Nosocomial infection · Hand washing compliance

INTRODUCTION

Nosocomial infection is a serious hospital hazard throughout the world. Despite of the advance in the control and prevention of nosocomial infection, it is still a major side effect of hospital treatment and contributes significantly to the rate of morbidity, mortality and increased cost of care particularly in patients admitted to intensive care unit (ICU)[1,4,19,23]. Patients admitted to ICU are at risk of developing life-threatening nosocomial infection especially with organisms resistant to commonly used antibiotics[3]. According to the result of a survey by Korean Society for Nosocomial Infection Control (KOSNIC) in 1996, the nosocomial infection rate in Korea was 3.70 cases/100 discharged patients, namely, 3.70% . The rate in ICU (10.3～39.7%) was 1.7～7 times higher than that in general wards. The reason of frequent incidence of hospital infection in ICU is that the severity of diseases in patients admitted to ICU is higher than that in those admitted to general wards and patients in ICU have more underlying disease and are exposed to invasive medical devices or operation longer and more frequently[13].

Currently, the circle of medicine is conducting research and preventive education to minimize the incidence of hospital infection. However, there have not been many researches that explain the relevancy of hospital infection to hospital environment and facilities. Thus, this study aimed at identifying the effects of improvement in environmental condition on hand washing compliance and the incidence of nosocomial infection in neurosurgical patients in ICU

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and determining the risk factors of nosocomial infection.

MATERIALS AND METHODS

1. Patient population

The subjects of this study were 424 neurosurgical patients who were hospitalized for more than 48 hours in ICU of Kangbuk Samsung Medical Center. The first survey on hand washing compliance and the nosocomial infection rate was conducted with 167 patients for 12 months from April 1, 2002 to March 31, 2003. As new ICU opened on May 7, 2003, the second survey was conducted with 243 patients for 12 months from July 1, 2003 to June 30, 2004. Fourteen patients who participated in both the 1st and the 2nd surveys were excluded. The number of subjects was 167 (88 men and 79 women) in the 1st survey and 243 (150 men and 93 women) in the 2nd survey, and the average age was 55.44 (SD±14.5) and 54.45 (SD±17.1), respectively. Glasgow coma scale (GCS) score less than 8 points was 30% of the subjects in the 1st survey and 24.7% in the 2nd survey. The percentage of patients who only had intubation was 16.8% and 30%, respectively, and that of those who had tracheostomy after two days from intubation was 15% and 11.1% respectively. The total duration of stay was 2,219 days and 3,378 days averaging was 13.29 days and 13.90 days, respectively. No difference was observed in all characteristics between the two groups of subjects (Table 1), and there was no epidemic infection during the time of research.

2. Improvement in ICU design

The number of beds in ICU increased from 18 in the first survey to 34 in the second survey, and four isolation rooms were newly made to isolate infected patients. Air clearance was over 100,000 class during the first survey but decreased to 10,000 class in the second survey.

The old ICU facility had opened by wards, and had only a few poorly located sinks for hand washing (bed to sink ratio 3:1). In the new ICU facility, the location of hand washing and the distribution of beds were optimized (bed to sink ratio 1.6:1). The bed to sink ratio was improved from 3:1 to 1.6:1, and the location of beds and sinks was redesigned in consideration of medical staffs' flow line and hand washing geography. In addition, the size of area assigned to each bed increased from 11.262 m^2/bed to 14.336 m^2/bed(Table 2).

3. Evaluation of hand washing compliance

During the periods of the two surveys, we conducted a questionnaire survey of 16 nurses working in ICU on the actual number of times to wash the hands in situations that require hand washing for a day and calculated the percentages. Situations that required hand washing were largely before and after suction, before and after position change, and after infection-free nursing. In addition, infection control education was given continuously during the periods of the two surveys with the same contents. ICU nurses' hand washing compliance was 25.65% in the first survey and 47.90% in the second survey, showing improved compliance in all categories in the second survey(Table 3).

4. Definition of nosocomial infection

The nosocomial infection was defined according to the criteria set by the Center for Disease Control and Prevention (CDC)[8] and was categorized by specific infection site.

5. Statistical analyses

Collected data were analyzed by a commercially available computer software program (SPSS for Windows version 10.0: SPSS INC., Chicago, IL). Hand washing compliance and the nosocomial infection rate were presented in percentage and the heterogeneity of the first and the second subjects was tested through χ^2-test and unpaired t-test. In addition, difference between the nosocomial infection rates between the two groups was analyzed by χ^2-test and Fisher's exact test, and risk factors affecting nosocomial infection were identified through logistic regression test.

RESULTS

1. Incidence of nosocomial infection

1) Distribution of hospital infections by site

Total of 71 cases of nosocomial infection occurred in the first survey. Among them, 44 cases (61.9%) were urinary tract infection, 22 (30.9%) pneumonia, 3 (4.2%) central nervous system (CNS) infe-

Table 1. Characteristics of study populations

Variable	1st survey (n=167)	2nd survey (n=243)	P-value
	No. (%)	No. (%)	
Gender			0.060
Male	88(52.7)	150(61.7)	
Female	79(47.3)	93(38.3)	
Age (yr)	55.44(SD 14.5)	54.45(SD 17.1)	0.083
Glasgow coma scale			0.239
>8	117(70)	183(75.3)	
<8	50(30)	60(24.7)	
History of other infection			0.363
Yes	11(6.6)	11(4.5)	
No	156(93.4)	232(95.5)	
Diabetes mellitus			0.455
Yes	33(19.8)	41(16.9)	
No	134(80.2)	202(83.1)	
Neurosurgical operation during ICU admission period			0.133
Yes	99(59.3)	135(55.6)	
No	68(40.7)	108(44.4)	
Presence of nasogastric tube			0.240
Yes	58(34.7)	70(28.8)	
No	109(65.3)	173(71.2)	
Intubation only			0.287
Yes	28(16.8)	51(30)	
No	139(83.2)	192(70)	
Intubation and tracheostomy within 2 days*			0.116
Yes	12(7.2)	9(3.7)	
No	155(92.8)	192(96.3)	
Intubation and tracheostomy after 2 days*			0.249
Yes	25(15)	27(11.1)	
No	142(85)	216(88.9)	
Use of ventilator			0.607
Yes	45(26.9)	60(24.7)	
No	122(73.1)	183(75.3)	
Length of stay (day)**	13.29	13.90	0.490

*Patients who had both intubation and tracheostomy were divided into a group who had tracheostomy after two days from intubation and those who had tracheostomy within two days from intubation.

**Because all neurosurgical patients in ICU had foley insertion, the duration of stay in ICU was the same as the duration of urinary catheter.

ction, and 2 (2.8%) blood- stream infection. In the second survey, total 70 cases of nosocomial infection happened, and among them, 41 cases (58.5%) were urinary tract infection, 18 (25.7%) pneumonia, 4 (5.7%) bloodstream infection, 3 (4.2%) CNS infection, and 4 (5.7%) other types of infection.

2) Overall nosocomial infection rate and incidence density

The total duration of hospital stay of 167 patients in the first survey was 2,219 days and 71 cases of nosocomial infection occurred. The total duration of stay of 243 patients in the second survey was 3,378 days and 70 cases of nosocomial infection occurred. Accordingly, the overall nosocomial infection rate was 42.51 cases/100 patients during the first survey and 28.80 cases/100 patients during the second survey, showing significant decrease (p=0.02). The overall incidence density decreased from 31.99 cases/1,000 patient days to 20.72 cases/ 1,000 patient days (p= 0.04) (Table 4).

3) Site specific nosocomial infection rates and incidence densities

During the period of two surveys, there were 22 and 18 cases of nosocomial pneumonia, respectively. The incidence of nosocomial pneumonia decreased from 27.4 cases/100 patients to 13.2 cases/100 patients (p=0.01), and the incidence density of nosocomial pneumonia (the patient-days rate of nosocomial pneumonia) decreased significantly, from 9.9 cases/1,000 patient days to 5.3 cases/1,000 patients days (p=0.03).

As for catheter-associated urinary tract infection, the incidence decreased from 26.34 cases/100 patients to 16.87 cases/100 patients (p=0.03) and the incidence density decreased from 19.82 cases/1,000 patient days to 12.13 cases/1,000 patient days (p=0.05) (Table 4).

Table 2. Facility design change of the intensive care unit

	first survey	second survey
Number of beds	18	34
Isolation room	0	4
Air clearance	100,000 class	10,000 class
Humidity	Humidifier	Central control (30-35%)
Bed-sink ratio	3:1	1.6:1
Area	11.262 m^2/bed	14.336 m^2/bed

Table 3. Hand washing compliance between the 1st and 2nd survey

Activity	1st survey	2nd survey
	Done/Needed (%)	Done/Needed (%)
Before suction	32/160(20%)	80/192(41.6%)
After suction	64/160(40%)	96/192(50%)
Before position change	6/ 64(9.3%)	40/ 64(62.5%)
After position change	14/ 64(21.8%)	31/ 64(48.43%)
After hygiene	2/ 12(16.6%)	5/ 14(35.7%)
Total	118/460(25.65%)	252/526(47.9%)

2. Infective organisms

The causative bacterial strain of nosocomial pneumonia occurring in the first survey was MRSA in 10 cases(46%), Pseudomonas aeruginosa in eight(36.36%), Acinetobacter baumanni in two, Klebsiella pneumoniae in one and Enterobacter cloacae in 1. In the second survey, as well, MRSA was cultured most frequently (eight cases (44%)), and Pseudomonas aeruginosa in six (33%), Acinetobacter baumanni in three and Klebsiella pneumoniae in one patient. In both surveys, MRSA was the most frequent causative bacterial strain of nosocomial pneumonia, and Pseudomonas aeruginosa was the second. As for urinary tract infection, Candidia spices was detected in 43% and 36% respectively in the first and the second survey and Enterococcus spices was the second most frequent causative bacterial strain.

3. Risk factors of nosocomial infection

As for risk factors related to nosocomial pneumonia, tracheostomy was the most significant risk factor (odds ratio=10.406, 95% CI 5.431～31.271) and next the use of ventilator (odds ratio=8.141, 95%CI 1.733～19.359), diabetes mellitus (odds ratio=7.656, 95%CI 1.557～13.359), the duration of stay (odds ratio=7.602, 95%CI 3.494～17.839), the duration of tracheostomy and GCS score (Table 5).

In the case of urinary tract infection, duration of catheter indwelling (odds ratio=78.280 95%CI 35.748～153.246) was the most important risk factor and diabetes mellitus and female gender were also significant (Table 6).

Table 4. Overall nosocomial infection rates and incidence densities

	first survey	second survey	p-value
Overall nosocomial infection (NI)			
Rate of NI per patients (%)	42.51	28.80	0.02
NI per 1,000 patient days (case)	32.0	20.72	0.04
Nosocomial pneumonia (NP)			
Rate of NP per patients (%)	27.4	13.17	0.01
NP per 1,000 patients days (case)	9.91	5.32	0.03
Nosocomial urinary tract infection (NUTI)			
Rate of NUTI per patients (%)	26.34	16.87	0.03
NUTI per 1,000 patients days (case)	19.82	12.13	0.05

Table 5. Risk factors of nosocomial pneumonia

Risk factors	Odds ratio	95% CI*	p-value
Intubation and tracheostomy after 2 days	10.406	5.431-31.271	0.006
Use of ventilator	8.141	1.733-19.359	0.004
Diabetes mellitus	7.656	1.557-13.359	0.006
Duration of stay	7.602	3.494-17.839	0.022
Duration of tracheostomy	6.925	1.482-12.913	0.031
Glasgow coma scale	5.634	1.749-10.236	0.038

*CI; confidence intervals

DISCUSSION

1. Definition and incidence of nosocomial infection

According to the definition by the Center for Disease Control and Prevention (CDC), 'hospital infection' is hospital acquired infection that did not appear or lie latent on admission but has occurred during the stay in hospital as a result of exposure to

Table 6. Risk factors of nosocomial urinary tract infection

Risk factors	Odds ratio	95% CI*	p-value
Duration of stay	78.280	35.748-153.246	<0.001
Diabetes mellitus	13.314	6.175- 27.721	<0.001
Sex (female)	6.660	2.619- 13.114	0.010

*CI; confidence intervals

pathogenic microorganism in hospital environment or by endogenous microorganism that has already been in the patient[11]. Hospital infection is divided into endogenous infection and extrinsic infection. Endogenous infection is caused by bacteria in the patient's mouth, intestines, and etc. It occurs as patients' resistance against the infection weakens. Extrinsic infection is caused by bacteria from outside and is often related to various types of treatment (urinary catheter insertion, intubation, central line, and etc.). Infection occurs directly or indirectly by ordinary residents or temporary contaminants on various devices and medical supplies used in these processes[9]. In the present study, the infection rates in ICU neurosurgical patients during the two surveys were 42.51% and 28.8%, respectively, showing high frequencies. Particularly for neurosurgical patients, the disease course itself is often poor and invasive procedures such as intubation and tracheostomy are applied more frequently. As a result, morbidity and mortality resulting from hospital infection appear higher in ICU than in other departments[18].

2. Effects of facility design change of ICU on hand washing compliance and the incidence of nosocomial infection

American researchers who studied the efficiency of hospital infection control reported that around 30% of hospital infections can be controlled through appropriate infection control. And hand washing is the most convenient and effective method of infection control[15,16]. Austin et al.[2] reported that strict hand washing compliance reduced the probability of dissemination from patients infected with VRE to other patients from 79% to 36%. The nosocomial infection rate of VRE was reduced from 145 cases/1,000 days to 114 cases/1,000 days by keeping hand washing strictly, reinforcing ward disinfection and preventing contagious infections, showing that hand washing is an important method of infection control in reducing the nosocomial infection rate[14]. Even though hand washing has been proved to be an effective method of infection control, it is known that nurses' hand washing compliance is still low[13]. Dubbert[7] emphasized the necessity of continuous education on hand washing to reduce hospital infection, reporting that hand washing compliance increased and the hospital infection rate went down significantly while hand washing education was being executed, but hand washing compliance decreased and the hospital infection rate went up again as the education was stopped. With regard to the improvement of hospital environment, however, Vietri et al.[22] reported that facility design was changed radically for optimal infection control but it was not enough in reducing the nosocomial spread of MRSA. In this study, however, we executed infection control education with the same contents during the two surveys and hand washing compliance was improved from 25.65% in the first survey to 47.90% in the second survey, after facility design change, and the overall nosocomial infection rate was reduced from 42.51% to 28.80%. Thus, together with continuous infection control education, change in facility design improved hand washing compliance and decreased the overall nosocomial infection rate. In general, problems related to hospital infection result more from medical staffs and practices than from facilities. However, because all medical activities are performed within a given space and the space induces a set of actions, the change of design of ICU facilities can be an essential factor for hospital infection control although it cannot control infections completely. In this study as well, we could induce the improvement of nurses' hand washing compliance through environmental improvements such as optimized hand-washing geography and distribution of beds and bed-sink ratio.

3. Infective organism and risk factors of nosocomial pneumonia

Nosocomial pneumonia occupies 7~54% of nosocomial infections occurring in ICU and is known as a major cause of death resulting from nosocomial infection, showing death rate as high as 30 ~50%[5,16]. Particularly in neurosurgical patients, the incidence of nosocomial pneumonia was the highest as 27.0% in a survey on the domestic hospital infection rate in 1996.

In this research, MRSA was cultured 46% and 44% at the sputum of patients infected with nosocomial pneumonia during

the first and the second surveys, and Pseudomonas aeruginosa was 36.36% and 33%. In the U.S., the most frequent strain causing nosocomial pneumonia was Pseudomonas aeruginosa until 1985 but, since then, Staphylococcus aureus increased and became a more frequent strain than Pseudomonas from 1990[12,17]. MRSA spreads through contact rather than through aerial infection and is closely related to nosocomial infection rate of medical practitioners' hands and nasal cavity[10]. Thus, it is important to practice hand washing strictly.

In this study, the most important factor affecting the incidence of nosocomial pneumonia was tracheostomy conducted two days after intubation and next the use of ventilator, diabetes mellitus, the duration of stay, tracheostomy and GCS score. The morbidity rate to nosocomial pneumonia was 10.4 times higher in patients who had tracheostomy two days after intubation than in those who did not, 8.14 times higher in patients using a ventilator than those without a ventilator, and 7.65 times higher in patients with diabetes mellitus than in those without. This is similar to a report by Heckmann et al.[10] that the risk factors of nosocomial infection are age, the length of hospital day, the duration of intubation, the duration of ventilation, the presence of diabetes mellitus, and etc.. These risk factors can be used as important data in establishing infection control strategies. For example, in the case of patients who stay long in the hospital due to underlying diseases, hospital infection can be detected and treated early through continuous infection monitoring, and in the case of patients of low consciousness, the aspiration of discharge from the respiratory system can be prevented through taking an oblique position or a lateral position. Moreover, breathing aids such as respirator are used, thorough disinfection and hand washing are important in preventing infection. In this way, the analysis of risk factors is very important.

4. Infective organism and risk factors of catheter-associated urinary tract infection

Catheter-associated urinary tract infection is one of the most common nosocomial infections in general. The major problems in this type of infection include antibiotic resistance and enormous direct and indirect cost of treatment[20,21]. While they are often asymptomatic and cost less than nosocomial surgical site infections or nosocomial pneumonia, they are the major reservoirs of antimicrobial resistant pathogens. According to Dettenkofer et al[6], in organisms cultured in the urine of patients with catheter-associated urinary tract infection, E. coli was 14.6%, Enterococcus spp. was 10.2% and S. aureus was 9.6%. In a report by Verhaz et al.[21] as well, the most common causative bacterial organism was E. coli (33.6%), and next Pseudomonas aeruginisa (14.1%) and Proteus mirabilis (13.1%). In this study, however, the most frequently detected strain in the two surveys was Candida spices (43% and 36% respectively) and Enterococcus spices was the next. This difference is probably related to the preventive use, misuse or overuse of antibiotics. All of the subjects in this study took antibiotics in prevention and itself probably contributed the increase in the infection rate of Candida spices and Enterococcus spices.

In this study, the duration of urinary catheter appeared to be the most important risk factor on the incidence of nosocomial urinary tract infection and next the presence of diabetes mellitus and female gender. In particular, patients using a urinary catheter showed 78.28 times higher morbidity rate to urinary tract infection than those without, suggesting that the early removal of urinary catheter is important in preventing urinary tract infection.

CONCLUSION

In the present study, change in facility design and environmental improvement in ICU enhanced hand washing compliance and reduced the incidence of nosocomial infection. Because all medical activities are performed within a given space and the space induces a set of actions, the change in design of ICU facilities can be an essential factor for hospital infection control although it cannot control infection completely. However, nosocomial infection is related not only to environmental factors but also to personnel factors, method of infection control, the appropriate use of antibiotics, etc. So further research should be made with regard to these factors.

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