Classification of Infections in Intensive Care Units: A Comparison of Current Definition of Hospital-Acquired Infections and Carrier State Criterion

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Abstract

Background: The rate of nosocomial infection appears to depend on whether it is calculated using the Center for Disease Control (CDC) or carrier state criteria. The objective of this study was to differentiate between primary endogenous (PE), secondary endogenous (SE) and exogenous (EX) infections, and to compare this classification with CDC criteria for nosocomial infections.

Methods: Children hospitalized for more than 72 h at pediatric intensive care unit during 2004–2005 were enrolled. Children, who had the infection before the admission, and or did not develop an infection within the hospitalization were excluded. Surveillance samples were sampled on admission, and then twice a week. Diagnostic samples were obtained when infection was suspected based on the clinical condition and laboratory findings. Infections were evaluated as PE, SE and EX, and their incidences were compared with CDC criteria for nosocomial infections.

Results: One hundred seventy eight patients were enrolled in the study. Forty-four patients (24.7%) develop infection. Twenty-seven patients (61.3%) had PE, 10 patients (22.7%) had SE, and 7 patients (15.9%) had EX infection. Secondary endogenous and EX infections are considered as nosocomial, thus 17 patients (38.6%) had a nosocomial infection. Thirty-one patients (70.5%) met CDC criteria for nosocomial infections. Seventeen patients (55%) were classified as PE, and 14 patients (45%) as SE or EX infections.

Conclusion: Seventy percent of infections (31 out of 44 patients) met the CDC criteria for nosocomial infections, but only 39% of infections (17 out of 44 patients) were classified as nosocomial based on carrier state classification.

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Introduction

Nosocomial infections are one of the most frequent causes of mortality and morbidity in children requiring intensive care including mechanical ventilation.[1] In pediatric intensive care units (PICU), bloodstream and lower airway infections are the most common infections.[2] They are almost always associated with prolonged use of invasive methods in the treatment of critically ill patients such as methods of catheterization

and mechanical ventilation.[3]

According to the criteria of Centers for Disease Control and Prevention (CDC criteria), infections accuring in ICUs have been taditionally divided into two by two means. One is the Gram staining technique, which groups both micro-organisms and infections into Gram-negative and Gram-positive categories, and the other is incubation time, which distinguishes community from nosocomial infections.[4]

Classifying infections is crucial in any infection surveillance program, in particular in the intensive care units (ICU). From the practical point of view, time cut-offs, generally 48 h, have been accepted to distinguish community and hospital-acquired infections from infections due to micro-organisms acquired during the patient's stay in the ICU (i.e., ICU-acquired infections).[5] However, many clinicians have appreciated that an infection developing after 48 h of ICU stay, due to a micro-organism carried by the patient on admission to the ICU, can not be considered as "true" ICU acquired. Obviously, this infection is nosocomial, i.e. the infection occurs in the ICU because the patient required intensive care treatment for her/his underlying disease associated with the immuno-paralysis. However, the causative micro-organism does not belong to the ICU microbial ecology, as the patient imported the micro-organism in her/his admission flora.[4]

A new classification of ICU infections, based on the knowledge of patient's carrier state, has been proposed. This approach allows the distinction between imported, or primary, and secondary carriage of potentially pathogenic micro-organisms (PPMs), in addition to endogenous and exogenous infections.[6]

The objectives of this study were to evaluate the incidence of infections and infection complications in children admitted to the PICU, University Children´s Hospital, Brno, Czech Republic during years 2004–2005, to differentiate between primary endogenous (PE), secondary endogenous (SE) and exogenous (EX) infections, and to compare this classification with traditional classification of infections and identify the most common pathogens causing nosocomial infections at PICU.

Materials and Methods

This prospective observational study included all the patients hospitalized for more than 3 days (72 hours) at PICU from Jan 1, 2004 to Dec 31, 2005. Patients who had had the infection before the admission and those who did not develop an infection during the hospitalization were excluded from the study.

Surveillance samples of oropharyngeal and rectal swabs were obtained on admission to the PICU, and twice weekly (e.g. on Mondays and Thursdays) thereafter. Diagnostic or clinical samples were obtained in the case of suspicion of infection based on the clinical condition and laboratory findings [tracheal aspiration (TA), bronchoalveolar lavage (BAL), blood, urine, smear, etc.]. Infections were defined based on the criteria.[7-11]

The microorganisms causing the infections were classified based on their pathogenicity as potentially pathogenic microorganisms (PPM) such as Streptococcus pneumoniae, Haemophilus influenzae, Moraxella catarrhalis, Staphylococcus aureus, Escherichia coli, Candida albicans, or pathogenic microorganisms (PM) such as Klebsiella species, Proteus species, Morganella species, Enterobacter species, Citrobacter species, Serratia species, Acinetobacter species, Pseudomonas species, Stenotrophomonas species.[12]

All the infections were classified based on the traditional classification of infections (CDC criteria) such as the cut-off interval (infections appearing before or after 48 hours of hospitalization),[5] and based on the carrier state.[6]

Knowledge of the carrier state, together with diagnostic cultures, allows the distinction between the three types of infection occurring in the ICU.[6] Primary endogenous infections (PE) were defined as an infection caused by PPM or PM brought into the unit with the patient who carried the PPM in throat and/or gut on admission. Secondary endogenous infections (SE) was an infection caused by a PPM or PM not carried by the patient on admission, but acquired in the unit followed by oropharyngeal and/or gastrointestinal carriage and subsequent infection. Exogenous infections (EX) were infections caused by PPM or PM that was never present in throat and/or gut of the patient. Bacteria are transferred directly into an internal organ without previous carriage. According to this criterion, only secondary endogenous and exogenous infections are labeled ICU-acquired infections, whilst primary endogenous infections are considered to be imported infections.[4]

The patients were classified as having either infection at the time of admission or without infection. The patients without infection at the time of admission were split into groups of those with complications caused by an infection and those without them.

The study recorded following data for all the patients: age, weight, sex, Pediatric Risk of Mortality (PRISM) score at admission, the basic cause of the illness, Multiorgan Failure Score (MOFS), the length of the hospitalization, classification of the infections based on traditional classification of infections and carrier state criteria, the incidence of specific microorganisms, and the type of infection caused by them later on.

Swabs of throat, nose and stool (surveillance samples) were qualitatively and semi-quantitatively processed in order to determine the carrier state type. Identification, typing and sensitivity of all the microorganisms were done using standard microbiological methods.

Descriptive statistics and basic statistical methods (Fisher exact test, Pearson's chi-square test and Mann-Whitney U test) were used for analysis of the findings depending on data type. Data analysis was performed using Statistica (version 8.0 Copyright©StatSoft, Inc.). A P value of ≤0.05 was considered statistically significant.

Results

Out of 617 patients admitted in the years 2004 and 2005, 264 (42.7%) patients were hospitalized for more than 72 hours. Of the hospitalized patients, 86 (32.6%) were infected on admission. The study dealt with 178 (67.4%) patients, who were without infection at the time of admission. Out of the 178 patients 44 (24.7%) developed an infection during hospitalization. They included 22 boys and 22 girls with an average age of 88.1 months, average weight of 26.9 kg, and average length of stay 3.9 days.

Table 1 compares the patients with an infection during hospitalization and the patients without one. Both groups had similar demographic data including age, weight, sex and the cause of the basic illness, the severity of illness on admission (PRISM, MOFS), or mortality. There was however, statistically significant difference in the length of stay (13.9 days for patients with an infection vs. 8.9 days for patients without an infection, P=0.0001). The distribution of the bacterial and yeast infections according to two classification schemes, namely 48 hour cut-off interval was based on traditional classification of infections (CDC criterion) and carrier state criterion.

Based on the CDC criteria 70.5% of all the infections were classified as nosocomial and 29.5% of them as community infections. Using the carrier state criteria, 27 (61.3%) infections were classified as PE, 10 (22.7%) infections as SE and 7 (15.9%) as EX.

In all three categories (PE, SE, EX), the most common one (95% [42 out of 44 infections]) was the lower airways infection (table 2). Primary endogenous and SE in most cases were caused by PPM that can be carried by healthy people as well (community bacteria). Primary endogenous infection in most cases (8 out of 24; 29.6%) was caused by E. coli, and SE was mostly (8 out of 10, 80%) caused by C. albicans. The most common EX were Klebsiella species and Pseudomonas aeruginosa, which are the typical nosocomial pathogenous microorganisms.

Discussion

The terms "exogenous" and "endogenous", derived from the Greek word "genous", which mean "depend" or "develop", and tell us whether the infections originated in the patient's inner or his outer environment.[13]

There is no evidence that infections occurring on, or at a specific time after ICU admission, are attributable solely to micro-organisms transmitted via the hands of care givers and, hence, acquired during the ICU stay.[14] It also still remains uncertain from the literature whether the given time cut-off refers to the number of days on the ICU or the number of days following intubation. The failure of the CDC guidelines to specify a time cut-off has led to the introduction of arbitrary and different time cut-offs, and to the use of the type of micro-organism causing the infections to distinguish between community-, hospital-, and ICU-acquired infections. Clinicians, in extending the time cut-off, appreciated that infections developing in the first days after ICU admission have nothing to do with the ICU microbial ecology, and hence

Table 1: The comparison of characteristics of the patients with and without nosocomial infection during hospitalization

		With infection	Without infection	P value
Number of patients		44	134	
Boys		22 (50%)	84 (63%)	n.s.[1]
Girls		22 (50%)	50 (37%)	
Average age (months)		88,1	96,3	n.s.[3]
Average weight (kg)		26,9	29,6	n.s.[3]
Average PRISM on admission		8,66	7,63	n.s.[3]
Origin of underlying disease	M	23 (52%)	47 (35%)	
	S	1 (2%)	9 (7%)	n.s.[2]
	T	18 (41%)	60 (45%)	
	O	2 (5%)	18 (13%)	
Average length of stay (days)		13,9	8.9	0.0001[3]
Average MOFS		2	1,77	n.s.[3]
Mortality		2 (5%)	10 (7%)	n.s.[1]

[1]Fisher exact test; [2]Pearson's chi-kvadrat test; [3]Mann-Whitney U test; PRISM: Pediatric risk of mortality; MOFS: Multiorgan failure score

Table 2: The distribution of pathogens based on carrier state criterion

	Microorganisms causing the infection	Number of infections
Blood	PE–*S. aureus*	1
	PE–*E. coli*	7
Lower airways	*C. albicans*	5
	S. aureus	4
	K. pneumoniae	4
	P. aeruginosa	3
	M. catarrhalis	2
	SE–*C. albicans*	8
	S. aureus	1
	K. pneumoniae	1
	EX–*K. pneumoniae*	2
	P. aeruginosa	2
	S. maltophila	1
	S. aureus	1
	C. albicans	1
Urinary tract	PE–*E. coli*	1

PE: Primary endogenous infections; SE: Secondary endogenous infections; EX: Exogenous infections

acknowledged that incubation time represents an inaccurate criterion for classifying infections in the critically ill patients. According to the pathogenesis of ICU-acquired infections, acquisition of a PPM is followed by carriage and overgrowth of that micro-organism before colonization and infection of an internal organ may occur. Undoubtedly, this process takes more than 2, 3, or 4 days to develop. Therefore, a low respiratory tract infection due to a PPM already carried in the throat and/or gut on admission and developing in a ventilated trauma patient after 3, 4, or even 10 days of ICU admission, can not be considered as ICU acquired.[4] Knowledge of the carrier state at the time of admission and throughout the ICU stay is indispensable in distinguishing infections due to "imported" PPMs (i.e., primary endogenous) from infections due to bacteria acquired on the unit (i.e., secondary endogenous and exogenous). Only secondary endogenous and exogenous infections are "true" ICU-acquired infections, as the origin of the causative bacteria is outside the ICU patient, the ICU environment. In the case of the secondary endogenous infections, the micro-organism acquired in the unit goes through a digestive tract phase, but this does not apply to the exogenous infections.[4]

We consider the classification of infections developed in the hospital, and especially at ICU, a key for the definition of nosocomial infections, because nosocomial infections lead to a higher mortality, prolong the hospitalization time, and increase the treatment costs.[1,2] Also, the percentage of occurrence of nosocomial infections is often a mark of quality of the critically ill patients treatment.[8] In our set of patients, the infection developed during hospitalization prolonged the hospitalization time at the ICU (13,9 vs. 8.9 day, P=0.0001), and did not affect mortality (2 vs 10

patients, not significant). Since both patient groups namely, those with and those without an infection during hospitalization, are similar in terms of the demographic content and the severity of illness (see table 1), the prolongation of the hospitalization time must be caused by the infections.

In our set of patients the infections acquired during hospitalization were divided into two groups of nosocomial (70.5%) and community ones (29.5%) based on CDC criteria.[5] The use of the carrier state criterion, however, led to significant differences in this classification resulting in the rate of 61.3%, for PE, 22.7% for SE, and 15.9% for EX. Based on the carrier state, the SE and EX infections are considered nosocomial, resulting in the total rate of nosocomial infections of 38.6%. A similar conclusion was suggested by other authors.[2,3,6] The evaluation of treatment quality of the critically ill children based on the percentage of nosocomial infections would be very different too. Another important aspect of this is the possibility to prevent the infections acquired during hospitalization.

The main message of the traditionalists, who use a time cut-off of 48 h for classifying infection, is that the ICU-acquired infectious problem is a huge early phenomenon involving about two-thirds (up to 85%) of all ICU infections. Their approach implies that most infections occurring in the ICUs are nosocomial, due to micro-organisms transmitted via the hands of care givers, except those established in the first two days. The 48 h time cut-off is also responsible for blaming staffs for almost all infections occurring in the ICUs and for initiating expensive transmission investigations. Therefore, hand washing is highly recommended by influential authorities,[15] as the most important measure to control the exaggerated nosocomial problem due to an overestimated level of transmission.

These concepts are in sharp contrast to the

data from our study. Our results show that more than 60% of all PICU infections are primary endogenous, i.e., due to micro-organisms not related to the ICU ecology, and develop during the first week of ICU stay. Hand washing cannot be expected to control primary endogenous infections because it fails to clear oropharyngeal and gastrointestinal carriage of PPMs present on arrival. Being inherently active solely on transmission, hand hygiene cannot reduce the major infection problem of primary endogenous infection, as transmission is not involved in this type of infection.[4]

Strictly identifying and evaluating the primary endogenous, and the nosocomial problem of secondary endogenous and exogenous infections, the surveillance of both infection and carriage allows the intensivist to start with the appropriate prevention measures, protective isolation or the selective decontamination of the digestive tract. Another benefit is reduction the danger of morbidity and mortality.

Conclusion

Based on the CDC definition of nosocomial infection, 70.5% (31 out of 44 patients) had nosocmial infection, and based on the carrier state criterion 38.6% (17 out of 44 patients) had the infection. Given that the incidence of nosocomial infections is one of the factors affecting the quality of care for critically ill patients, the precise classification of the infection is crucial. We believe that ICU patients may benefit from an infection control program that includes surveillance of both carriage and infection

Conflict of Interest: None declared

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