

Surgical Infections and Hand Hygiene in a Surgical Ward

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Abstract: The purpose of the study is to compare the community-acquired surgical infections with nosocomial infections caused by germs that are transmitted through the hands, in the General Surgery Department of the Baia Mare Emergency County Hospital, Romania. Materials and methods. There were selected all positive cultures with germs that are circulated through poor hygiene of hands from patients hospitalized during 2017. Samples were taken from surgical wound, peritoneal fluid, sputum, urine, stool, blood cultures and tegument. From the patient's electronic records were recorded: age, gender, DRG disease code (ICD 10), type of wound, administered antibiotics, postoperative progression, length of hospitalization and cost of day of hospitalization. Results. There were 201 (5.61%) patients with community-acquired infections and 71 (1.98%) with nosocomial infections with *Staphylococcus aureus* MSSA and MRSA, *Enterococcus*, *Klebsiella pneumoniae*, *Enterobacter*, *Pseudomonas aeruginosa*, *Candida*, *Clostridium difficile* and *Streptococcus pyogenes*. Community-acquired *Staphylococcus aureus* MRSA strains were more common in women, and the nosocomial ones in males. The most common deaths were caused by nosocomial infections with *Candida* (0.001), *Klebsiella pneumoniae* ($p = 0.026$) and *Enterococcus* ($p = 0.001$), and the highest cost / day of hospitalization was recorded in nosocomial infections with *Staphylococcus aureus* MRSA ($p = 0.045$), *Enterococcus* ($p = 0.001$) and *Candida* ($p = 0.001$). It was found resistance to betalactamic and vancomycin in the nosocomial strains of *Staphylococcus aureus* MRSA. Conclusions. Nosocomial infections with hands transmitted germs cause the worst surgical infections compared to community-acquired infections produced by the same types of germs.

Keywords: Community-Acquired, Nosocomial, Infection, Hand Hygiene

1. Introduction

It is already known that hand hygiene is the most important factor influencing the microbiota of the skin and mucous membranes and that the emergence of infectious diseases is directly correlated with it [1-3]. Gut flora composition and its modifications due to the unwashed hands are involved in the occurrence of focal infections requiring surgical treatment: acute cholecystitis [4], perforated diverticulitis [5], acute appendicitis [6] or primitive peritonitis [7]. This correlation is much more evident in the case of skin and subcutaneous tissue infections. There is therefore a direct link between patient hand hygiene and the mechanism of community-acquired surgical infections [8].

On the other hand, nosocomial infections have as their main transmitter the hands, and the implementation of hygiene protocols drastically reduces the incidence of these

infections in hospitals, all the more so as staff involvement and compliance are more rigorous [9, 10]. Germs whose transmission is associated with deficient hand hygiene [11] are responsible both for surgical infections for which the patient is hospitalized (community-acquired) and for those associated with health care. This study aims to compare the community-acquired surgical infections (CASI) with hand-transmitted infections associated with medical assistance (IAMA), treated over a year in the General Surgery Department (GSD) of the Baia Mare Emergency County Hospital (BMECH).

2. Materials and Methods

This is a retrospective study during the year 2017 (January 1st to 31 December) selecting patients with surgical infections caused by poor hand hygiene hospitalized in GSD of BMECH.

According to the World Health Organization, there are 7 germs that can cause surgical infections and have the primary way of transmitting dirty hands: *Staphylococcus aureus* (MSSA and MRSA), *Streptococcus Pyogenes* (Group A), *Enterococcus*, *Klebsiella*, *Enterobacter*, *Pseudomonas*, *Clostridium difficile* and *Candida* [11]. A surgical infections was considered to be all infections that require surgical treatment or are related to it, regardless of whether they require surgery, minimally invasive percutaneous treatment and / or medical treatment [12]. The term is much wider than organ, surgical or nosocomial infections that are, indeed, embedded.

The data were obtained from the hospital information system and from The National School of Public Health, Sanitary Management and Improvement. Day care patients were excluded from the study. Germs were identified by selecting conventional microbiology laboratory results which showed the presence of germs in specimens taken from surgical wounds, urine, sputum, stool, tears or hemocultures. These samples were collected only in patients with clinical signs of infection, and of their electronic files have been recorded: the type of bacteria isolated, age, gender, disease

DRG code (ICD 10), operative wound type - clean, clean / contaminated, contaminated or dirty [5], antibiotics administered, post-operative progression to healing / amelioration or death, duration of hospitalization and cost of day hospitalization in each of these patients. The data obtained were statistically processed with the MedCalc Statistical Software version 18.2.1 (Ostend, Belgium), and a value of $p < 0.05$ was considered statistically significant. There was no need to obtain the informed consent of patients. The study was approved by the Ethics Committee of the hospital.

3. Results

Of the 3582 patients admitted to GSD of BMECH during the year 2017, 411 were treated for infections, with a total of 686 germs isolated, out of which 272 (39.65%) with transmission due to poor hand hygiene. Most of them - 201 germs (73.89%) - were isolated within the first 48 hours of admission, representing community-acquired infections (Table 1).

Table 1. Germs related to hand hygiene, isolated in patients admitted to GSD, BMECH.

Germ	Staph aureus MSSA	Staph aureus MRSA	Enterococcus	Klebsiella	Enterobacter	Pseudomonas	Candida	C. difficile	Strep pyogenes
Total no of patients	58	41	78	39	16	22	13	1	4
In the first 48 hours, no and %	49 (82,75)	32 (78,04)	51 (63,38)	26 (66,66)	12 (75)	19 (86,36)	7 (53,84)	1 (100)	4 (100)
After 48 hours, no and %	9 (17,25)	9 (21,96)	27 (36,62)	13 (33,33)	4 (25)	3 (13,64)	6 (46,16)	-	-

The distribution of these germs by gender is represented in Table 2 and Table 3 and indicates the presence of *Staphylococcus aureus* MRSA statistically significant more frequent in women ($p=0,02$) as a community-acquired germ, and in men as a nosocomial infection ($p=0.03$).

Table 2. Gender distribution of germs related to hand hygiene, isolated within the first 48 hours of admission.

Germ	Staph aureus MSSA	Staph aureus MRSA	Enterococcus	Klebsiella	Enterobacter	Pseudomonas	Candida	C. difficile	Strep pyogenes
Women	23	22	20	9	4	10	4	0	2
Men	26	10	31	17	8	9	3	1	2
p value	1	0,02	0,26	0,25	0,48	0,81	0,71	0,001	1

Table 3. Gender distribution of germs related to hand hygiene, isolated after 48 hours of admission.

Germ	Staph aureus MSSA	Staph aureus MRSA	Enterococcus	Klebsiella	Enterobacter	Pseudomonas	Candida	C. difficile	Strep pyogenes
Women	2	3	11	7	1	2	2	-	-
Men	7	6	16	6	3	1	4	-	-
p value	0,30	0,03	0,31	0,36	0,40	0,71	0,69	-	-

Regarding the association germs related to hand hygiene with decades of age, only community-acquired *Candida* infections are approaching statistical significance in patients over 80 years and nosocomial infections with *Candida* in age groups 60-69 and 70-90 (3 patients in each group, $p = 0.099$, Pearson Chi Square test).

When association between hand transmitted germs and the type of operation was performed, it was found a statistically significant correlation of *Staphylococcus aureus* MRSA with dirty wounds, both in community-acquired infections and in those associated with medical care (19 patients, 59% vs 5

patients, 55.6%, $p = 0.024$, Pearson Chi Square test).

Leukocytosis ($> 11,000 / \text{mm}^3$) at admission was statistically significant associated only with community-acquired infections with *Staphylococcus aureus* MSSA: 20 patients, 40.8% ($p = 0.032$, Pearson Chi-Square test).

The most common associations of germs circulated through the hands with DRG diagnostic groups (ICD 10) are shown in Table 4. It was found statistically significantly more frequently *Staphylococcus aureus* and *Enterococcus* in nosocomial infections; in community-acquired infections had statistical significance *Klebsiella*, *Pseudomonas* and *Candida*,

and *Enterobacter* was isolated from the surgical wounds both before and after 48 hours of admission.

Table 4. The most common combinations of germs transmitted through hands and type of diagnosis - DRG group.

Germs	Staph. MSSA	Staph. MRSA	Enterococcus	Klebsiella	Enterobacter	Pseudomonas	Candida	C. difficile
Diagnostic type more commonly associated	K4	C K3 K8	C K5	K6	T81.41	K3	K25-26	K3
No of CASI	3	1 3 1	3 5	8	12	7	3	1
Incidence of CASI %	6,1	3,1 9,4 3,1	5,9 9,8	30,8	100	36,8	42,9	100
No of IAMA	3	2 2 2	6 6	0	3	3	0	
Incidence of IAAM	33,3	22,2	22,2	0	75	13,6	0	
p value	0,001	0,001	0,001	0,001	0,036	0,3	0,001	-

K25-26 – perforated gastro-duodenal ulcer, K3 – cecal appendix diseases, K4 – hernia and eventrations, K5 – intestinal occlusions, K6 – peritonitis and peritoneal abscesses, K8 – gallbladder diseases, T81.41 – surgical wound infection, C – malignant tumors

Infections most commonly associated with death were the ones with *Candida*, *Klebsiella*, *Enterococcus*, and *Staphylococcus aureus* MRSA, as can be seen in Table 5, the last approaching statistical significance, but without touching it.

Table 5. Infections transmitted by hands associated with patient death.

Germs	Candida	Klebsiella	Enterococcus	Staph. MRSA
No. and frequency (%) CASI	2 (28,6)	3 (11,5)	6 (11,8)	0
No. and frequency (%) IAMA	4 (66,7)	4 (30,8)	8 (29,6)	2 (22,2)
p value	0,001	0,026	0,001	0,076

Costs / day of hospitalization are statistically significantly higher for nosocomial infections with *Enterococcus*, *Candida* and *Staphylococcus aureus* MRSA, as can be seen in Table 6.

However, there were community-acquired infections that had higher costs than nosocomial infections with the same type of germs: *Staphylococcus aureus* MSSA and *Enterobacter*.

Table 6. Association of hand-transmitted germs with median cost / day of hospitalization for CASI și IAMA (RON).

Germs	Staph. MSSA	Staph. MRSA	Enterococcus	Klebsiella	Enterobacter	Pseudomonas	Candida	Clostridium difficile
cost / day of hospitalization for CASI	540	523	562	566	571	609	615	799
cost / day of hospitalization for IAMA	526	556	698	592	533,5	802	828	-
P value	0,56	0,045	0,001	0,71	0,31	0,11	0,001	-

In terms of length of stay, all hand-transmitted germs in nosocomial infections were associated with longer hospitalization than community -infections, the statistical significance being achieved for *Enterococ* (p = 0.001), *Klebsiella* (p = 0.001) and *Candida* (p = 0.007).

The most common antimicrobials used for infections

transmitted through hands, according to the antibiogram, were calculated based on the number of patients and the number of days of administration, compared to the two types of infections: community or hospital-acquired. They were taken into consideration only if they reached statistical significance. The results are shown in Table 7.

Table 7. Antimicrobials administered statistically significantly more frequently in hand-transmitted infections.

Germs	Staph. MSSA	Staph. MRSA	Enterococcus	Klebsiella	Enterobacter	Pseudomonas	Candida	Clostridium difficile
CASI	-	Amoxicillin / Clavulanic acid	-	-	Levofloxacin	-	-	-
IAMA	-	Ceftazidime Levofloxacin Invanz	Metronidazol Ceftriaxone Levofloxacin Invanz Meropenem Vancomycin	Ciprofloxacin	-	Levofloxacin Meropenem Linezolid	-	-

In infections with *Candida*, Fluconazole was administered more frequently in nosocomial infections, but without the

association to be statistically significant ($p = 0.058$).

4. Discussions

The diversity of bacteria on the surface of the hands influences other microbial habitats in the body, such as those on the oral mucosa, esophagus, stomach or intestine [13-15], besides that of the skin, causing infections including localized community acquired ones [1-3] that require surgical treatment. Compared with community acquired surgical infections (skin and subcutaneous tissue infections, acute appendicitis, acute cholecystitis, peritonitis, biliary tract infection, etc.), nosocomial surgical infections produced by the same hand-transmitted germs were and are much more studied. A question occurs: germs coming from the community are less dangerous and easier to treat than those with whom patients get infected in the hospital or infections caused by poor hand hygiene are all equally serious?

First of all, it was found that community-acquired infections with hand-transmitted germs are much more common than nosocomial infections, in line with other studies on the etiology of surgical infections [16, 17]. In the 3582 patients, 73 (2.03%) nosocomial infections were recorded during 2017 in the GSD of BMECH, of which 71 (97.26%) by hand-transmitted germs, consistent with data provided by the World Health Organization [11]. On the other hand, considering that these nosocomial infections occurred in a number of 71 patients, resulted in a rate of 1.98% nosocomial hand transmitted surgical infections in the GSD, comparable to other rates (2.1%, 3.8%) published studies with similar design after implementation of the hand hygiene protocols [18, 19]. It was found none nosocomial infections with *Clostridium difficile* and *Streptococcus pyogenes* in the GSD, probably because of the "Do not touch your mouth, nose or eyes if you did not wash your hands" protocol, strictly followed by patients.

There are large differences between women and men in terms of microbial flora [20], reflected in this study by the higher frequency in the community of *Staphylococcus aureus* MRSA in women, for the same germ to be found statistically significantly more frequently in nosocomial infections in men. Genotyping of the community and nosocomial strains found genotype ST72 more common in women and community infections, and the ST5 / ST239 genotype more frequently in males and in IAMA [21] explained by longer lengths of hospitalization in males and contaminations with *Staphylococcus aureus* MRSA found in the hospital (ST5/ST239).

Consistent with the literature [22], the only infection with differentiated distribution by age groups was found to be the one with *Candida*, more common in the elderly, both in community or hospital acquired infections, but without reaching statistical significance. This distribution is due to the increase in the number of the elderly who have been hospitalized and the decrease in immunity with aging. Because IAMA with *Candida* in GSD of BMECH is statistically significant associated with death, the

recommendation is to identify and treat prophylactically as effectively as possible these patients. In the group of patients we studied, MRSA *Staphylococcus aureus* was associated with dirty wounds ($p=0.024$), both in CASI and IAMA, explained by the presence of this bacterium in severe infections (acute perforated appendicitis, malignant tumors complicated with perforation, severe biliary tract infections), which led to the association of increased costs of hospitalization ($p = 0.045$) and the death of patients ($p=0.076$). In hospitals, *Staphylococcus aureus* MRSA has an increased incidence among nosocomial infections due to the ability to survive on amorphous surfaces and to gain rapid resistance [23].

Leukocytosis at admission is considered predictive of postoperative morbidity and mortality [24, 25], but in our study it was statistically significant associated only with *Staphylococcus aureus* MSSA in community-acquired infections, infections that were not associated with death or prolonged hospitalization, but were treated with statistically significantly higher costs than IAMA with the same bacterium.

When trying to find in the pathology we treat in our department the preference of germs for certain organs or systems, some statistically significant associations were encountered. Nosocomial infections in patients treated for hernia or eventration (type of clean operation) were more frequently contaminated with *Staphylococcus aureus* MSSA ($p = 0.001$) and their rate could possibly be reduced by nasal decolonization with mupirocin [26]. The prevalence of *Staphylococcus aureus* MRSA in patients treated for malignant tumors, appendicular peritonitis or gall bladder pathology coincides with the severity of the pathology, and its reduction involves the monitoring of hand hygiene protocols that would also play an important role in decreasing IAMA due to *Enterococ*, *Klebsiella*, *Enterobacter* and *Candida*. Decreasing the rate of these nosocomial infections would also decrease the death rate, statistically significantly more frequent in patients contaminated with these germs in the hospital, compared with the infections present at admission. The data are consistent with the literature [27], and prevention measures are well-known: monitoring of the hand hygiene and cleaning protocols, control of antibiotic use and of antibiotic resistance. The nosocomial infections that produced the most deaths are the same as those with statistically significant longest length of stay: *Enterococcus*, *Klebsiella* and *Candida*, which means that a significant decrease in costs would result from a stricter implementation of prevention measures.

The sensitivity to antibiotics was different for community acquired germs compared to those associated with IAMA. Community-acquired infections with *Staphylococcus aureus* MRSA, prevalent in infections associated to malignant tumors, in perforated appendicitis and biliary tract infections, have responded well to treatment with beta-lactam antibiotics associated with beta-lactamase inhibitors. The beta-lactamase resistance of *Staphylococcus aureus* responsible for IAMA was mediated by the occurrence of the *mecA* and *mecC*

genes (lateral transfer of genes), which allows for the synthesis of PBP2a protein, able to restore the microbial wall in the presence of increased concentrations of beta-lactam antibiotics [28], mechanism also involved in Vancomycin resistance [29]. The strains of Vancomycin-resistant *Staphylococcus aureus* in the patients studied were susceptible to Ceftazidime, Fluoroquinolones and Ertapenem. Patients with nosocomial infections in which strains of Enterococci have been isolated (*E. faecalis*, *E. faecium* and *E. gallinarum*) have rarely received penicillins and aminoglycosides due to their acquired resistance, which has associated them with high costs of hospitalization and frequent deaths, consistent with results communicated in other hospitals [30]. In this patient population, the nosocomial strains of *Klebsiella pneumoniae* retained their susceptibility to Ciprofloxacin and those of the community acquired Enterobacter to Levofloxacin, associated with lower cost differences between the two types of infection and a reduced rate of death. *Pseudomonas aeruginosa* is a pathogenic opportunistic germ that is increasingly isolated in patients with long-term hospitalization and in which studies show increasing resistance to Ciprofloxacin, aminoglycosides and cephalosporins [31]. The strains isolated from the patients have a similar pattern, and levofloxacin, carbapenems and oxazolidinones have been required for their treatment.

Candida community-acquired surgical infections are less dangerous and often self-limited if the source is controlled [32], in contrast to nosocomial ones that occur after prolonged hospitalization and antifungals were only given at the end.

5. Conclusions

Nosocomial infections transmitted by hands, though less numerous, are far more serious than those acquired in the community and compliance to the hand hygiene and cleaning protocols along with antibiotic control can keep them at a low rate. The strains of Enterococcus, *Klebsiella* and *Candida* transmitted due to poor hand hygiene of the healthcare staff are associated with statistically significantly higher hospitalization costs and death rate. Hand hygiene, in addition to reducing the number of germs, prevents the transfer of genes that provide resistance to antibiotics. Elderly patients and those with prolonged hospitalization benefit from early fungal infection prophylaxis.

Conflict of Interest

The authors declare that they have no competing interests.

The first author has contributed with: the conception and design of the study, analysis and interpretation of data, revising it critically for important intellectual content and final approval of the version to be submitted.

The second author has contributed with: acquisition of data, drafting the article and final approval of the version to be submitted.

The authors have approved the final article form.

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