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Original Article

Hospital-acquired infection in public hospital buildings in the Philippines: Is the type of ventilation increasing the risk?

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Abstract

Introduction: Hospital-acquired infections (HAIs) are associated with increased morbidity and mortality, especially in developing countries. However, limited information is available about the risk of HAIs in naturally ventilated wards (NVWs) and mechanically ventilated intensive care units (MVICUs) of public hospitals in the Philippines. We aimed to assess the association between HAIs and type of ventilation in an urban tertiary care hospital in the Philippines.

Methodology: A cross-sectional point-prevalence survey of infections was done in NVWs and MVICUs of a tertiary care hospital in December 2013. Multivariate analyses were done to examine the associations between HAIs and type of ventilation and other risk factors.

Results: Of the 224 patients surveyed, 63 (28%) patients had 69 HAIs. Pneumonia was the most common HAI (35%). Wards near areas with high vehicular activity had more respiratory HAI cases. Being immunocompromised is a risk factor for HAI for pediatric and adult patients. Among pediatric patients, staying in MVICUs had a lower risk for HAIs (adjusted odds ratio [AOR]: 0.33; 95% confidence interval [CI]: 0.10–1.08) compared to staying in NVWs. For adult patients, a higher risk for HAIs (AOR: 2.41; 95% CI: 0.29–18.20) was observed in MVICUs compared to NVWs.

Conclusions: Type of ventilation is not a risk factor for HAIs. Patients who are immunocompromised may be at a higher risk for HAI. Indoor air pollution, proximity to congested main thoroughfare, and increased human foot traffic may contribute to the susceptibility of patients to HAIs. Hospital layout should be considered in infection control.

Key words: hospital-acquired infection; ventilation; particulate matter; wards and intensive care units.

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Introduction

Infection transmitted via the airborne pathway is a leading cause of mortality and morbidity worldwide [1]. Furthermore, hospital-acquired infections (HAIs) are associated with increased morbidity and mortality [2,3]. In public hospital buildings (PHBs), HAIs are a major public health problem, especially in developing countries such as the Philippines. Evidence from recent studies has shown association between air movements in buildings, ventilation, and the spread or transmission of infectious diseases, namely tuberculosis, influenza, measles, chickenpox, smallpox, and severe acute respiratory syndrome (SARS) [4].

At PHBs in the Philippines, increasing cases of multidrug-resistant tuberculosis have been documented among healthcare workers and admitted patients. With limited resources for a prospective active surveillance approach, a point-prevalence study is a suitable alternative methodology to analyze the rate of HAIs at the PHBs. Numerous point-prevalence studies have been conducted for HAIs [5-12], including a study that investigated device-associated infection rates in intensive care units (ICUs) [13]. However, no point-prevalence studies have been carried out before that examined HAIs in ICUs that are mechanically ventilated and in wards that are naturally ventilated in tertiary healthcare facilities in the Philippines. The aims of this study were to estimate the point prevalence and to evaluate the risk factors of HAIs in primary care wards (naturally ventilated) and in ICUs (mechanically ventilated) of an urban tertiary hospital.

Methodology

Study site

A state-owned national tertiary referral center, the Philippine General Hospital (PGH) is a national university teaching hospital located in Manila, Philippines, with 500 beds for private and 1,000 beds for indigent patients. PGH is the largest government hospital in the Philippines. The study sites comprised the general pediatric and adult medicine wards and the adult medicine intensive care unit (MEDICU) on the first floor. All the intensive care units except for MEDICU are located on the higher floors of the hospital, namely the neonatology intensive care unit (NICU) on the fourth floor, the pediatric intensive care unit (PEDICU) on the second floor, and the adult central intensive care unit (CENICU) also on the second floor of the hospital. All the wards on the first floor are naturally ventilated in design structure, with large open windows and high ceilings, while the CENICU, MEDICU, PEDICU, including the NICU, are all mechanically ventilated with an air conditioning system and exhaust outlets. Institutional ethics review committee approval was obtained from the ethics review board of the University of the Philippines, Manila.

Prevalence survey of infection

A fellow of the section of infectious diseases of the department of medicine of the hospital carried out the cross-sectional point-prevalence survey of infections at the study sites on 8 December 2013. For patients included in the study, standard information was collected, including age (years), sex, length of time in hospital (days), recent surgery, immunocompetence, intubation, and the presence and length of time (days) on central intravascular catheter, urinary catheter, peripheral intravascular catheter, nasogastric tube, and total parenteral nutrition. In addition, for patients in the adult specialty, whether they had ever smoked status, diabetic status, and hypertension status were also collected.

Case definition for HAI

HAI was defined as an infection considered to have been acquired from a hospital-based surgical procedure or during a hospital stay. Infections were excluded when infections were developed in the hospital, but the standard period of incubation of disease signified that the infection might have been acquired in the community or from another hospital. Moreover, since University of the Philippines – Philippine General Hospital (UP-PGH) is the state-owned national tertiary referral center for many hospitals; a thorough attempt

Table 1. Characteristics of study population by specialty ward and type of ventilation (N = 224).

	Adult (N = 95)			Pediatric (N = 129)		
Characteristic	**Wards (n = 82)**	**ICUs (n = 13)**	**p-value**	**Wards (n= 82)**	**ICUs (n = 47)**	**p-value**
Age (years, mean ± SD)	51.0 ± 18.6	58.2 ± 20.0	0.20	**4.7 ± 5.2**	**0.04 ± 0.30**	**< 0.01**
Male (%)	44.0	38.5	0.71	**61.0**	**42.6**	**0.04**
LOHS (days, mean ± SD)	**7.7 ± 9.6**	**19.5 ± 41.5**	**0.02**	17.6 ± 28.2	16.8 ± 15.1	0.86
Immunocompromised (%)	34.1	38.5	0.76	**51.2**	**87.2**	**< 0.01**
Had surgery (%)	17.1	7.7	0.47	**28.0**	**2.1**	**< 0.01**
Intubated (%)	**9.8**	**61.5**	**< 0.01**	11.0	17.0	0.33
# days intubated (mean ± SD)	**0.9 ± 4.0**	**5.8 ± 6.5**	**< 0.01**	1.2 ± 3.7	1.2 ± 4.2	1.00
On UC (%)	**15.9**	**53.8**	**< 0.01**	12.2	4.3	0.21
# of days on UC (mean ± SD)	**0.4 ± 1.3**	**2.1 ± 2.6**	**0.01**	0.7 ± 2.2	0.1 ± 0.6	0.07
On CIC (%)	9.8	15.4	0.62	4.9	4.3	1.00
# of days on CIC (mean ± SD)	0.9 ± 3.6	1.8 ± 4.7	0.42	0.3 ± 2.0	-	-
On PIC (%)	97.5	100	1.00	**92.7**	**34.0**	**< 0.01**
# of days on PIC (mean ± SD)	2.9 ± 2.0	2.5 ± 2.1	0.51	**1.9 ± 1.3**	**0.5 ± 1.2**	**< 0.01**
On NT (%)	**12.2**	**61.5**	**< 0.01**	**36.6**	**72.3**	**< 0.01**
# of days on NT (mean ± SD)	**0.7 ± 2.9**	**6.1 ± 6.5**	**< 0.01**	3.0 ± 5.8	2.2 ± 5.5	0.44
On TPN[f] (%)	**1.2**	**100**	**< 0.01**	**3.7**	**17.0**	**0.02**
Smoker (%)	34.1	30.8	1.00	-	-	-
Diabetic (%)	25.6	23.1	1.00	-	-	-
Hypertensive (%)	**37.8**	**69.2**	**0.04**	-	-	-
Hospital-acquired infection (%)	15.9	30.8	0.24	40.2	27.7	0.15

LOHS: length of hospital stay; UC: urinary catheter; CIC: central intravascular catheter; PIC: peripheral intravascular catheter; NT: nasogastric tube; TPN: total parenteral nutrition; ICU: intensive care unit.

was done to leave out HAIs acquired at the other hospitals. For HAIs, the following types of infection were included in the analysis: pneumonia, line-related infection, bloodstream infection, surgical wound infection, sepsis, conjunctivitis, meningitis, urinary tract infection, upper respiratory tract infection, gastroenteritis, cellulitis pressure ulcer, ventriculo-peritoneal shunt infection, necrotizing enterocolitis, and bronchiolitis acquired during hospital admission.

Statistical analysis

Univariate and multivariate analyses of the associations between HAI and all the risk factors were examined. A multivariate logistic regression model was used to estimate adjusted odds ratios (ORs) with 95% confidence intervals (CIs). Variables that were clinically relevant and a dummy variable for type of ventilation (natural or mechanical) were included *a priori* into the multivariate logistic regression model. Likelihood ratio test was used to test the significance of variables. All the logistic regression analyses were performed in R (http://www.r-project.org). P values ≤ 0.05 were considered statistically significant.

Results

On 8 December 2013, the day of the survey, the wards and ICUs included in the study had an occupancy rate of 83%, and the total number of patients included in the study was 224. The study characteristics and clinical data of the participants are presented in Table 1. For the naturally ventilated adult wards, the mean age of the study patients was 51.0 ± 18.6 (standard deviation [SD]) years and 44.0% were men, whereas for the mechanically ventilated adult ICUs, the mean age was 58.2 ± 20.0 years and 38.5% were males. Likewise, the percentage of HAIs in the adult ICUs (30.8%) was higher than in the adult wards (15.9%); however, the difference was not statistically significant (p = 0.24). The mean length of hospital stay (LOHS) for the adult ICUs was more than two times higher compared to the mean LOHS for the adult wards (19.5 ± 41.5 and 7.7 ± 9.6 days, respectively; p = 0.02). A higher percentage of patients with hypertension was observed in the mechanically ventilated adult ICUs compared with the adult wards (69.2% versus 37.8%; p = 0.04), while no difference was observed for diabetics (23.1% versus 25.6%; p = 1.00) and patients who had ever smoked (30.8% versus 34.1%; p = 1.00).

The general pediatric ward, which is naturally ventilated, had a higher percentage of patients who has had surgery compared with the mechanically ventilated pediatrics ICUs (28.0% and 2.1%, respectively; p < 0.01). There was also a statistically significant mean age difference between pediatric patients from the mechanically and naturally ventilated units. The mean age of patients from the naturally ventilated ward was 4.7 ± 5.2 years, and that of the patients from the mechanically ventilated PEDICU and NICU was 0.04 ± 0.30 years (p < 0.01).

Point prevalence for HAIs

Of the 224 patients surveyed, 63 (28.1%) patients had 69 HAIs. Six patients had two episodes of infections. Five of the six patients who had two HAIs were from the pediatric wards (three males and one female) and the NICU (one male). The distribution of different HAIs is presented in Table 2.

The prevalence for HAIs in the ICUs was 17/60 (28.3%), while the prevalence for HAIs in the wards was 46/164 (28.0%). The highest number of HAIs in ICUs and wards occurred in patients under 1 year of age (n = 13, 76.4%) and in patients 1–12 years of age (n = 18, 39.1%), respectively (Table 2). Males had more HAIs compared to females in both mechanically ventilated ICUs (58.8% versus 41.2%) and naturally ventilated wards (63.0% versus 37.0%). The most common HAI was pneumonia (in adults: n = 8, 44.4%; in children: n = 16, 31.4%), followed by line-related

Table 2. Patients by age, sex, and type of ventilation.

	Mechanically ventilated ICUs		Naturally ventilated wards	
	HAI (n = 17)	Not infected (n = 43)	HAI (n = 46)	Not infected (n = 118)
Sex (%)				
Male	58.8	34.9	63.0	48.3
Female	41.2	65.1	37.0	51.7
Age (%)				
< 1 year	76.4	76.7	26.2	13.6
1–12	0.0	2.3	39.1	22.9
13–18	0.0	0.0	6.5	5.0
19–59	11.8	7.0	13.0	39.0
> 60	11.8	14.0	15.2	19.5

ICU: intensive care unit; HAI: hospital-acquired infection.

infection in adults (n = 5, 27.8%) and bloodstream (n = 7, 13.7%) and surgical site (n = 7, 13.7%) infections in children. Among the pediatric admissions, 14 (27.5%) HAIs happened in the ICUs, while 37 (72.5%) occurred in the wards. The majority of HAIs in the pediatric ICUs were neonatal pneumonia (42.9%), followed by neonatal sepsis and conjunctivitis (21.4% each). Moreover, among the adult inpatients, 4 (22.2%) HAIs occurred in the ICUs, while 14 (77.8%) HAIs happened in the wards. In the adult wards, the most common HAIs were line-related infections (35.7%) and pneumonia (28.6%) (Figure 1, Table 3).

Risk factors for HAIs

Table 4 shows the risk factors associated with HAIs for the adult and pediatric patients. For pediatric patients, results from the multivariate model showed that pediatric patients in mechanically ventilated ICUs (PEDICU and NICU) were associated with a decreased risk of developing HAI, though this was not statistically significant (odds ratio [OR]: 0.33; 95% confidence interval [95% CI]: 0.10–1.08]. However, the risk of developing HAI was 4.45 (95% CI: 1.67–13.05) times higher among male pediatric patients compared to female pediatric patients, and 9.46 (95% CI: 3.53–28.78) times higher among patients with two or more inserted devices/tubes compared to patients with none or one inserted device/tube. Additionally, patients who were immunocompromised had a higher risk of developing HAI compared to non-immunocompromised patients (adjusted OR: 3.23; 95% CI: 1.14–10.11). Furthermore, for a one-day increase in hospital stay, there was about a 3.75% increase (95% CI: 0.42–7.62) in the odds of a pediatric patient having an HAI. For adult patients, several risk factors (although they were not statistically significant) were associated with increased risk of developing HAIs, including mechanical ventilation (multivariate OR: 2.41; 95% CI): 0.29–18.20), diabetes (multivariate OR; 4.87; 95% CI 0.84–36.39), smoking (multivariate OR: 1.61; 95% CI: 0.09–30.50), having had surgery (multivariate OR: 1.12; 95% CI: 0.15–6.74), having two 2 or more inserted devices/tubes (multivariate OR: 2.53; 95% CI: 0.55–11.94), length of hospital stay (multivariate OR: 1.04; 95% CI: 0.99–1.13), and age (multivariate OR: 1.04; 95% CI: 0.99–1.08). Moreover, the risk of developing an HAI was 8.62 (95% CI: 1.83–54.32) times higher among immunocompromised patients than non-immunocompromised patients.

Figure 1. Distribution of site of infection (N = 69).

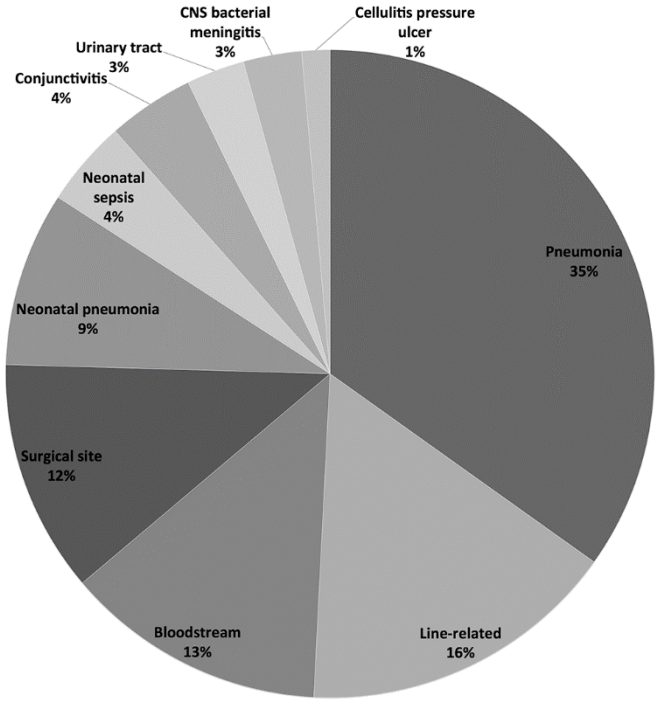

Table 3. Distribution of hospital-acquired infections by specialty (adult and pediatric).

Site of infection	Adult (N = 18)		Pediatric (N = 51)	
	Wards (n, %)	ICUs (n, %)	Wards (n, %)	ICUs (n, %)
Pneumonia	4 (28.6)	4 (100.0)	16 (43.2)	-
Line-related	5 (35.7)	-	6 (16.2)	-
Bloodstream	2 (14.3)	-	6 (16.2)	1 (7.1)
Surgical site	1 (7.1)	-	7 (18.9)	-
Neonatal pneumonia	-	-	-	6 (42.9)
Neonatal sepsis	-	-	-	3 (21.4)
Conjunctivitis	-	-	-	3 (21.4)
CNS bacterial meningitis	-	-	1 (2.7)	1 (7.1)
Urinary tract	2 (14.3)	-	-	-
Cellulitis pressure ulcer	-	-	1 (2.7)	-

There were 69 infections in 63 patients, with 6 patients having two infections; ICU: intensive care unit; CNS: central nervous system.

Table 4. Adjusted odds ratios (ORs) with 95% confidence intervals (95% CI) for the associations between hospital-acquired infection and type of ventilation and patient characteristics.

	Adult patients (N = 95)	Pediatric patients (N = 129)
Characteristics	**OR (95% CI)**	**OR (95% CI)**
Age	1.04 (0.99–1.08)	0.96 (0.85–1.07)
Sex		
Female	1.00	1.00
Male	0.23 (0.01–3.05)	**4.45 (1.67–13.05)**
Type of ventilation		
Natural	1.00	1.00
Mechanical	2.41 (0.29–18.20)	0.33 (0.10–1.08)
Hospital stay (days)	1.04 (0.99–1.13)	**1.04 (1.00–1.08)**
Immunocompromised		
No	1.00	1.00
Yes	**8.62 (1.83–54.32)**	**3.23 (1.14–10.11)**
Had surgery		
No	1.00	1.00
Yes	1.12 (0.15–6.74)	1.63 (0.43–6.34)
Device/tubes inserted		
0–1	1.00	1.00
2 or more	2.53 (0.55–11.94)	**9.46 (3.53–28.78)**
Diabetes mellitus (DM) Status		
Non-DM	1.00	-
DM	4.87 (0.84–36.39)	-
Smoking status		
Never smoker	1.00	-
Ever smoker	1.61 (0.09–30.50)	-
Hypertension status		
Non-hypertensive	1.00	-
Hypertensive	0.28 (0.04–1.62)	-

Discussion

Our point-prevalence survey was conducted on 8 December, when Manila was just leaving the rainy season and was about to enter the cooler season. This could be one of the reasons why pneumonia (neonatal/adult) was the predominant type of infection for all the wards and ICUs. There were more pneumonia cases in the pediatric wards compared to the adult wards, and pneumonia was the only type of infection in adult CENICU and MEDICU. Neonatal pneumonia was the major type of infection in NICU and PEDICU, suggesting the probability of the pneumonia related to labor and childbirth [14]. Although there was no significant difference in the point prevalence of HAIs between naturally ventilated wards and mechanically ventilated ICUs in both specialties (adult and pediatric), the most concerning finding from the survey was the high HAI prevalence rates (> 15%) from all the wards and ICUs, with the highest HAI prevalence rate from the pediatric wards (40%). We hypothesize that the high prevalence rate in pediatric wards could be due to overcrowding in the ward. The large number of patients, relatives of the patients (especially the parents), healthcare providers, and other workers could be a factor for the high HAI prevalence rate at the pediatric ward. The high volume of people entering and exiting the pediatric ward could serve as a dispersal vector of microorganisms and other potential human pathogens [15]. Furthermore, our previous study on the indoor air quality of PGH showed that the concentration of the particulate matter with aerodynamic diameter of 2.5 microns ($PM_{2.5}$) at the wards was higher and exceeded the World Health Organization (WHO)'s guideline of 25 micrograms/m^3 compared to the ICUs of the hospital [16]. The high average $PM_{2.5}$ concentration at the pediatric wards of 32.8 ± 10.4 μgm^{-3} in 2013 and 28.4 ± 8.0 μgm^{-3} in 2014 could explain the higher number of pneumonia cases in the pediatric wards [17]. In contrast, the lowest average $PM_{2.5}$ concentration of 20.5 ± 5.2 μgm^{-3} was observed from the mechanically ventilated neonatal intensive care unit in 2013, and in 2014 from the mechanically ventilated adult ICU (19.6 ± 7.4 μgm^{-3}) [16]. In addition, the pediatric wards are located beside a driveway leading to the emergency unit of the hospital. Diesel ambulances and other vehicles frequently drive in the driveway, which could increase the air pollution exposure of pediatric patients in the wards. Moreover, the higher

temperature and relative humidity could also promote microbial growth in the pediatric wards.

Several point-prevalence surveys from other countries had reported lower HAI prevalence rates [2,11-12]. Azzam and Dramaix [11] reported the HAI prevalence rate to be 6.8%, slightly lower than that (8%) reported by Balkhy *et al*. [12]. Likewise, Puhto *et al*. reported a HAI prevalence rate of only 10.1% [2]. Unlike other studies [18-20], where the majority of the HAIs occurred in ICUs, our study reported that more than half of the HAIs occurred in the pediatric wards. In other countries, natural ventilation may be a good alternative for an effective environmental measure; it could minimize the risk of infection spreading in resource-limited settings, where negative-pressure isolation rooms are hard to install. Moreover, natural ventilation may also offer a low-cost environmental control possibility in PHBs, especially in the Philippines, because the weather permits the implementation of such an infection control program. However, our results have shown that having a naturally ventilated PHB alone would not be sufficient to have an effective and efficient infection control program for PHBs. We found more cases of HAI at the naturally ventilated wards of the hospital than at the ICUs. Further studies are needed to verify the results of our study and to recommend and implement cost-effective and cost-efficient infection control programs for hospital wards and ICUs of PHBs in the Philippines.

Our study also examined different possible risk factors related to HAIs, including the type of ventilation, and stratified the analysis by specialty (adult and pediatric). For the pediatric patients, our results showed several significant associations between the occurrence of HAIs and several independent risk factors. Our results suggested that immunocompromised male patients, patients with two or more inserted devices/tubes, and patients who stay longer in the hospital may be at higher risk for developing HAIs in either pediatric wards or ICUs. For adult patients, we found a significant association between being immunocompromised and the occurrence of HAIs. Our results further suggest that diabetics, patients who had ever smoked, patients who had surgery, who had two or more inserted devices/tubes, and who were admitted to a mechanically ventilated ICU may be at particular risk of acquiring HAIs. These risk factors did not reach statistical significance, perhaps due to our sample size. In addition, we found no additional risk for patients staying in either the naturally ventilated wards or ICUs. Our results, although not statistically significant, suggest that pediatric patients in mechanically ventilated ICUs are less susceptible to HAIs than are pediatric patients in naturally ventilated wards. This could be due to the more polluted environment of the naturally ventilated wards of the pediatric department [17].

To our knowledge, our study is the first to look at HAIs in naturally ventilated wards and mechanically ventilated ICUs of a tertiary hospital in the Philippines. In our point-prevalence survey, a fellow of infectious disease reviewed and verified all the data on HAIs; this approach has been shown to improve the accuracy of the collected data [21].

There are several limitations in our study. First, our study only examined four wards and four ICUs, which does not represent the true current state or status of the whole hospital. Second, for the HAI analysis, bias due to residual or unmeasured confounding and predictor factors for HAI cannot be ruled out. Third, a point-prevalence study is only a one-day sample that fails to account and capture any variations in the patient population; this type of study is known to overestimate the magnitude of infections compared with incidence surveillance [22-23]. Lastly, the results from the point-prevalence survey may not be generalizable to other racial and ethnic groups and to other private and public hospitals with a different hospital design structure. HAIs in these different types of hospitals should be considered in future studies.

Conclusions

The type of ventilation in the hospital was not found to be a risk factor for HAIs; however, immunocompromised patients admitted in wards or ICUs may be at a higher risk for acquiring HAIs. This study showed that HAIs are disturbingly frequent in government hospitals, especially in overcrowded and polluted naturally ventilated wards and mechanically ventilated ICUs. Improvements in everyday infection control practices in the wards and ICUs are necessary in PHBs to minimize the number of HAIs.

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staff of the University of the Philippines - Philippine General Hospital.

Authors' contributions

GVD was responsible for study concept and design, analysis and interpretation of data, drafting of manuscript, critical revision, and final version approval. JI was responsible for acquisition of data, analysis and interpretation of data, drafting of manuscript, and final version approval. ESB was responsible for study concept and design, acquisition of data, analysis and interpretation of data, drafting of manuscript, critical revision, and final version approval.

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