**Summary**

**Introduction.** Nosocomial infections are a common complication in patients hospitalized in intensive care units. The aims of this research were to examine the incidence of nosocomial infections in patients admitted to the pediatric surgical intensive care unit, the impact of hospital length of stay and type of surgical disease on the incidence of nosocomial infections, the frequency of microorganisms causing nosocomial infections and their antibiotic susceptibility profile. **Material and Methods.** Data on 50 subjects were extracted from the database. The following data were taken from the medical histories of the examinees: age, sex, diagnosis, number of days at the hospital before admission to the intensive care unit, number of days in the intensive care unit, levels of C-reactive protein, applied antimicrobial drugs, isolated microorganisms and their susceptibility to antibiotics. **Results.** The incidence of nosocomial infections in the study period was 52%. Patients who developed nosocomial infection remained longer in the intensive care unit than those who did not develop it (p = 0.003). Patients with the diagnosis of acute abdomen had a statistically significantly higher incidence of nosocomial infections compared to other patients (p = 0.001). Gram-negative bacteria were the most commonly isolated pathogens (46.8%). Acinetobacter baumanii proved to be the most resistant species in this study, since 80% of the strains did not show sensitivity to any of the tested antibiotics. **Conclusion.** Nosocomial infections are present in slightly more than half of the patients treated at the pediatric surgical intensive care unit. Patients who developed nosocomial infections stayed longer in the pediatric surgical intensive care unit, which had negative consequences for their health and treatment costs.

**Key words:** Intensive Care Units, Pediatric; Cross Infection; Child; Acinetobacter Infections; Drug Resistance, Multiple, Bacterial; Gram-Negative Bacteria; Microbial Sensitivity Tests

**Sažetak**

**Uvod.** Bolničke infekcije su česta komplikacija kod pacijenata hospitalizovanih u jединциma intenzivnog lečenja. Ciljevi ove studije bili su da se ispiteta učestalost bolničkih infekcija pacijenata primljenih u pedijatrijsku jedinicu hirurškog intenzivnog lečenja, uticaj dužine hospitalizacije i vrste hirurške bolesti na pojavu bolničkih infekcija, učestalost mikroorganizama koji uzrokuju bolničke infekcije i njihov profil osetljivosti na antibiotike. **Materijal i metode.** Iz baze podataka izdvojeni su podaci o 50 ispitanika. Iz medicinske dokumentacije ispitanika su preuzeti sledeći podaci: uzrast, pol, dijagnoza, broj dana u bolnici pre prijema u jedinici intenzivnog lečenja, broj dana u jedinici intenzivnog lečenja, vrednosti C-reaktivnog proteina, primjenjivi antimikrobni lekovi, izolovani mikroorganizmi i njihova osetljivost na antibiotike. **Rezultati.** Učestalost bolničkih infekcija u ispitivanom periodu iznosila je 52%. Pacijenti koji su razvili bolničku infekciju ostajali su duže u jedinici intenzivnog lečenja u odnosu na one koji je nisu razvili (p = 0,003). Pacijenti sa dijagnozom akutnog abdomeni imali su statistički značajno veću incidenciju razvijenih bolničkih infekcija u odnosu na ostale grupe (p = 0,001). Gram-negativne bakterije su najčešće izolovani patogeni (46,8%). Acinetobacter baumanii po kazao se najrezistentnijom bakterijom u studiji, s obzirom da 80% sojeva nije pokazalo senzitivnost ni na jedan ispitivan antibiotik. **Zaključak.** Bolničke infekcije su prisutne kod većine pacijenata pedijatrijske hirurške jedinice intenzivnog lečenja. Pacijenti koji su razvili bolničku infekciju ostajali su duže u jedinici intenzivnog lečenja, što je imalo posledice na njihovo zdravstveno stanje i troškove lečenja.

**Ključne reči:** pedijatrijske jedinice intenzivne nege; bolničke infekcije; dete; infekcije izazvane Acinetobakterijama; bakterijska multirezistencija; Gram-negativne bakterije; testovi mikroben osetljivosti

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**NOSOCOMIAL INFECTIONS IN A PEDIATRIC SURGICAL INTENSIVE CARE UNIT: AN UNICENTRIC CROSS-SECTIONAL STUDY**

**BOLNIČKE INFEKCIJE U PEDIJATRIJSKOJ JEDINICI HIRURŠKOG INTENZIVNOG LEČENJA: UNICENTRIČNA STUDIJA PRESEKA**

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The children included in the study were divided into 4 groups according to the primary diagnosis that caused admission to the surgical ICU. The first group included newborns and infants admitted due to various congenital anomalies. The second group included children after elective surgeries. The third group included patients admitted after trauma or burns, and the fourth group included children admitted due to the diagnosis of acute abdomen.

For the needs of the research, a special protocol and database were designed, and all data were subsequently statistically processed and analyzed using appropriate tests. Comparison of the analyzed variables was performed by Mann-Whitney, Kruskal-Wallis as well as χ²-test. Spearman’s correlation analysis examined the correlation of the examined parameters. Statistical significance was set at p < 0.05.

Results

Our study included 50 children who were admitted to the Department of Pediatric Anesthesiology, Intensive Care and Pain Therapy (surgical ICU), Clinic of Pediatric Surgery, Institute for Child and Youth Health Care of Vojvodina, in the period between July and September 2019.

General data

The age of children included in the study ranged from the first day of life to less than 18 years. The mean age of the children was 8.14 ± 7.01 years. There were 27 (54%) male and 23 (46%) female children. The average age of male children was 10.41 ± 6.42 years and of female children 5.48 ± 6.87 years.

The children included in the study were divided into 4 groups according to the primary diagnosis that caused admission to the surgical ICU. Most children were in the group admitted after trauma or burns (15, 30%). The second most numerous group of 14 (28%) children included newborns and infants admitted due to various congenital anomalies. The condition of the acute abdomen was the admission diagnosis in 11 (22%) cases, while 10 (20%) children underwent elective surgery. The number of admitted children distributed by the primary diagnosis is shown in Graph 1.

Nosocomial infections

The initial CRP level on admission to the surgical ICU was measured in each patient. The mean CRP level, upon ICU admission, in all patients was 50.1 ± 80.1 ng/l. The CRP level was monitored daily until discharge from the surgical ICU. Patients with an increase in CRP levels by more than 50% in relation to the initial level on admission were defined as patients with a nosocomial infection. There were 24 patients (48%) without clear signs of infection, while the number of those with nosocomial infection was 26 (52%).

Comparison of patients with and without nosocomial infection by age, length of stay at the hospital and length of stay at the surgical ICU is shown on Table 1.
We also investigated the incidence of nosocomial infections between the groups. The Chi-square test showed that there was a significant difference between the groups (p = 0.001). The difference was significant due to the group of patients with the diagnosis of acute abdomen on admission, because all these patients had elevated CRP. There were 6 patients (42.8%) in the group with congenital anomalies, 6 (40%) in the group with traumas, and 3 (30%) in the group of patients undergoing elective surgery who developed nosocomial infection (Graph 2).

Microorganisms and their antibiotic sensitivity

During our study, we investigated the biological sample taken for microorganism analysis determined by the hospital protocol. A positive throat swab was found in 6 (12%) patients. The obtained antibiogram showed the presence of Escherichia coli, Stenotrophomonas maltophilia, Staphylococcus aureus and Acinetobacter spp. A positive blood culture was found in 7 (14%) patients. The obtained antibiogram showed the presence of coagulase-negative staphylococci in 5 patients, while in one patient Enterobacter spp. and Candida parapsilosis were isolated. Positive stool tests were found in 11 (22%) patients. Fungi (Saccharomyces or Candida spp.) were found in all samples. A positive abdominal swab was found in 7 (14%) patients. The most commonly isolated bacterium was Escherichia coli, in one patient associated with Providencia rettgeri, or Pseudomonas aeruginosa. In one case, we isolated Acinetobacter spp. A positive drain tip culture was found in 4 (8%) patients. The isolated bacteria were Bacillus spp., Escherichia coli and coagulase-negative staphylococci. A positive wound swab was found in 3 (6%) patients. The isolated bacteria were Enterococcus faecium and coagulase-negative staphylococci. Graph 3 shows the overall incidence of positive antimicrobial susceptibility testing results.

Of the 62 isolated pathogens, most were Gram-negative bacteria (46.8%), followed by Gram-positive bacteria (30.6%), while the remaining microorganisms were fungi (22.6%). The most common microorganisms were: Escherichia coli (24.7%), fungi (22.6%), coagulase-negative staphylococci (19.5%), Acinetobacter spp. (8.1%) and Enterococcus spp. (6.5%). The remaining microorganisms (Staphylococcus aureus, Bacillus spp., Proteus mirabilis,
Stenotrophomonas maltophilia, Providentia rettgeri, Pseudomonas aeruginosa, Enterobacter spp.) were present in only one or two isolates.

The antibiograms show that bacteria may be sensitive, moderately sensitive, or resistant to certain antibiotics. Thus, the most effective antibiotics for isolated strains of Escherichia coli were from the carbapenem group imipenem, meropenem and ertapenem (100% of sensitive strains), followed by amikacin from the aminoglycoside group (94% of sensitive strains). Ampicillin and amoxicillin from the group of beta-lactam antibiotics were the least effective (23.5% of sensitive strains). Coagulase-negative staphylococci strains were 100% sensitive only to vancomycin from the group of glycopeptide antibiotics. The next in efficiency were linezolid from the class of oxazolidinone (93.3% of sensitive strains), tetracyclines (60% of sensitive strains), fusidic acid (53% of sensitive strains), while staphylococci were mostly resistant to all other tested antibiotics. Acinetobacter spp. proved to be the most resistant bacteria in this study, since 80% of strains did not show sensitivity to any of the tested antibiotics.

Among them, only one strain was intermediate to antibiotics from the penicillin group – ampicillin/sulbactam. The only antibiotic to which 100% of Enterococcus spp. strains showed sensitivity were linezolid from the oxazolidine class and tigecycline from the glycyycycline class. Half (50%) of the isolated strains of Enterococcus spp. showed sensitivity to ampicillin, amoxicillin and amoxicillin/clavulanic acid from the group of penicillins, vancomycin and teicoplanin from the class of glycopeptide antibiotics. The Table 2 shows the sensitivity of the most commonly isolated bacterial pathogens to antibiotics.

### Table 2. The sensitivity of the most commonly isolated bacteria to antibiotics

| Antibiotic                  | Escherichia coli | Coagulase-negative staphylococci | Acinetobacter spp. | Enterococcus spp. |
|-----------------------------|------------------|----------------------------------|-------------------|------------------|
| Ampicillin/Ampicillin       | 23.5%            | /                                | /                 | 50%              |
| Amoxicillin/Amoxicillin     | 23.5%            | /                                | /                 | 50%              |
| Amoxicillin clavulanic acid| 41.2%            | 16.7%                            | /                 | 50%              |
| Imipenem/Imipenem           | 100%             | /                                | 20%               | /                |
| Meropenem/Meropenem         | 100%             | /                                | 20%               | /                |
| Ertapenem/Ertapenem         | 100%             | /                                | /                 |                  |
| Amikacin/Amikacin           | 94%              | /                                | 20%               | /                |
| Vancomycin/Vankomicin       | /                | 100%                             | /                 | 50%              |
| Tigecycline/Tigeciklin       | /                | /                                | /                 | 100%             |
| Linezolid/Linezolid         | /                | 93.3%                            | /                 | 100%             |
| Teicoplanin/Teikoplanin     | /                | /                                | /                 | 50%              |
| Tetracyclines/Tetraciklin   | /                | 60%                              | /                 |                  |
| Fusidic acid/Fusidinska kiselina | / | 53% | / | |

Discussion

Prevention, control and treatment of infections in ICUs requires detailed knowledge of local epidemiological data: incidence of infections, incidence of microorganisms and their antimicrobial resistance profiles, as well as potential risk factors for infection [6].

Numerous studies indicate that one-third to one-half of critically ill patients develop a nosocomial infection [7]. These results are in line with the incidence of nosocomial infections in our surgical ICU, which is 52%. In most foreign studies, pediatric ICUs are usually multidisciplinary, so they do not separate children with surgical pathology from other children, which may be the reason for a significantly lower incidence of infections in their ICUs (20%) compared to ours [8, 9]. Also, they usually have separate neonatal ICUs, which is different in our clinic. Finally, in our ICU there are plenty of emergency patients who are prone to infections in general.

According to our study results, patients with nosocomial infections stayed longer in surgical ICU than those without a nosocomial infection. Similar results were reported by Baviskar A. et al. in their study conducted in surgical ICU, as well as Becerra M. et al.
whose study was conducted in a pediatric ICU [9, 10]. Patients with a nosocomial infection stay longer in the ICU, because it takes a certain period of time to recover from the infection. Also, our study shows that nosocomial infections are more common in patients diagnosed with acute abdomen than in other groups of patients. In the group of patients who developed nosocomial infection in the surgical ICU in the study of Baviskar A. et al., most patients were also those whose admission diagnosis was acute abdomen/abdominal surgery (65%). The higher incidence of nosocomial infections in patients with abdominal surgery/acute abdomen can be explained by a higher incidence of surgical wound infections. These patients underwent emergency surgery with suboptimal preoperative bowel preparation, which leads to wound contamination [11].

As in the study by Baviskar A. et al., the most common isolated organisms that cause nosocomial infections were Gram-negative bacteria - 72.3% (in our study - 46.8%). Also, among the most common Gram-negative causes of infections were Escherichia coli - 26.6% and Acinetobacter spp. - 18.1% (in our study - 27.4%; 8.1%, respectively) [9]. Regarding the sensitivity of the most commonly isolated pathogens, the results of Bayram A. and Balci I. differ from ours in terms of resistance of coagulase-negative staphylococci, since in their surgical ICU they were all (100% of strains) resistant to tetracyclines, and in ours about 40% [6]. As in the study by Tran G. et al., Acinetobacter spp. appears to be the most resistant bacteria in their ICU, since most strains (80 to 90%) showed to be resistant to antibiotics such as imipenem, meropenem, and amikacin (in our study - 80%) [11]. Escherichia coli strains showed similar sensitivity in our and the study of Bayram A. and Balci I., in whose surgical ICU the most effective antibiotics were imipenem - 90% and amikacin - 95% (in our study - 100%; 94%) [6].

Multidrug-resistant bacteria are microorganisms resistant to 3 or more groups of antibiotics. In this study, Acinetobacter spp. shows the highest percentage of multidrug-resistant strains (80%), and the results of other studies are similar, such as the study of Baviskar A. et al., where Acinetobacter spp. is the leading bacteria with the highest number of strains resistant to several different groups of antibiotics (65%) [9].

Conclusion

Higher percentage of nosocomial infections in intensive care unit patients, especially pediatric patients, is probably multifactorial: immature immune system, insufficient number of nurses, irrational use of antibiotics, longer hospitalization, invasive monitoring and generally inadequate hygiene, etc. Thus, control of infections in intensive care units primarily means their prevention. The most important aspect of prevention is the implementation of strict hygiene measures. Hospital hygiene is also extremely important. Supervision of antibiotic use is a special segment and it is carried out with the aim of their rational use, since it largely contributes to the development of antimicrobial resistance.

These data show the current state of the epidemiological situation in a surgical intensive care unit and indicates the importance of infection control in it. High percentage of nosocomial infections, which is most likely the cause of longer treatment and stay of children in the intensive care unit, have more severe consequences for their health and the cost of treatment. Since this is a cross-sectional study, it is not possible to determine the direct reason for this situation, but it is certain that the cause is multifactorial. Future research should monitor further development of the epidemiological situation in pediatric intensive care units.

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