

Device-related nosocomial infection in intensive care units of Alexandria University Students Hospital

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العدوى المستشفوية ذات الصلة بالأجهزة في وحدات العناية المركزة في مستشفى جامعة الإسكندرية

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الخلاصة: استهدفت هذه الدراسة وصف مقدار ومحددات العدوى المستشفوية ذات الصلة بالأجهزة في وحدات العناية المركزة في مستشفى جامعة الإسكندرية، وتحديد الميكروبات الرئيسية المسؤولة عن العدوى. وقد تم أخذ عينات من البلغم والبول، وأجريت مزرعة للدم وتصوير للصدر بالأشعة السينية، لكل مريض عند دخوله المستشفى وعند ظهور أية علامة أو أي عرض من أعراض العدوى. وقد أصيب بالعدوى المستشفوية 45 شخصاً من جملة 400 شخص أُدخلوا 3 وحدات للعناية المركزة خلال مدة الدراسة (أي بنسبة 11.3%). وشملت أهم محددات العدوى: سوابق الدخول في وحدات العناية المركزة (سواء في نفس المستشفى أو غيره)، ومدة المكوث في المستشفى. وعموماً، اكتسب 38 مريضاً 43 عدوى مستشفوية ذات صلة بالأجهزة (أي بمعدل 1.13 نوبة لكل مريض). وكانت العدوى الرئيسية المتصلة بالإجراءات الجراحية هي الالتهاب الرئوي المتصل بأجهزة التنفس الصناعي، ثم عدوى المسالك البولية الناجمة عن استخدام القثطار، ثم عدوى مجرى الدم.

ABSTRACT We studied the magnitude and determinants of device-related nosocomial infections in intensive care units (ICU) and identified the predominant microorganisms involved. Sputum, urine, blood cultures and chest X-ray were taken from each patient on admission and on appearance of any sign/symptom of infection. Out of 400 patients admitted to 3 units during the study, 45 (11.3%) developed nosocomial infections. The most important determinants of infection were previous admission to an ICU, whether in the same or another hospital, and duration of stay. Overall, 38 patients developed 43 device-related nosocomial infections (1.13 episodes per patient). The main infected association with invasive procedures were ventilator-associated pneumonia followed by catheter-related urinary tract infection and bloodstream infections.

Infections nosocomiales liées aux dispositifs médicaux dans les services de réanimation de l'Hôpital universitaire d'Alexandrie

RÉSUMÉ Nous avons étudié l'ampleur et les déterminants des infections nosocomiales liées aux dispositifs médicaux dans les services de réanimation et identifié les micro-organismes prédominants impliqués. Pour chaque patient, on a procédé à des prélèvements d'expectorations et d'urine ainsi qu'à une hémoculture et à une radiographie des poumons à l'admission et lors de l'apparition de tout signe/symptôme d'infection. Sur les 400 patients admis dans les trois services pendant l'étude, 45 (11,3 %) ont contracté une infection nosocomiale. Les déterminants les plus importants de l'infection étaient l'admission antérieure dans un service de réanimation, que ce soit dans le même hôpital ou dans un autre établissement, et la durée du séjour. En tout, 38 patients ont contracté 43 infections nosocomiales liées aux dispositifs médicaux (1,13 épisode par patient). La pneumonie associée à la ventilation artificielle suivie par les infections des voies urinaires et les infections sanguines liées à un cathéter constituaient les principales infections associées à des procédures invasives.

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Introduction

Nosocomial infection is an infection acquired by a patient in a hospital or other health care facility that was not present or incubating at the time of admission or that was the residual of an infection acquired during a previous admission [1–4]. Nosocomial infections have been recognized for over a century as a critical problem affecting the quality of health care and a principal source of adverse health care outcomes. Today, nosocomial infections account for 50% of all major complications of hospitalization; the remainder are due to medication errors, patient falls and other non-infectious adverse events [5,6].

Nosocomial infection constitutes a major problem globally, with major social, economical, moral and personal effects, that increases the morbidity and mortality of hospitalized patients in intensive care units (ICUs) [7–9]. The highest infection rates are in intensive care patients. The rates in ICUs are approximately 3 times higher than elsewhere in hospitals. The sites of infection and the pathogens involved are directly related to treatment in ICUs [10,11].

The important risk factors for acquisition of infection are invasive procedures, which include operative surgery, intravascular and urinary catheterization and mechanical ventilation of the respiratory tract [1]. A device-associated infection is an infection in a patient given a device (central venous catheter, mechanical ventilator or indwelling urinary catheter) that was in use within 48 hours before the onset of infection [12].

Nosocomial pneumonia has been associated with high fatality rates. It is associated with a mortality rate of up to 50% among ICU patients. Most infections of the urinary tract (66% to 86%) follow instrumentation, mainly urinary catheterization.

Although not all catheter-associated urinary tract infections can be prevented, it is believed that many could be avoided by the proper management of the indwelling catheter [13,14]. Catheter-related bloodstream infections are associated with increased morbidity, a mortality rate of 10% to 20%, prolonged hospitalization (mean of 7 days) and increased medical costs.

In 1994, the first German national study was conducted on the prevalence of nosocomial infections in medical, surgical, obstetric and gynaecological departments as well as ICUs; the overall rate reported was 3.5% [15]. The reported rate for Spain in 1992 was 9.9% [16] and for Belgium in 1998 was 9.3% [16]. During 1997, in Norway, the reported prevalence was 6.1%. In Saudi Arabia, an overall nosocomial infection prevalence rate was reported to be 5.7% in 1991, 2.7% in 1995 and 2.2% in 1997 [17]. In the United Arab Emirates, a rate of 4.7% was reported over an 18-month period [18].

In Egypt, a study conducted in 1983 and 1984 in Alexandria University Hospital reflected overall rates of nosocomial infections of 21.4% and 20.3% respectively [19]. In 1995, nosocomial infection was 25% in ICUs, and 10% in the burns unit at Ain Shams University Hospital [20]. Alexandria University Students Hospital provides services to a population of more than 50 000, including university students (undergraduate and postgraduate), staff of different faculties, different employees working in the university and their families. On average, 500–600 cases are admitted every year to the ICUs of the hospital. Data regarding device-related nosocomial infection in the ICUs of Alexandria Hospital in general and in Alexandria University Students Hospital in particular are scarce. Availability of accurate data on nosocomial infection is mandatory for proper prevention and control of nosocomial infections.

The current study aimed to describe the magnitude and determinants of device-related nosocomial infections in the ICUs of Alexandria University Students Hospital and to identify the predominant microorganisms involved.

Methods

The study was carried out at the 3 ICUs of the Alexandria University Students Hospital: the general, coronary and intermediate ICUs. All patients admitted to ICUs were followed from admission to discharge and for 2 days after discharge from the ICU to the general ward, during a period of 1 year from January 2000 to February 2001. The total sample amounted to 400 patients.

Patients admitted were followed up daily for the development of device-related nosocomial infections: ventilator-associated pneumonia (VAP), catheter-related urinary tract infection (CR-UTI) and catheter-related bloodstream infection (CR-BSI). The Centers for Disease Control and Prevention case definitions of device-related nosocomial infection were used [21].

Data collection and scoring

Questionnaires, observations and record reviews were used to collect the following information about patients onto a pre-structured sheet:

- Sociodemographic data.
- Clinical background: diagnosis at entry, other associated problems, past medical history, previous hospitalization and history of present condition.
- ICU data: length of stay, invasive devices used (mechanical ventilator, central venous catheter or urinary tract catheter) and length of exposure to invasive device.

- Investigations: sputum, urine and blood cultures were taken on admission and on appearance of any sign and/or symptom of infection. Isolation and identification of any cultured organisms was performed and the antibiotic sensitivity of organisms was tested. Chest X-rays were also performed.
- Follow up: to study the development of device-related nosocomial infection all patients were followed-up daily during their stay and for 2 days after discharge from ICUs to the wards of the hospital.

Data analysis

Quantitative variables were expressed as arithmetic mean and standard deviation (SD). Odds ratio (OR) was calculated to find the determinants of the risk of developing ICU device-related nosocomial infection. Stepwise multiple logistic regression analysis was performed to explore the effect of dependent variables.

The variables entered in the logistic regression analysis for the determinants of nosocomial infection were: previous ICU admission in the same hospital, previous ICU admission in other hospital, duration of stay in hospital and number of invasive devices. The variables entered in the logistic regression analysis for the determinants of pneumonia and urinary tract infection were: duration of stay in hospital, duration of stay in ICU, level of consciousness, endotracheal tube insertion, duration of endotracheal tube insertion, use of ventilator, level of head, presence of other infection, use of nasogastric tube and use of sedation.

Results

Profile of the sample

The study sample comprised 400 patients, 57.0% males and 43.0% females, with an

age range from 5 to 95 years [mean (SD) age 52.0 (19.9) years]. More than half of the patients (51.8%) were admitted to the general ICU, 29.5% were admitted to the coronary ICU and 18.8% were admitted to the intermediate ICU.

Out of 400 patients, 45 (11.3%) developed nosocomial infection in the ICU. Nearly two-thirds of them (31 patients) were admitted to the ICU without any infection; the remaining 14 patients were admitted to the ICU with an existing infection (community-acquired or nosocomial from another hospital or ICU) and then developed another type of infection (a new species and a new organism detected). Of the 45 patients with infections, 25 had previously been hospitalized (18 in the same hospital, 7 in another) and 7 had previously been in an ICU (3 in the same hospital, 4 in another).

No infections occurred after discharge from ICU to wards during the 48 hours of follow-up.

Effect of age and duration of stay

Table 1 shows the mean age and duration of hospitalization for patients who did and did not develop infection. Duration of stay in the ICU and duration of stay in hospital were significantly higher for patients who

developed infection ($P = 0.02$ and $P = 0.007$ respectively).

Table 2 shows the crude odds ratio and 95% confidence interval of previous hospitalization and ICU admission as determinants of infections. Patients who were previously hospitalized and those who were previously admitted to the ICU were at increased risk of nosocomial infection.

After adjusting for all other variables, multivariate logistic regression analysis (Table 3) showed that the most important determinants of nosocomial infection were previous admission to the ICU, whether in the same or another hospital, and duration of stay in the hospital.

Comparing patients who developed nosocomial infection and those who did not showed no significant difference with regard to mean age ($t = 0.42$). However, the mean duration of stay in hospital and in the ICU for patients who developed nosocomial infection was significantly longer than those who did not develop infection (t values -2.28 and -2.81 respectively).

Effect of using invasive devices

Patients who had an invasive device inserted had a higher risk of developing nosocomial infection in the ICU than those without a device (Table 4). For the 17 patients given

Table 1 Mean age and duration of hospitalization for patients according to development of nosocomial infection

Variable	Developed infection		<i>t</i> -test	<i>P</i> -value
	Yes (<i>n</i> = 355)	No (<i>n</i> = 45)		
Age (years)	53.6 (23.6)	52.0 (19.5)	0.42	0.677
Duration of stay in ICU (days)	20.3 (40.9)	6.3 (10.5)	2.28	0.02
Duration of stay in hospital (days)	33.0 (45.5)	12.5 (16.9)	2.81	0.007

Values shown are mean (standard deviation).

n = number of patients.

ICU = intensive care unit.

Table 2 Crude odds ratio (OR) and 95% confidence interval (CI) of previous hospitalization and intensive care unit (ICU) admission as determinants of nosocomial infection

Variable	Crude OR	95% CI
<i>Previous hospitalization</i>		
Same hospital	1.51	0.73–3.12
Other hospital	15.20	3.88–61.66
<i>Previous ICU admission</i>		
Same hospital	9.21	1.42–59.76
Other hospital	18.42	2.78–150.44

ICU = intensive care unit.

an endotracheal tube the odds ratio for acquiring a nosocomial infection was 40.3, for 152 patients with a central venous catheter the odds ratio was 26.2 and for 184 patients with a urinary tract catheter it was 21.0. The risk of infection increased with the increasing number of invasive devices used; the odds ratios were 4.79, 5.21, 31.68 for 1, 2 and 3 devices respectively.

Table 5 shows that the risk of developing ICU nosocomial infection increased for patients who had an endotracheal tube,

Table 3 Multivariate logistic regression model: adjusted odds ratio (OR) and 95% confidence interval (CI) of some determinants of nosocomial infection

Variable	Adjusted OR	95% CI
Previous ICU admission in same hospital	5.96	1.01–35.64
Previous ICU admission in other hospital	8.83	1.25–62.34
Duration of stay in hospital	1.03	1.01–1.04

ICU = intensive care unit.

Table 4 Crude odds ratio (OR) and 95% confidence interval (CI) of invasive devices as determinants of nosocomial infection for patients given different types of invasive device

Device	Crude OR	95% CI
Endotracheal tube insertion	40.3	5.45–21.19
Central venous catheter insertion	26.2	5.95–35.20
Urinary tract catheter insertion	21.0	3.50–18.52

central venous catheter or urinary tract catheter for a duration more than 3 days and for those who had these devices inserted once or more than once.

Adjusting all other variables for their effect on the prevalence of nosocomial pneumonia and nosocomial urinary tract infection showed that the following variables were significantly associated with the outcome: patients who were in coma; endotracheal tube insertion; and use of a ventilator for pneumonia. The risk of infection increased with every incremental increase in the duration of stay in the hospital and duration of device insertion (Table 6).

Device-related nosocomial infections

Of the 45 patients who developed a nosocomial infection in the ICUs, 38 had a device-related infection. Table 7 shows that out of 58 infections, 43 were device-related nosocomial infections: 11 pneumonia, 30 urinary tract infection and 2 bloodstream infection. Thus 38 patients developed 43 device-related nosocomial infections (1.13 episodes per patient).

Of the 17 patients on mechanical ventilators, 11 (64.7%) developed VAP. Of 184

Table 5 Crude odds ratio (OR) and 95% confidence interval (CI) as determinants of nosocomial infection for patients given different types of invasive device

Variable	Endotracheal tube		Central venous catheter		Urinary tract catheter	
	Crude OR	95% CI	Crude OR	95% CI	Crude OR	95% CI
Device inserted once	7.88	3.24–20.01	10.63	4.06–29.45	9.99	4.70–21.34
Device inserted twice	20.29	1.97–193.70	134.44	24.74–212.48	23.85	3.00–219.33
Device < 3 days	1.51	0.17–13.13	5.02	0.64–31.28	1.59	0.18–11.72
Device 3 days	1.02	0.01–8.80	2.86	0.38–16.92	6.38	1.53–25.00
Device > 3 days	14.48	5.59–39.70	20.08	7.67–55.60	19.94	8.38–48.00

ETT = endotracheal tube.

with a urinary tract catheter, 30 (16.3%) of them developed CR-UTI. Of 152 patients with a central venous catheter, 2 (1.3%) developed CR-BSI.

For the patients with VAP, 2 were conscious, 2 semi-conscious, 3 in a coma, 1 progressed and 3 deteriorated.

Microorganisms isolated: sensitivity and resistance

The most common microorganisms isolated from patients with VAP were *Klebsiella* spp. in 6 infections (54.5%) and *Pseudomonas* spp. in 5 (45.5%). The antibiotic

sensitivity tests showed that *Klebsiella* spp. were sensitive to imipenem, and resistant to meropenem, amikacin and sulbactam/cefoperazone. *Pseudomonas* spp. were sensitive to amikacin and ceftazidime and resistant to meropenem and sulbactam/cefoperazone.

As regards CR-UTI cases, *Escherichia coli* 16 infections (53.3%), *Candida albicans* 11 (36.7%), *Klebsiella* spp. 2 (6.7%) and *Pseudomonas* spp. plus *E. coli* 1 (3.3%) were the most common; they were sensitive to imipenem and ketoconazole.

Table 6 Adjusted odds ratio (OR) and 95% confidence interval (CI) of determinants of nosocomial pneumonia and urinary tract infection in the intensive care units (ICU)

Variable	Pneumonia		Urinary tract infection	
	Adjusted OR	95% CI	Adjusted OR	95% CI
Duration of stay in hospital	2.97	1.85–4.29	1.18	1.03–45.00
Coma	42.37	1.84–120.12	–	–
Device inserted	12.27	1.07–115.23	–	–
Duration of device insertion	2.18	1.50–3.18	15.67	4.55–53.97
Ventilators	21.05	1.71–29.80	–	–
Duration of stay in ICU	–	–	1.21	1.02–45

Table 7 Distribution of nosocomial infections developed in the intensive care unit according to type of infection and invasive device use

Type of infection	No. of infections		Total
	Invasive device Yes	No	
Pneumonia	11	11	22
Urinary tract infection	30	4	34
Bloodstream infection	2	0	2
Total	43	15	58

The microorganism isolated from both cases with CR-BSI was *E. coli* and it was sensitive to imipenem and ceftriaxone and resistant to ampicillin/sulbactam and cefturoxime.

Outcome

Nearly half of the patients who developed nosocomial infection in the ICU died (44.4%, 20/45). Mortality was highest for patients with VAP (63.6%, 7/11).

Discussion

The relation between nosocomial infection and mortality in hospitals remains unclear; however, the highest rates of nosocomial infections are observed in ICUs. In this study period 11.3% of patients admitted to the ICUs of the Alexandria University Students Hospital developed nosocomial infection and 44.4% of them died. Previous hospital admission, previous ICU admission and length of stay were the most important determinants for developing nosocomial infection. A study done in France showed that transferred patients had a greater risk of nosocomial infection—the risk of being infected on a given

day was more than 4 times higher in transferred patients—however, the risk was similar between patients transferred from another hospital and patients transferred within the hospital [22]. The multivariate analysis showed that intra-hospital transfer, length of hospital stay over 7 days and having had at least one invasive procedure were independent risk factors for infection.

In the present study, 38 patients developed 43 device-related nosocomial infections (1.13 episodes per patient). A similar study in France revealed 41 patients developed 60 nosocomial infections (1.46 episodes per patient): 33 urinary tract infections, 15 pneumonias and 12 central venous catheter-related infections [23]. A significant association between nosocomial infection and the type of device, the number of invasive devices at the same time, the number of insertions for the same device and the duration of invasive device was observed in both studies, as each item increased the risk of nosocomial infection in parallel.

The current study revealed that VAP occurred in 64.7% of patients on mechanical ventilators, with an associated mortality of 63.6%. This higher figure than other reports (9%–21%) [24] may be attributed to the small number of cases on mechanical ventilators (17) of whom 11 developed infection. It may also be related to reasons such as lack of knowledge and poor practices of the medical and nursing staff and inadequate supplies leading to reuse of single-use supplies.

Several studies have examined the potential risk factors for nosocomially acquired bacterial pneumonia. These risk factors may be: extremes of age; severe underlying conditions (including patients on immunosuppressant therapy and post-operative patients); administration of antimicrobials, H₂-receptor blockers and

sedatives; admission to an ICU; underlying chronic lung disease; coma; endotracheal intubation; insertion of a nasogastric tube; supine position; use of mechanical ventilator support with potential exposure to contaminated respiratory equipment or contact with contaminated or colonized hands of health care workers [25,26]. In the present study, the risk factors for VAP were duration of hospital stay; coma; insertion of an endotracheal tube; frequency and duration of endotracheal tube use; and use of a ventilator. We found *Klebsiella* and *Pseudomonas* spp. were the pathogens associated with VAP and this is similar to a study in the USA by Fridkin who found that 69% of pathogens associated with VAP were gram-negative pathogens, most commonly *Pseudomonas aeruginosa* and *Enterobacter* spp. [27].

Each year, urinary catheters are inserted in more than 5 million patients in acute-care hospitals and extended-care facilities. CR-UTIs are the most common nosocomial infection in hospitals and nursing homes, comprising more than 40% of all institutionally acquired infections. Nosocomial bacteriuria or candiduria develops in up to 25% of patients requiring a urinary catheter for ≥ 7 days, with a daily risk of 5% [14]. Platt et al. suggested that nosocomial CR-UTIs were associated with substantially increased institutional death rates, unrelated to the occurrence of urosepsis [28].

Although some studies consider CR-UTI as the most common nosocomial infection in ICUs [14,28], it was observed in the present study that CR-UTI was the second most common nosocomial infection after VAP, affecting 16.3% of the patients with a urinary catheter. This finding was in accordance with that of Fridkin et al. [27] and Gikas et al. [29].

The risk of acquiring a UTI depends on the method and duration of catheterization,

the quality of catheter care and host susceptibility [14]. UTIs have been identified in approximately 30% of patients with urinary catheters within 2 weeks and virtually 100% at 6 weeks [24]. Another study reported infection rates ranging from 1%–5% after a single brief catheterization to virtually 100% for patients with indwelling urethral catheters draining into an open system for longer than 4 days [27]. In our study, the number of catheter insertions, duration of catheterization and previous admission to an ICU or general ward played a significant role in determining the occurrence of CR-UTIs.

The most common microorganisms isolated from the patients with CR-UTIs in the current study were *E. coli*, *C. albicans*, and *Klebsiella* spp. and *Pseudomonas* spp. respectively. Similar organisms were found in other studies, highlighting the fact that CR-UTIs comprise perhaps the largest institutional reservoir of nosocomial antibiotic-resistant pathogens and are caused by a variety of pathogens [14,24].

CR-BSI occupies the third rank of nosocomial infection in ICUs [4]. It occurs in less than 1% of hospitalized patients, but the greatest risk occurs in ICU patients [24]. It is often associated with intravascular catheters. Often attention is directed only towards the fact that the catheter breaks the integrity of the skin, while other environmental factors include the dressing, frequency of dressing changes, the topical antimicrobial agent and the indication for antimicrobials [30]. The present study revealed a similar prevalence (1.3%) as CR-BSI occurred in 2 patients from a total of 152 with central-line catheters, and *E. coli* were isolated in both cases.

Studies showed that since the mid-1980s, an increasing proportion of nosocomial bloodstream infections reported to the Nosocomial Infections Surveillance Sys-

tem (at the Centers for Disease Control and Prevention) have been due to gram-positive, rather than gram-negative organisms. It was largely due to major increases in 4 pathogens: coagulase-negative staphylococci, *Candida* spp., enterococci and *Staphylococcus aureus*. The distribution of these pathogens varied by hospital size and affiliation [30].

Establishing a relationship between severity of illness, therapeutic activity, occurrence of nosocomial infections and outcome requires separate analyses of illness severity and therapeutic activity as causes of nosocomial infections, and of nosocomial infections as causes of excess illness severity and extra-therapeutic activity.

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