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CLOSED VERSUS OPEN SUCTION SYSTEM OF THE AIRWAYS IN THE PREVENTION OF INFECTION IN VENTILATED PATIENTS

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Abstract

Aim: The aim of our study was to show the influence of the type of suction system (Closed versus Open Suction System) on the minimisation of the risk of respiratory infections in ventilated patients (Ventilator Associated Pneumonia - VAP). *Methods:* A retrospective study was conducted. The sampling was intentional. Inclusion criteria for the patients were: at least three days´ stay in hospital and endotracheal or tracheostomy intubation. Patients with acute or chronic respiratory disease and sepsis were excluded. Of the total (n = 100) sample 49 patients had closed and 51 had open suction systems. To collect empirical data, we used content analysis of the findings in the medical records. A research protocol included VAP diagnostic signs: changes in body temperature (BT > 38°C; BT < 36°C), leukocytosis, leukopenia, PaO_2 below 10kPa, a positive finding on a chest X-ray, the nature of removed secretions, microbial colonization, uncontrollable VAP risk factors (age, gender, primary disease, the mortality rate in ventilated patients at the Clinic of Anaesthesiology and Intensive Medicine - CAIM). *Results:* We did not observe differences in the incidence of changes in BT in terms of physiological values, leukocytes values, or PaO_2 in patients with artificial lung ventilation in relation to the type of suction system. Similarly, other diagnostic signs of infection were not statistically significant. We found significant results in the relationship between microbial colonization (Acinetobacter spp, Proteus mirabilis) and the type of suction system (Pearson´s Chi-square = 4.060; p = 0.044 and Pearson´s Chi-square = 4.273; p = 0.039). Closed suction systems led to faster colonization by multi-resistant microorganisms. *Conclusion:* The type of suction system does not affect the incidence of nosocomial respiratory tract infections in ventilated patients. It is crucial to respect general precautions in sanitary - epidemiological regime and barrier nursing techniques.

Key words: artificial lung ventilation, closed and open suction system, Ventilator Associated Pneumonia.

Introduction

Respiratory airway care – securing of air passages, ensuring the ventilator circuit, ventilation regime, heating, humidification of the inhaled mixture and respiratory toilet are essential interventions for patients on artificial lung ventilation (ALV). Tracheal suction is carried out by means of special tracheal suction catheters on the principle of closed (CSS) or open (OSS) suction systems. The advantages of closed suction systems are: easy handling; short preparation for the procedure; suctioning and lavage can be carried out by a single nurse; it is an aseptically performed procedure; there is a lower decrease in functional residual capacity after the suctioning in patients requiring PEEP(positive end - expiratory pressure); low aerosol leakage (indicating a maximally closed system); sputum leak into space is excluded; reducing the risk of transmission of infection to nursing staff and other patients; it involves less handling with a ventilator circuit; ventilation is continuous during suction; the patient is not disconnected from the ventilator; when the acoustic alarm is turned off during the procedure, patients are not mentally traumatized, they are calmer and willing to cooperate.

Tracheal suction is an invasive nursing intervention. For the patient, it may mean pain, irritative cough, nausea or vomiting. The transmission of infection is a serious problem associated with airway suctioning in ventilated patients. Patients are at risk of developing Ventilator-Associated Pneumonia (VAP) (Firment et al., 2009, p. 297; Zadák et al., 2007, p. 174). Chytra (2003) defines VAP as nosocomial pneumonia in a patient ventilated invasively for more than 48 hours (Chytra et al., 2003, p. 284). From an epidemiological point of view, VAP is characterized by inflammation of the lung parenchyma, caused by

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an infectious agent, which was not present at the time of hospitalization, even in the incubation period. Causative infectious agents vary according to the type of patients in intensive care, length of stay in hospital and diagnostic methods used. The risk of VAP is affected by primary diagnosis, the overall status of the organism and the etiological agent of inflammation. VAP is most often of bacterial origin, dominated by aerobic gram-negative bacteria (*Pseudomonas aeruginosa* and *Enterobacteriaceae*). Polymicrobial etiology is frequent. Gram-positive bacteria *(Staphylococcus aureus* and *Streptococcus spp*.) and other pathogens, including yeasts, anaerobes, and atypical pathogens may be present. In some cases, VAP with viral etiology can also occur. Early VAP is developed within four days of intubation. The disease-causing pathogens are often sensitive to common antibiotics. This is usually bacterial flora by which the patient has been colonized before starting ALV (*Staphylococcus aureus, Haemophilus influenzae, Streptococcus pneumoniae*). Late VAP is developed after four days and is caused by resistant pathogens (*Pseudomonas aeruginosa, Acinetobacter spp., Enterobacteriaceae* and others). Progress in late VAP is much more difficult and the prognosis is worse. Pneumonia occurs as a result of the penetration of pathogens into the lower respiratory tract by oropharyngeal aspiration, inhalation of contaminated aerosols or a hematogenous route from peripheral sites, but also the translocation of bacteria from the digestive tract. Aspiration is considered to be the principal mode of penetration by bacteria into the lower respiratory tract (Chytra et al., 2003, p. 285). Risk factors for VAP development are traditionally classified as ´controllable´ and ´uncontrollable´. The most important controllable risk factors for VAP are: ALV duration longer than 24 hours, the presence of a nasogastric tube, the use of antacids, H2 blockers, enteral nutrition, reintubation, tracheostomy, frequent changes of the ventilator circuit, antibiotic therapy, supine position without elevated upper body, pressure in the tracheal tube cuff below 20 cmH_2O, nebulization therapy, patient transport outside the department, use of muscle relaxants, and aspiration. The uncontrollable risk factors for VAP include: age, co-morbidity, male gender, and the character of primary disease. The highest risk of the VAP development has been established in patients with burns, CNS function disorders, trauma, and in patients after surgery in the chest area (Dostál, 2005, p. 262). Diagnostics is based on X-ray findings, clinical status and microbiological findings (Zadák et al., 2007, p. 175). Comparative studies on the specificity and sensitivity of diagnostic criteria indicate that the accuracy of VAP clinical criteria (body temperature, leukocyte count, character of sputum, X-ray findings – infiltrate, a decrease in PaO_2) is adequate and that non-invasive (blind) and invasive (bronchoscopic) sampling techniques are of no higher informative value, especially if, for diagnostics, clinical criteria are used in combination with non-invasive sampling techniques and the effectiveness of treatment is monitored (Firment et al., 2009, p. 298). Clinical findings are crucial for making a diagnosis. In suspected VAP and the initiation of antibiotic therapy, X-ray findings, and two or more clinical symptoms (body temperature above 38°C or below 36°C, leukocytosis or leukopenia, purulent sputum) are sufficient.

The prevention of nosocomial infections, including VAP, is based on basic sanitary and anti-epidemiological principles, such as hand hygiene; use of disposable devices; strict adherence to aseptic techniques and procedures during suctioning of the patient; use of sterile instruments and devices; securing a separate location for patients according to risk of development and transmission of infection; and ensuring and observing isolation and barrier precautions (Pokorná, 2006, p. 34-35). In the care of patients on ALV it is recommended to continuously remove secretions above the balloon of the cannula with the chest and a head in an elevated position, the use of filters in respiratory circuits, and regular replacement of the ventilator circuit. The most important, but also the most vulnerable focus of prevention is compliance with established procedures by nursing staff (Firment et al., 2009, p. 299).

Aim

The aim of our study was to show the influence of the type of suction system (closed vs. open) on the minimisation of the risk of respiratory infections in a ventilated patient. Theoretical knowledge of VAP informed the list of diagnostic signs we monitored.

- general signs of infection: changes in body temperature (BT) and the onset of fever in view of length of stay at the Clinic of Anesthesiology and Intensive Care (CAIM), leukocytosis, time onset of leukocytosis, leukopenia;

- a decrease in PaO_2 below 10kPa;

- a positive finding on a chest X-ray (inflammatory changes, bronchopneumonia), time factor of the onset of changes on an X-ray;

- the nature of removed secretions (whitish - yellowish, yellowish and others);

- microbial colonization on admission and during hospitalization;

- uncontrollable VAP risk factors: age, gender, primary disease;
- mortality rate of ventilated CAIM patients.

Based on the set aims and problems, we formulated nine hypotheses in which we assumed differences in the incidence of change in BT as compared with physiological values (BT > 38°C, BT < 36°C), differences in time onset of the change in BT over 38°C, differences in the incidence of leukocytosis and its onset, differences in the incidence of a decrease in PaO_2 below 10kPa, differences in the incidence of changes in X-rays (inflammatory changes, bronchopneumonia) and their time onset, differences in the incidence of changes in the nature of removed secretions (whitish - yellowish, yellowish and others) in ventilated patients, which would indicate the type of secretion removal from the respiratory tract (CSS vs. OSS). In four other hypotheses, we assumed that the location from which the patient was admitted to CAIM (taken by emergency medical aid, medical air rescue service, transfer of patient from another department within the hospital, and transfer from another health-care facility) affects microbial colonization of the airways. We hypothesized that the type of secretion removal from the airways (CSS vs. OSS) has an influence on airway microbial colonization, the length of CAIM hospitalization and mortality rate in ventilated patients.

Methods

Design

We conducted a retrospective study.

Sample

The research was carried out in the inpatients´ department of CAIM at UHM (University Hospital in Martin). The research sample consisted of patients admitted to CAIM from 1st January 2010 to 31st December 2010. Sampling was deliberate. Inclusion criteria were: patient´s hospitalization for at least three days and endotracheal or tracheostomy cannula. Patients admitted with acute or chronic respiratory disease and patients with sepsis were excluded from the sample. Of the total (n = 100), 49 were patients cleared by CSS and 51 by OSS. With regard to gender, 27 (27%) were women and 73 (73%) men. The age range of the sample varied from 20 to 85 and the mean age was 56.3 years (± 16.1). The mean age of women was 58.9 (± 17.4) and the mean age of men was 55.4 years (± 15.6). In the age group ≥ 75, there were 11 (11%) patients; in the age group 66-75, there were 23 (23%) patients; in the age group 51-65 27 (27 %) patients; and in the age group 20-50, there were 39 (39%) patients.

Patients were admitted to CAIM with various medical diagnoses, to the total of 24 according to the International Classification of Diseases (ICD). The most common cause of hospitalization was intracranial hemorrhage (S06) in 33% patients, of whom five were women and 28 men. Another quite common diagnosis was cardiac arrest (I46), which occurred in 22% patients, of whom eight were women and 14 men. In third place, was subarachnoid hemorrhage (I60), in 13 cases, of which there were four women and nine men. With regard to length of stay in hospital, when only hospitalization lasting at least three days[1] was taken into account, of the total of the research sample, 35% patients were hospitalized for three days, 19% patients were hospitalized for four days and 46% patients were hospitalized for five days or more. The longest time of hospitalization was 22 days. Thirty-five patients were transferred from other UHM departments, 31 patients were admitted from another health-care facility and 34 patients were brought in by emergency medical aid (EMA) or medical air rescue service (MARS) either from home, as victims of road traffic accidents or from environments other than a health-care facility. Exitus letalis was confirmed in 19 ventilated patients, of whom three were women and 16 men.

Data collection

A content analysis of the findings from the medical records of CAIM patients was used as the primary research tool for collecting empirical data in clinical practice. From medical records we used patients´ daily records, nurses´ records of nursing care provided, laboratory results of blood and blood gas analysis, and microbiological results.

Data analysis

The data obtained in the research protocol were encoded and transcribed into Microsoft Excel 2007 for statistical processing. We used a frequency analysis, in which we determined the absolute (n) and relative (%) frequency, mean and standard deviation. For the inductive analysis we used Pearson´s chi-squared test at a significance level $\alpha = 0.05$.

Results

We hypothesized differences in the incidence of ***change in BT compared with physiological values*** (BT > 38°C, BT < 36°C) in ALV patients in relation to the type of suction system (CSS vs. OSS). BT < 37°C was measured in three patients on whom CSS

was not used. BT in the range of > 37°C and < 37.5°C was measured in 19 patients, nine of whom underwent CSS. BT > 37.6°C and < 38°C was measured in 20 patients, nine of whom underwent CSS. BT in another dividing line > 38.1°C and < 38.5°C was measured in 40 patients, 23 of whom underwent CSS. OSS was used on 17 patients. BT > 38.6°C was measured in 18 patients, eight of whom underwent CSS. The relationship between changes in BT and type of suction system (Pearson´s chi-square = 4.337; p = 0.362) was not statistically proven. Similarly, we obtained statistically insignificant results by monitoring the onset of change in BT >38°C on individual days of hospitalization, which would implicate the type of suction system. Between the first and fourth day, of 49 patients who underwent CSS, BT > 38°C was measured in 31 patients.

Leukocytosis or leukopenia is significant VAP markers. There was only one case of leukopenia in a patient with OSS. Leukocytosis was found in 41 patients with CSS and in 41 patients with OSS. The relationship between leukocytosis/leukopenia and the type of suction system used was not statistically confirmed (Pearson´s chi-square = 2.956, p = 0.707). On the first day of hospitalization, leukopenia occurred in one case and the leukocyte count increased over 12x109/l in 57 cases, 31 of which involved the use of CSS and 27 of which did not. On the second day of hospitalization, leukocytosis was observed in 17 patients, five of whom were suctioned by CS. On the third day, four patients had leukocytosis, two of whom were suctioned by CSS. In the patients who were hospitalized ≥ four days, three patients had leukocytosis, of whom two were suctioned by CSS. Throughout the whole period of hospitalisation, leukocytosis did not occur in 18% patients. The hypothesis of the relationship between the development of leukocytosis, length of hospitalisation and the type of suction system used was not statistically confirmed (Pearson´s chi-square = 4.311; p = 0.506).

A decrease in PaO_2 below ten kPa is a typical symptom in patients with VAP. In our sample neither the relationship between the decrease in PaO_2 below ten kPa and the type of suction system (Pearson´s chi-square = 6.142; p = 0.189), nor the relationship between the length of hospitalisation, a decrease in PaO_2 below ten kPa and the type of suctioning were confirmed (Pearson´s chi-square = 6.561; p = 0.161).

As part of the research we also monitored the records of ***radiograph changes*** (inflammatory changes, bronchopneumonia) in ventilated patients, which would implicate the type of suctioning. More than half of the patients had negative radiographs, irrespective of whether CSS was used or not. More positive X-ray findings occurred in patients with CSS (up to 18 cases). In patients on whom OSS was used, there were 15 cases. The relationship between change in radiograph and type of suction system was not statistically confirmed (Pearson´s chi-square = 6.628; p = 0.250). We recorded the time interval of the incidence of changes in radiographs both with and without the use of CSS. On the first day of hospitalization at CAIM, a positive finding on a radiograph was confirmed in seven (14.3%) patients who had CSS and in ten (19.6%) patients with OSS. On the second day of hospitalisation, positivity was found in five (10.2%) with CSS and three (5.9%) without a suction system. On the third day there was an even split: in both cases one patient had a positive X-ray finding. During hospitalisation ≥ four days the positivity occurred in five patients with CSS and in one case with OSS. In up to 31 (63.3%) cases using CSS and 36 (70.7%) cases with OSS, radiographs remained negative throughout the whole hospitalization.

We hypothesized differences in the incidence of changes in the ***nature of removed secretions*** (whitish - yellowish, yellowish and others) in ventilated patients, which would point to the method of airway clearing (CSS vs. OSS). Whitish sputum was removed from 18 (36.7%) of 49 patients who had CSS and from 28 (54.9%) of the 51 patients who did not. Whitish - yellowish sputum was removed from ten (20.4%) patients with CSS and in six (11.8%) patients without it. In both cases nurses removed yellowish sputum from 12 patients and bloody sputum from three patients. Yellow - brown sputum was removed from six patients with CSS and from three patients on whom CSS was not used. The type of suction system does not affect the nature of removed secretions.

We gained statistically significant relationships when observing the presence of microbial colonization. We first evaluated swabs which were taken on the day of admission to CAIM. Table 1 shows 14 microorganisms which were represented in the microbiological results of the research sample (n = 100). The most frequently occurring microorganism in patients who were transferred from another UHM department (n = 35) was *Klebsiella pneumoniae*, it was confirmed in 11 (31.4%) cases. The least occurring microorganisms were *Streptococcus pneumoniae* (5.7%) and *Streptococcus agalactiae* (5.7%). Similarly, patients brought from other health-care facilities (n = 31) had airways most frequently colonized by *Klebsiella pneumoniae* (eight cases (25.8%). Patients brought by EMA or MARS (n = 34) were diagnosed with *Candida albicans*

Table 1 Relationship of the place from which the patient was admitted to CAIM and microbial colonization

Airway microbial colonization	UHM department (N = 35)		Health-care facility in Slovakia (N = 31)		EMA, MARS (N = 34)		Total	%
	N	%	N	%	N	%		
Pseudomonas aeruginosa	5	14.3	3	9.6	1	2.9	9	9.0
Enterobacter	4	11.4	0	0	5	14.7	9	9.0
Staphylococcus aureus	7	20	5	16.1	8	23.5	20	20.0
Streptococcus spp	4	11.4	4	12.9	3	8.8	11	11.0
Streptococcus pneumoniae	2	5.7	3	9.6	1	2.9	6	6.0
Haemophillus influenzae	4	11.4	3	9.6	3	8.8	10	10.0
Acinetobacter spp	3	8.6	1	3.2	3	8.8	7	7.0
Klebsiella pneumoniae	11	31.4	8	25.8	6	17.6	25	25.0
Proteus mirabilis	5	14.3	2	6.4	3	8.8	10	10.0
Candida albicans	6	17.1	7	22.6	10	29.4	23	23.0
Enterococcus faecalis	4	11.4	3	9.6	5	14.7	12	12.0
Streptococcus agalactiae	2	5.7	1	3.2	0	0	3	3.0
Streptococcus viridans	3	8.6	6	19.3	7	20.6	16	16.0
Escherichia coli	4	11.4	4	12.9	3	8.8	11	11.0

N - absolute frequency; % - relative frequency; UHM - University Hospital in Martin; EMA - Emergency medical aid; MARS - Medical air rescue service

in ten (29.4%) cases. In the sample of all the observed patients (n = 100), *Klebsiella pneumoniae* occurred most often (25%), followed by *Candida albicans* (23%) in second place and *Staphylococcus aureus* (20%) in third place according to incidence. *Streptococcus agalactiae* occurred least, in only three cases out of 100. The place from which a patient was admitted to CAIM does affect airway microbial colonization. We hypothesized that the method of removing secretions from the airways (CSS vs. OSS) affects the incidence of airway microbial colonization. We analysed the results of the microbiological examination of swabs from the airways, which were collected after the third day of hospitalization at CAIM. In patients whose airways were cleared by CSS, *Klebsiella pneumoniae* (32.6% patients), *Staphylococcus aureus* (26.5%), *Proteus mirabilis* (16.3%), *Candida albicans* (16.3%), and *Haemophilus influenzae* (14.3%) were found to be most prevalent. In patients with OSS, *Candida albicans* (29.4%), *Streptococcus viridans* (19.6%), *Klebsiella pneumoniae* (17.6%), *Staphylococcus aureus* (13.7%), and *Enterobacter* (13.7%) were most common. Statistically significant relationships which would point to a relationship between microbial colonization and the type of suction, in favour of OSS, were obtained in *Acinetobacter* (Pearson´s chi-square = 4.060; p = 0.044) and *Proteus mirabilis* (Pearson´s chi-square = 4.273; p = 0.039). For detailed information, see Table 2.

Summary of monitored signs of infection in relation to the type of suction system is presented in Table 3.

Discussion

In the care of ventilated patients hospitalized in the department of intensive care medicine, invasive nursing and therapeutic procedures, including the suctioning of a patients´ airways, rank among the factors triggering nosocomial infections. Nosocomial pneumonia (VAP) is the most common type of nosocomial infection, which ranges from 8% to 28% according to various sources (Sas, 2010).

We did not prove the effects of the type of suction system (CSS vs. OSS) on general symptoms of infection. Changes in BT in patients using CSS and OSS were not statistically significant, neither was the onset of BT over 38°C in relation to the length of hospitalization and the type of suction system. In ventilated patients, it is necessary to implement broad differential diagnostics. Fever arises on the basis of infectious and non-infectious etiology (Hall, 1999, p. 693-694). A thermoregulatory centre in the hypothalamus responds to changes in the internal environment, trauma and exogenous pyrogenes (bacteria and their products, especially endotoxins, viruses, fungi, yeasts, protozoa, certain hormones, drugs and synthetic polynucleotides). Macrophages and other cells of the immune system are stimulated and the production of endogenous pyrogenes occurs

Table 2 Relationship between microbial colonization and the type of suction system

	Closed suction system (N = 49)		**Open suction system** (N = 51)		**Chi-quadrate**	**p**
	pos	neg	pos	neg		
Pseudomonas aeruginosa	6	43	3	48	1.235	0.266
Enterobacter	2	47	7	44	2.837	0.092
Staphylococcus aureus	13	36	7	44	2.561	0.110
Streptococcus spp	5	44	6	45	0.062	0.803
Streptococcus pneumoniae	2	47	4	47	0.627	0.428
Haemophillus influenzae	7	42	3	48	1.961	0.161
Acinetobacter spp	6	43	1	50	4.060	**0.044**
Klebsiella pneumoniae	16	33	9	42	3.001	0.083
Proteus mirabilis	8	41	2	49	4.273	**0.039**
Candida albicans	8	41	15	36	2.416	0.120
Enterococcus faecalis	7	42	5	46	0.475	0.491
Streptococcus agalactiae	2	47	1	50	0.386	0.534
Streptococcus viridans	6	43	10	41	1.008	0.315
Escherichia coli	4	45	7	44	0.790	0.374

N - absolute frequency; p – probability; pos – positive finding; neg - negative finding

(Hulín, 2004, p. 16-22). The rise of BT may be related to a breach in asepsis during invasive nursing procedures. Leukocytosis is an accompanying sign of infection. From the results, it is evident that of the patients admitted to CAIM, up to 82% had elevated leukocyte values on the day of admission. The type of suction system had no influence on leukocyte values.

Table 3 Diagnostic signs of infection in a ventilated patient in relation to the type of suction system

Diagnostic sign of infection	**Closed suction system** (N = 49)	**Open suction system** (N = 51)	**Total**	**Pearson´s chi-quadrate**	**p**
Body temperature (BT > 38°C; BT < 36°C)	31	27	58	4.337	0.362
Leukocytosis or leukopenia	41	42	83	2.956	0.707
PaO_2 below 10kPa	18	18	36	6.142	0.189
Changes in chest X-ray	18	15	33	6.628	0.250
Microbial colonization	33	38	71		
Acinetobacter spp	6	1	7	4.060	**0.044**
Proteus mirabilis	8	2	10	4.273	**0.039**

N - absolute frequency; BT - body temperature; p – probability

Changes in PaO_2 may occur during airway clearing. A decrease below ten kPa is associated with patients with VAP. The relationship between a decrease in PaO2 and the type of suctioning was not established. Lasocki et al. (2006) conducted a study in which they confirmed a statistically significant relationship ($p < 0.05$) with respect to the type of suction system. In patients with OSS a decrease in PaO_2 and an increase in $PaCO_2$ occurred during suctioning and these changes persisted for more than 15 minutes after the suctioning procedure was completed. The research sample consisted of patients with acute pulmonary disease (Lasocki et al., 2006, p. 39-47). On the other hand, Bourgault et al. (2006), in a sample of internal-surgical patients do not describe significant changes in PaO_2 values, which might be related to the type of suction system. In both cases there was a very small sample, n = 18 patients (Bourgault, 2006, p. 268-278). Another foreign study observed changes in oxygen saturation during suctioning in patients on CSS vs. OSS. The result was favourable for both systems, patients maintaining PaO_2 within normal values. The author refers to hyperoxygenation with 100% oxygen for at least one min., which should be the first method of choice for all hyperoxygenation procedures in order to prevent a reduction in PaO_2

(Bourgault, 2006, p. 268-278). In comparison with OSS, CSS endotracheal suctioning significantly reduces heart rate changes and changes in mean arterial pressure (Jongerden et al., 2007, p. 260-270). Differences in the incidence of X-ray changes (inflammatory changes, bronchopneumonia) which would implicate the type of suction system were not observed in our study. More positive X-ray findings occurred in patients with CSS, (up to 18 cases), but without statistical significance compared with OSS. Whitish - yellowish, yellowish to yellowish - brown sputum indicates an infection in the airways. Such coloration was found in sputum removed from 28 patients with CSS and 20 patients with OSS, again without statistical significance.

We achieved significant results in the relationship between microbial colonization (*Acinetobacter spp, Proteus mirabilis*) and the type of suction system ($p = 0.044$; $p = 0.039$). CSS led to a faster colonization by multiresistant microorganisms. When using OSS, nurses follow strict aseptic techniques: during each suctioning they use a new sterile disposable catheter, wear suitable protective clothing and hand hygiene (disinfection) is observed. Several foreign studies have confirmed CSS to be disadvantageous regarding colonization of the airways. Statistically significant relationships related to microbial colonization in connection with this type of suction system were confirmed by Topeli et al. (2004). A higher incidence of *Acinetobacter spp* and *Pseudomonas aeruginosa* were observed in patients whose airways were cleared by CSS ($p = 0.04$). They state that CSS increases airway microbial colonization in ventilated patients, but does not affect the incidence of VAP nor length of stay in the intensive care unit (Topeli et al., 2004). Jongerden et al. (2007) conducted a meta-analysis of 15 studies on the advantages of CSS in ventilated patients. They did not identify any significant results which would suggest the preference of CSS over OSS, with no effect on the incidence of VAP (eight studies, 1 272 patients) or on mortality rate at the ICU in ventilated patients (five studies, 1 062 patients). They did not observe evidence favouring CSS, as the use of CSS increases bacterial colonization of the endoluminal surface of the suction catheter (Jongerden et al., 2007, p. 260-270).

The type of suction system did not influence the length of hospital stay of CAIM patients, nor the mortality rate; out of 19 deaths, ten patients were suctioned by CSS and nine by OSS. Similar conclusions are also described by Siempos et al. (2008) in a meta-analysis of nine randomized controlled trials. The statistical evaluation of the incidence of VAP, mortality rate and the length of hospital stay in ventilated patients in ICU showed no benefits to the using of CSS (Siempos, Vardakas, Falagas, 2008, p. 299-306).

Vonberg et al. (2005) also conducted a meta-analysis of randomized controlled trials. They analysed the impact of the type of suction system (CSS vs. OSS) on the incidence of VAP. They evaluated a total of 648 patients with OSS and 644 with CSS. VAP occurred in 128 (20%) patients with OSS and 120 (19%) with CSS (relative risk 0.95). They did not observe any impact of the type of suction system on the incidence of VAP. A suction system should be chosen based on handling skills, price and the individual patient´s health status etc. (Vonberg et al., 2006, p. 1329-1335). Lorente et al. (2005) conducted a prospective and randomized study. The aim of the study was to analyse the prevalence of VAP in relation to the type of suction system (CSS vs OSS). They monitored a total of 443 patients (210 with CSS and 233 with OSS). There were no significant differences with regard to age, gender, diagnosis on admission, and mortality rate between the observed groups. They did not find statistically significant relationships that would suggest the influence of the type of suction system on the incidence of VAP (20.47% vs. 18.02%) and the incidence of VAP exogenous risk factors. The only differences were related to financial costs, to the detriment of CSS ($p < 0.001$) (Lorente et al., 2005, p. 115-119). A prospective, randomized study was conducted by Zeitoun, de Barros, Diccini (2003) in a sample of 24 patients with CSS and 23 with OSS. The type of suction system did not affect the incidence of VAP. They monitored VAP exogenous risk factors but did not establish any significant differences with regard to CSS vs. OSS (Zeitoun, de Barros, Diccini, 2003, p. 484-489). Gastmeier and Geffers (2007) carried out an extensive analysis of 15 randomized trials and seven meta-analyses, concerning VAP prevention. They state that there is no evidence in studies that would suggest any advantages to CSS over OSS in preventing VAP. Preventive measures can reduce the incidence of VAP by more than 40%. This requires simple interventions: to reassess standards of infection prevention in ventilated patients, standards of suction and hand hygiene (Gastmeier, Geffers, 2007, p. 1-8). A lower incidence of VAP in patients using CSS as compared with OSS was observed by Rabitsch et al. ($n = 24$) and Lee et al. ($n = 70$), the patients were internal-surgical (Rabitsch et al., 2004, p. 886-892; Lee et al., 2001, p. 239-244).

Higher costs associated with the use of CSS are confirmed by Lorente et al., Adams et al., Lee et al. and others (Lorente et al., 2006, p. 538-544; Adams et al., 1997, p. 72-76; Lee et al., 2001, p. 239-244).

Conclusion

The type of suction system does not affect the incidence of nosocomial respiratory tract infections in ventilated patients. It is crucial to comply with general preventive measures of sanitary and epidemiological regime and barrier nursing techniques (Nemcová, 2007, p. 15-17). The basis of prevention is thorough hand hygiene (hygienic hand washing and hygienic hand disinfection) (Kelčíková, 2013, p. 23-24; Ševčík et al., 2003, p. 106), including nail grooming: nails should be appropriately cut, unvarnished, without rings and other jewelry, and without artificial nails (WHO Guidelines on Hand Hygiene in Health Care, 2009, p. 140-141; decree of Ministry of Health of Slovakia, n. 553/2007)). To prevent the occurrence and spread of nosocomial infections, it is important to take additional precautionary measures: the clean protective equipment and clothing should be used; in high-risk departments each patient should be given individual equipment for the entire stay (thermometer, stethoscope, bedpan etc.); sterile surgical instruments and aids should be used; gloves and possibly a face mask should be worn wherever there is impaired skin integrity and communication with body cavities, or whenever non-physiological input is made in the body. Used instruments and aids contaminated with biological materials, especially blood, must be decontaminated with disinfectant. The handling of biological materials and waste disposal, and handling of linen and food are also important. Doctors need to be disciplined in the indications of antibiotics, should not unnecessarily prolong a patient´s hospital stay (Maďar et al., 2004, p. 16; Podstatová, 2010, p. 103); and they should check several times a day whether the indication for ALV still persists (Černý et al., 2009, p. 110). Visits to patients should be regulated with respect to the operations and character of the department.

ALV in critically ill patients requires adequate technical equipment and staffing. The actual process of care for ventilated patients should be ensured according to established standards and guidelines. Thus, it is important to develop standards of adequate airway suctioning techniques using both open and closed suction systems. CAIM management should ensure the process of control, supervision and training of personnel in the prevention of infection.

VAP remains a major cause of mortality in critically ill patients. In terms of management, it is associated with high treatment costs. Several European and American scientific societies have developed guidelines for its prevention. At the present time, several new strategies have appeared which are associated with the prevention of VAP, relating to, for example, the use of the type of endotracheal tube (a cannula with an ultra-thin membrane, with continuous monitoring of cuff pressure etc.). The results of the studies are, however, controversial.

Ethical aspects and conflict of interest

The study complies with the fundamental ethical principles established for research on human subjects. The authors are not aware of any conflict of interest.

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