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THE RISK FACTORS FOR HOSPITAL-ACQUIRED PNEUMONIA IN THE INTENSIVE CARE UNIT

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ABSTRACT

INTRODUCTION. Patients in the intensive care units (ICU) are exposed to many factors that may cause hospital acquired pneumonia (HAP), a particular type of which is ventilator-associated pneumonia (VAP). The specific risk factors for developing VAP affect patients already on the day of their admission to a unit and are associated with their underlying diseases and invasive medical procedures, which they undergo. The aim of this study was to evaluate the risk factors for VAP associated with a patient and the used invasive treatment.
MATERIAL AND METHODS. 1227 patients were subject to the retrospective analysis. These patients were hospitalized between 2010 and 2014 in Intensive Care Unit (ICU) in the St. Luke District Hospital in Tarnów. Data about procedures used in ICU were obtained from the electronic hospital registration system and the decursus from each day when a patient stayed in the hospital, while information about hospital infections was obtained from the periodic department reports prepared by the Infection Control Team. In the diagnosis of VAP infections the definitions of nosocomial infections issued by CDC (Centers for Disease Control and Prevention) and ECDC (European Center for Disease Prevention and Control) were used.
RESULTS. In the analyzed unit, 58 cases of VAP were detected in patents who underwent mechanical ventilation. Infections were more common among men (43 cases, that is 6%) than in women (15 cases, that is 3%). Mechanical ventilation longer than 20 days was a major determinant of VAP ($p < 0.001$). Patient's underlying diseases (which are the reason for patient's admission to a unit) had an impact on the incidence of VAP, and the most important of them are: multiple trauma (20 cases of VAP per 217 patients (9.2% incidence)), sepsis (3 cases of VAP per 31 patients (9.7% incidence)), central nervous system disease (10 cases of VAP per 124 patients (8.1% incidence)), endocrine system (1 case of VAP per 12 patients (8.3% incidence)), respiratory diseases (11 cases of VAP per 168 patients (6.5% incidence)). Invasive medical procedures performed in the patients' respiratory tract were significant risk factors ($p<0.001$) for developing VAP: reintubation ($R=0.271$), tracheostomy ($R=0.309$) and bronchoscopy ($R=0.316$). In the period from 2010 to 2014 VAP incidence was 4.7% and incidence density per 1000 ventilation-days was 10.5 and the mortality rate with VAP was 32.8%. The most common etiological factors of VAP were *Acinetobacter Baumannie* (21 isolates, that is 36.4%), *Pseudomonas aeruginosa* (8 isolates, that is 13.8%), *Escherichia coli* (7 isolates, that is 12%).

Key words: *hospital acquired pneumonia (HAP), ventilator-associated pneumonia (VAP), intensive care unit (ICU)*

INTRODUCTION

A specific aspect of intensive care units is the use of advanced medical techniques involving invasive monitoring and mechanical support of the activities of failing organs or systems, including the respiratory system. One of the most commonly performed therapeutic procedures in ICU is intubation and tracheostomy, and also mechanical ventilation, which is performed thanks to them, while the presence of the endotracheal tube is the most important risk factor for developing VAP. Creating an artificial respiratory tract deprives a patient of the possibility to heat, humidify and purify inhaled air. This in turn, generates a series of nursing

and medical interventions that may be conducive to developing VAP (1).

MATERIAL AND METHODS

The retrospective analysis was carried out among patients treated in ICU in the St. Luke District Hospital in Tarnów between 2010 and 2014. The study included 1227 patients who were treated with mechanical ventilation longer than 48 hours. ICU patients were treated and cared for according to the recommendations for VAP prevention recommended by the experts, such as: the reclining body position of a patient, taking care about the oral hygiene, maintaining the proper pressure in a cuff, using humidifiers, using the heat and humidity exchangers, and using endotracheal tubes with a thin cuff with the possibility of subglottic suction (1). Data about the treatment course of patients were obtained with the use of the electronic database in a hospital system InfoMedica. Ventilator-associated pneumonia was diagnosed on the basis of definitions by CDC (Centers for Disease Control and Prevention) (2) and ECDC (European Center for Disease Prevention and Control) including microbiological diagnosis for hospital acquired pneumonia (PN) (3, 4). The classification of VAP was based on a method of obtaining material from the patient's respiratory tract: bronchoalveolar lavage method (BAL), brushes (PN1), tracheal aspirates (PN2), qualitative sputum culture (PN4) (3, 4). Microbiological tests were taken from patients with the suspicion of VAP infection. Etiological factors of infections were diagnosed with the use of classic methods of microorganism cultivation. The identification of staphylococci, bacilli from the *Enterobacteriaceae* family, non-fermenting bacillus was made with the use of Vitek 2 Compact – the automatic identification system (the bioMérieux company).

In order to evaluate the epidemiological situation, the following indicators were used: incidence = the number of VAPs/the number of patients x 100; density incidence (DI = the number of VAPs/the number of ventilation-days x 1000); mortality (% death = the number of deaths associated with VAPs/the number of diagnosed cases of VAP x 100); ventilator utilization ratio (VU-R = the number of ventilation-days /the number of person-days, and according to ECDC (3, 5) IU-R = the intubation-days/the number of person-days x 100). The results were analyzed statistically with the use of the STATISTICA 10 program.

RESULTS

In ICU in the St. Luke District Hospital in Tarnów, during the 5-year period, 1227 patients underwent mechanical ventilation, including 712 men (58%) and 515 (42%) women. The average age of patients was 59 years; for women it was 51 years, for men it was 57 years. VAP infections were more frequently diagnosed in men – 43 cases (6% incidence), than in women – 15 cases (incidence 3%). The greatest number of VAP infections was diagnosed in the age group of 51-75 years – 32 case of VAP (5.3% incidence). The duration of mechanical ventilation above 20 days, was a statistically significant (p = 0.001) determinant of VAP occurrence (32 cases of VAP – 33.7% incidence) (Table I).

Table I. The age category and the duration of mechanical ventilation of patients in ICU considering VAP occurrence in 2010 – 2014

Category of factor	Number of patients without VAP		Number of patients with VAP		p*
	n= 1227	%	n=58	%	
Age category (years)					
1-18	42	3.42	1	1.56	
19-30	84	6.84	1	4.68	
31-50	218	17.11	13	21.87	p=0.532
51-75	632	49.06	32	54.68	
>75	280	22.81	11	17.18	
Duration of mechanical ventilation (days)					
	n=1227	%	n=58	%	
1-4	642	52.32	2	9.37	
5-10	326	26.56	8	15.62	p<0.001
11-20	164	13.36	16	25	
>20	95	7.66	32	50	

n – number of patients, VAP – ventilation-associated pneumonia, p*- significance level of the chi-square test

The diseases that caused patients' hospitalization in ICU were analyzed (diagnosis given on the day of admission to a unit). The disease that was most often accompanied by a treatment complication in a form of VAP was multiple trauma (20 cases of VAP per 217 patients – 9.2% incidence). Patients with this diagnosis stayed in hospital for the longest time, they were also the youngest age group of patients. In this group men constituted 76% of all patients with multiple trauma. Also with other diseases the incidence of VAP was high: sepsis (3 cases of VAP per 31 patients – 9.7% incidence), diseases of the central nervous system (10 cases of VAP per 124 patients – 8.1% incidence), diseases of endocrine system (1 case of VAP per 12 patients – 8.3% incidence), respiratory diseases (11 cases of VAP per 168 patients – 6.5% incidence) and others (Table II).

The following invasive medical procedures that were applied to the patients had influence on the incidence of VAP (p<0.001): tracheostomy, bronchoscopy, reintubation, enteral and parenteral nutrition, analgosedation, tube, mechanical ventilation longer than 48 hours, aspiration, chest drainage, unconscious patient. The correlation of statistical significance was obtained

Table II. The patients' underlying diseases as risk factors of VAP occurrence in ICU in 2010 – 2014

Diagnosed underlying disease on the day of admission to the unit	n=1227	Number of patients with VAP	Percentage of infections	Average duration of stay (days)	Patients' age (years)	Median of age (years)	M	W	p*
Sepsis	31	3	9.7	7	61	58	15	16	p = 0.689
Multiple trauma	217	20	9.2	11	46	45	165	52	p < 0.01
Endocrine disrupters	12	1	8.3	10	61	59	7	4	p = 0.554
Central nervous system	124	10	8.1	8	53	52	57	67	p = 0.651
Respiratory system	168	11	6.5	10	65	68	97	71	p = 0.422
Digestive system	142	4	2.8	8	66	66	81	61	p = 0.905
Circulatory system	159	4	2.5	8	68	68	90	69	p = 0.312
Tumor	41	1	2.4	7	59	59	29	12	p = 0.499
Musculoskeletal system	49	1	2.0	8	53	56	27	22	p = 0.365
Poisoning	51	1	2.0	8	49	49	35	16	p = 0.692
Genitourinary system	80	1	1.3	4	70	71	43	37	p = 0.125
Others	153	1	0.7	8	54	54	78	75	p = 0.032

n – number of patients, VAP – ventilation-associated pneumonia, M – men, W – women, p* – significance level of the chi-square test

between risk factors and VAP incidence in cases of reintubation (R=0.271), tracheostomy (R=0.309) and bronchoscopy (R=0.316) (Table III).

Table III. Risk factors for VAP associated with patient treatment in 2010 – 2014

Risk factors for VAP associated with treatment	(p) significance level of the chi-square test for VAP	Coefficient value / Spearman's correlation
Tracheostomy	p<0.001	0.316
Bronchoscopy	p<0.001	0.309
Reintubation	p<0.001	0.271
Enteral nutrition	p<0.001	0.208
Analgosedation	p<0.001	0.179
Tube	p<0.001	0.171
Mechanical ventilation > 48 hours	p<0.001	0.167
Intubation	p<0.001	0.163
Aspiration	p<0.001	0.149
Parenteral nutrition	p<0.001	0.146
Chest drainage	p<0.001	0.125
Unconscious patient	p<0.001	0.066
Craniocerebral trauma	p=0.281	0.067
Central venous catheter	p=0.301	-0.018
Paralysis	p=0.310	0.046
Wounds and pressure sores	p=0.003	0.092

VAP – ventilation-associated pneumonia

The highest VAP incidence occurred in 2010 (7.6%). In that year we could also note the highest density rate per 1000 patient-days which amounted to 9.4. The mortality rate among patients with VAP was the highest in 2012 (70%) and the lowest in 2010 (17.6%) (Table IV). The incidence of VAP is related to the number of ventilation days, this indicator is referred to as incidence density and shows the frequency of VAP occurrences among ventilated patients. The highest incidence density was observed in 2010 (21 cases per 1000 ventilation-days) (Table V).

Cases of VAP were classified by means of microbiological diagnostics based on the type of materials taken from patients according to the criteria of pneumonia (PN) recognition by ECDC: by broncho-alveolar lavage (BAL) 15 isolates responsible for VAP (PN1) were obtained, 6 isolates from tracheal aspirate (PN2), 37 isolates by qualitative sputum (PN4). The most common etiological factor of VAP was *Acinetobacter baumannii* (21 isolates, that is 36.4%) and in 96% cases the bacteria was resistant to carbapenems and two other groups of drugs. The next most common was *Pseudomonasaeruginosa* (8 isolates, that is 13.8%) where all grown strains showed resistance to carbapenems and two other groups of drugs. The third most common factor was *Escherichia coli* (7 isolates, that is 12%), among which 17% was ESBL (+) *(Extended Spectrum Betalactamases)* (Table VI).

DISCUSSION

Healthcare associated infections in ICU are a phenomenon that causes many adverse health effects on patients. They cause prolonged hospitalization, increase mortality and significantly increase of the treatment costs (6). Authors of many publications claim that 20-50% of all healthcare associated infections are developed in ICU (1, 7, 8). The increased risk of

Table IV. The number of diagnosed VAP episodes in patients treated in ICU between 2010 and 2014, incidence, incidence density per 1000 patient days, and mortality

Year	n	Patient days	Number of VAP episodes	Incidence VAPs %	VAPs /1000 patient days	Number of death	% death	The average duration of stay in a unit of a patient with VAP (days)
2010	225	1815	17	7.6	9.4	3	17.6	26
2011	255	1767	10	3.9	5.7	4	40.0	37
2012	222	1591	10	4.5	6.3	7	70.0	22
2013	268	1596	11	4.1	6.9	2	18.2	22
2014	257	1919	10	3.9	5.2	3	30.0	31
Total	1227	8688	58	4.7	6.7	19	32.8	28

n – number of patients, VAP – ventilation-associated pneumonia

Table V. Number of VAP episodes considering epidemiological indicators: incidence density per 1000 ventilation-days and ventilator utilization ratio in ICU between 2010 and 2014

Year	n	Number of VAP episodes	Number of ventilation-days	VAP incidence density per 1000 ventilation-days	Number of patient days	IU-R according to ECDC	VU-R according to CDC
2010	225	17	814	20.88	1815	44.8	0.45
2011	255	10	1170	8.55	1767	66.2	0.66
2012	222	10	1112	8.99	1591	69.6	0.7
2013	268	11	979	11.24	1596	61.1	0.61
2014	257	10	1459	6.85	1919	76	0.76
Total	1227	58	5534	10.48	8688	63.6	0.63

n – number of patients, VAP – ventilation-associated pneumonia, IU-R intubation utilization ratio calculated according to ECDC, VU-R ventilator utilization ratio CDC

Table VII. Quantitative and qualitative characterization of bacteria isolated from patients diagnosed with VAP in ICU between 2010 and 2014

VAP – ventilation-associated pneumonia	Number of microorganisms in VAP	% of total number of microorganisms for VAP n=58
Acinetobacter baumannii	21	36.4
Klebsiella pneumoniae	8	13.8
Pseudomonas aeruginosa	7	12
Staphylococcus aureus	6	10.4
Escherichia coli	6	10.4
Candida albicans	2	3.4
Enterococcus faecium	2	3.4
Kliebsiella oxytoca	1	1.7
Morganella morgannii	1	1.7
Citrobacter freundii	1	1.7
Enterobacter cloace	1	1.7
Proteus vulgaris	1	1.7
Proteus mirabillis	1	1.7
Total	58	100

VAP – ventilation-associated pneumonia

developing infections in patients in ICU is related to the necessity of the use of invasive procedures whose aim is to support ineffective systems (9). The average age of the analyzed patients in ICU in Tarnów was 59 years, men were hospitalized more frequently (58%) than women (42%). A similar relation is shown in the Wieder–Huszla study (6), in that group with HAI male were more dominant and the average age was 57 years.

According to the American Thoracic Society and the Infectious Diseases Society of America, hospital acquired pneumonia constitutes up to 25% of all infections on intensive care units, 90% of which is ventilator-associated pneumonia (VAP) (10). In ICU, hospital acquired pneumonia is associated with invasive method of mechanical ventilation (intubation, tracheostomy), referred to as IAP or VAP (2, 3). According to Łazowski et al. (11) the incidence of VAP is at the level of 10.1%. In the American study, VAP was determined at the level from 2.5% to 22.8%, and incidence density was from 1.3 to 8.5 per 1000 ventilation-days (12). In one of the European studies that involved 27 intensive care units, the incidence density of VAP was from 13 to 16.6 per 1000 ventilation-days (13). The study of ECDC from 2007 showed that the incidence density of VAP in ICU was 14 per 1000 ventilation-days, and in 2011-2012 (14, 15) it was 10.5 per 1000 ventilation-days. According to the annual epidemiological report by ECDC from 2014, pneumonia (PN) was diagnosed in 5.3% of patients, 93% of these cases involved patients with mechanical ventilation and density incidence associated with VAP was 10.1 per 1000 ventilation-days (16). In Poland, the incidence density of VAP varies from 10.2 to 16.5 per 1000 ventilation-days (8, 17, 18). In the studied population (1806 patients) in ICU in the St. Luke District Hospital in Tarnów the incidence of

Table VII. Comparison of VAP occurrence in ICU between 2010 and 2014 with the research results obtained in Poland, Europe and USA

Source of data	Number of person-days	Number of ventilation-days	Number of VAP episodes	VAP Incidence density	VU-R ** CDC	VU-R*** ECDC
PL Studied ICU in Tarnów	8688	5 534	58	10.5	0.63	63.60
PL Clinical Department of Wrocław Medical University [22]*	11 862	8 425	93	10.2	0.71	71.24
ECDC Report 2007 (ICU) 2012 [18]*	570 968	310830	4173	14.0	na	54.4
ECDC Report 2011-2012 (ICU) 2013 [19]*	95 379	nd	543	10.5	na	56.6
CDC Report NNIS 1992-2004 [23]*	979 550	351 705	nd	5.1	0.37	na
CDC Report NHSN 2006-2008 [24]*	498 463	181 102	398	2.2	0.36	na
CDC Report NHSN 2011 [25]*	444 893	156 191	152	1.0	0.35	na
CDC Report NHSN 2012 [26]*	606 883	206 731	191	2.0	0.34	na

PL - Poland, VAP- ventilation-associated pneumonia, ICU – Intensive Care Unit, VU-R – ventilator utilization ratio (CDC**, ECDC***) , nd – no data, na – not applied, *references item

VAP was 4.7% and incidence density was 10.5 per 1000 ventilation-days. In the American studies, VAP occurred less frequently than in the studied unit and other European countries. In the infections surveillance report in the NNIS program (ICU) 1992-2004 the detected incidence density of VAP was at the level of 5.1 per 1000 ventilation-days (19). While in the NHSN program from 2006-2008 the incidence density of VAP was 1.0/1000 ventilation-days (21) and in 2012 it was 2.0/1000 ventilation-days (22).

In Poland there is no official record of the occurrences of nosocomial infections. In order to reflect the credibility of the carried out surveillance, the obtained results about the incidence density of VAP were compared with the results of other study that was carried out in Poland in the Anesthesiology and Intensive Care Department in Wrocław where the similar number of patients was analyzed. In that Department the incidence density of VAP was similar to the one in the analyzed unit in the St. Luke District Hospital in Tarnów. Whereas in the ECDC report the incidence density of VAP (data from 9 EU countries) in the study from 2007 was higher (14.0), and in 2011-2012 it was 10.5. The results of the American surveillance report indicate a much lower incidence density of VAP (Table VII). The demonstrated differences in incidence density of VAP between the European and American programs can indicate the difference in the quality of care provided to patients with mechanical ventilation.

After analyzing the microbiota responsible for occurrence of hospital acquired pneumonia in the Anesthesiology and Intensive Care Unit in the St. Luke District Hospital in Tarnów, it can be stated that the dominant microorganism responsible for VAP was *Acinetobacter baumannii* and *Pseudomonas aeruginosa*. According to ECDC (23) the most often isolated microorganism in VAP cases was *Pseudomonas aeruginosa*..

CONCLUSIONS

1. The most important risk factors for VAP associated with treatment were reintubation and bronchoscopy.
2. The highest VAP incidence was observed in patients admitted to ICU who were diagnosed with multiple trauma.
3. The duration of ventilation above 20 days was a significant determinant of VAP incidence.

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