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ORIGINAL ARTICLE

BACTERIAL PATHOGENS ISOLATED FROM SURGICAL SITE INFECTIONS AND THEIR ANTIBIOTIC SUSCEPTIBILITY

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Abstract

The increased reservoir of pathogenic bacteria sheltered in hospitals is the cause of various types of nosocomial infections and represents one of the major health problems. Surgical site infections (SSIs) count for 14 - 16% of all hospital-acquired infections (HAI) and represent the 3rd most occurring nosocomial infections and the 3rd most expensive HAI. We present a germ pattern (on 92 strains), located in post-operative dehiscence sites - treated with vacuum-assisted closure, in failed *per secundam* suture. The most common pathogens were *E. coli* – 18.47% (76.47% multi-drug resistant – MDR), *Pseudomonas aeruginosa* – 16.30% (33.33% MDR) and *Enterococcus faecalis* – 15.21%. *Acinetobacter baumannii* (100%) and *Klebsiella pneumoniae* (88.88%) also showed multi-drug resistance. Gentamicin, amikacin and carbapenems (> 50% sensibility) are eligible for treating SSIs, whereas cephalosporins have a higher resistance rate (> 50%). Knowledge of resistance patterns in SSIs is recommendable to ensure proper empirical treatment.

Rezumat

Rezervorul crescut de bacterii patogene din spitale reprezintă cauza multiplelor tipuri de infecții nosocomiale, fiind una dintre problemele majore de sănătate. Infecțiile plăgilor postoperatorii ocupă locul 3 atât ca incidență cât și ca cea mai costisitoare infecție nosocomială. Studiul prezintă tiparul de rezistență a unei serii de patogeni (92 de bacterii) din plăgile postoperatorii dehiscente, pentru care s-a aplicat sistemul de terapie cu presiune negativă, după eșuarea suturii *per secundam*. Cele mai frecvente bacterii au fost *E. coli* – 18,47% (76,47% multirezistent), *Pseudomonas aeruginosa* – 16,30% (33,33% multirezistent) și *Enterococcus faecalis* – 15,21%. În privința multirezistenței bacteriene s-au evidențiat și *Acinetobacter baumannii* (100%), *Klebsiella pneumoniae* (88,88%). Tratamentul cu gentamicină, amikacină și clasa carbapenemelor (sensibilitate > 50% fiecare) pot fi o soluție; terapia cu cefalosporine nu trebuie indicată de primă intenție (rezistență > 50%). Cunoașterea tiparelor de rezistență în infecțiile plăgilor operatorii este recomandabilă pentru a asigura un tratament empiric adecvat.

Keywords: pathogens, MDR bacterial pathogens, surgical site infections, vacuum-assisted closure, hospital-acquired infections

Introduction

The increased reservoir of pathogenic bacteria sheltered in hospitals is the cause of various types of nosocomial infections, called hospital-acquired infections (HAI), and represent one of the world's major health problems. Surgical site infections (SSIs) count for 14 - 16% of all HAI and represent the 3rd most occurring nosocomial infections and the 3rd most expensive HAI. It has been estimated that the hospital pays $20,785 *per* case [25, 40]. For example, in some countries, SSI prevalence was reported as 44.1% [22]. It represents a significant health problem, undoubtedly under-reported with a considerable impact: increases morbidity and mortality, delays hospital discharge, or requires readmission, further surgeries, with a suboptimal aesthetic outcome and low quality of life.

SSIs are becoming a challenge to treat due to the emerge of multi-drug resistant (MDR) bacterial pathogens. These cases associate an increased length of hospital stay, a 2-to-11-fold rise in the risk of mortality, and also surges the economic burden [4]. The battle between germs and their susceptibility to antibiotics is still a worldwide health problem. HAI by resistant bacteria

worsens the patients' conditions. Antibiotic resistance can affect any person at any stage of life, especially those with a weakened immune system. Besides, it threatens modern healthcare advancements with significant risks of infection (organ transplants, cancer therapy) [10].
The balance between the bacterial load and resistance against infection represents the major factor responsible for SSI. Germs from hospital environments, which are able to survive multiple disinfection, represent a real threat for patients.
American College of Surgeons and Surgical Infection Society set up recommendations for preventing SSI, especially in the era of multi-drug resistance bacterial pathogens, which burdens the patient, the physicians and the hospital [4]. A comprehensive assessment of society's costs and the individual patient attributable to SSIs indicates that the total healthcare burden represents only a tenth of the overall actual value [16].
Regarding SSIs treatment, pharmacological treatment is "a must", initially empiric and then adjusted subsequent to antibiogram analysis, with or without surgical treatment (drainage, debridement, *per secundam* suture, or vacuum-assisted closure - VAC). Multiple reviews demonstrated that the silver-nylon dressings are associated with decreased SSI and shorter periods of hospitalization. Negative pressure reduces the fluid accumulation and the frequency of dressing changes to only 3 - 5 days [29, 36].
Noting the rise of Methicillin-resistant *Staphylococcus aureus* (MRSA) prevalence, which developed as hospital-acquired bacteria, to a common community-acquired organism, affecting any person, at any stage of life, it concerns to see other MDR germs following a similar trajectory. A recent report estimated that by 2050 approximately 10 million people *per* year would die from antibiotic-resistance infections [5].
Therefore, the aim of our study was to investigate the resistance pattern of the microorganisms located in post-operative dehiscence sites treated with VAC in an emergency hospital from Bucharest, Romania.

Materials and Methods

Study design
The study retrospectively analysed patients' data that underwent surgery in "Elias" University Emergency Hospital, Bucharest, Romania, from January 2018 to November 2020. Medical records were examined from four surgical departments: reconstructive plastic surgery, obstetrics and gynaecology, neurosurgery and vascular surgery. We obtained for each patient, socio-demographic information, regarding sex, age and previous hospitalization.
The study population comprised hospitalized patients diagnosed with surgical site dehiscence, during this period, with two eligible criteria: (i) single germ infection of the surgical site; (ii) VAC treatment in cases with failure of *per secundam* suture.
Multiple germ infections on the surgical site represented an exclusion criterion.
92 patients met the inclusion criteria and were enrolled in the study. Due to the retrospective nature of the study, informed consent was not deemed necessary. All the patient data was anonymized and de-identified before analysis. The Ethics Committee of "Elias" Emergency University Hospital has approved the study design.
Sample size and Sampling Technique
Once the surgeon confirmed the failure of the *per secundam* suture, wound secretions were aseptically obtained. Specimens were collected on sterile cotton swabs without contaminating them with skin commensals. The samples were inoculated on Columbia 5% blood agar, Chocolate agar, CLED agar, Sabouraud agar (all media produced by OXOID Ltd., UK) and incubated for 18 - 24 hours at 37°C.
After the incubation period, colonies suggestive of pathogenically significant germs were subjected to species identification in the automatic Vitek 2C/Phoenix BD. system or biochemical tests. For identifying both Gram-negative and Gram-positive microorganisms, fluorogenic and chromogenic conventional tests were automatically performed. All the probes were treated uniformly in the hospital's laboratory.
Antimicrobial susceptibility
The isolated colonies were then tested for antimicrobial susceptibility in Vitek 2C/Phoenix BD. automated system or using the disc-diffusion technique and rendered according to the EUCAST standard.
Statistical analysis
Data were analysed using Microsoft Excel software (version 2019, Microsoft Corporation, Redmond, WA, USA), applying simple descriptive statistics and percentages for certain variables.

Results and Discussion

The study population's mean age was 65 years (ages from 40 - 86) and the majority of the patients were males (58.69%), as the literature described so far. 40.21% of the patients were already diagnosed as diabetics with altered perioperative blood glucose and 67.5% had a high body mass index (> 25). The mean duration of hospital staying was 30 days (5 - 98 days).
The patients enrolled benefited from both pharmacological and surgical treatment: empirical broad-spectrum anti-bacterial therapy, adjusted following the antibiogram analysis and suture of the surgical dehiscence site with subsequent failure, resorting to VAC treatment.
The looming danger of complicated SSI associated with microbial resistance is persuasive, underscoring the need to implement a set of measures ushering to rational antibiotic therapy. It must be based on an adequate selection of antibacterial agents, a relevant duration of their administration and a suitable route of administration. The proper identification of the

bacterial pathogen, assessing the germ's prevalence and their resistance to antibiotics is the basis for developing local guidelines for initial antibiotic therapy [30]. From a total of 92 samples, *E. coli* (18.47%) was the most common organism isolated, followed by *Pseudomonas aeruginosa* (16.30%) and *Enterococcus faecalis* (15.21%), as shown in Table I.

Table I

Distribution pattern of bacterial isolates and MDR germs

Isolated bacteria	n	%	MDR n (%)
Acinetobacter baumannii	7	7.60	7 (100%)
Corynebacterium striatum	2	2.17	2 (100%)
Enterobacter cloacae	1	1.08	0
Enterococcus faecalis	14	15.21	0
Enterococcus faecium	4	4.34	0
Enterococcus spp	1	1.08	0
Escherichia coli	17	18.47	13 (76.47%)
Klebsiella oxytoca	1	1.08	0
Klebsiella pneumoniae	9	9.78	8 (88.88%)
Morganella morganii	1	1.08	0
Proteus mirabilis	7	7.60	3 (42.85%)
Pseudomonas aeruginosa	15	16.30	5 (33.33%)
Serratia marcescens	2	2.17	0
Staphylococcus aureus	6	6.52	4 (66.66%)
Staphylococcus aureus MRSA	1	1.08	1 (100%)
Staphylococcus spp	2	2.17	2 (100%)
Achromobacter xylosoxidans	1	1.08	-
Alcaligenes faecalis	1	1.08	-
Total	**92**	**100**	**45 (48.91%)**

A study reviewing surveillance of SSI from hospitalized patients and also from the out-patient department reported isolated germs as *Acinetobacter baumannii*, *E. Coli* and *Klebsiella* (from hospitalized patients) and *E. Coli* and *Pseudomonas aeruginosa* (from the out-patient department) [6]. 883 germs isolated from SSIs in a study from Japan encompassed *E. faecalis* (19.3%), *S. aureus* (18.1%), *E. coli* (17.2%) and *P. aeruginosa* (15.4%) [43].

A recent report from 12 hospitals in Ethiopia collected biological specimens from SSIs, and the most common germ isolated was *E. coli* (23.1%), followed by multi-drug resistant *Acinetobacter* species. Pan-antibiotic resistance among *E. coli* was about 12.5% and among *Acinetobacter* species, 34.8% [15].

Regarding MDR (multi-drug resistant) pathogens in our study, the analysed data highlighted: 13/17 *E. Coli* samples (76.47%), 7/7 of *Acinetobacter baumannii*, 5/15 of *Pseudomonas aeruginosa* (33.33%), 8/9 of *Klebsiella pneumoniae* (88.88%), 3/7 of *Proteus mirabilis* (42.86%), 4/6 of *Staphylococcus aureus* (66.66%), 1 *Staphylococcus* MRSA, 2/2 *Corynebacterium striatum* and 2/2 of *Staphylococcus* spp. We also encountered two types of pathogens (*Achromobacter xylosoxidans* and *Alcaligenes faecalis*) with no standardized antibiogram in our laboratory. The distribution of germs and MDR strains are presented in Table I. Our results are consistent with Hedaoo *et al*., the most frequent pathogens were *Klebsiella* spp. (24%), *S. aureus* (20%), *E. coli* (15%) and *P. aeruginosa* (13%) [25]. A cohort in the Czech Republic, evaluating infected wounds, raised the antibiotic resistance topic exposing the alarming trend of increasing numbers of MDR strains [30]. The analysed data in our study did not meet pan-antibiotic resistance.

E. coli showed the highest resistance to cephalosporins (76.47% ceftazidime, 64.70% cefuroxime and 41.17% ceftriaxone), fluoroquinolones (64.70% levofloxacin) and aminopenicillins (82.35% to ampicillin). The literature reports *E. coli* as one of the most common pathogens isolated from SSIs [6].

In a study from Ethiopia, the resistance rates for *E. coli* were described as 83.3% to cefotaxime (our study registered a lower rate, 35.29%), 70.8% to ceftazidime, 95.8% – ampicillin, 83.3% – ceftriaxone and 87.5% for cefuroxime [15]. Another study from Southern China, which analysed complicated skin and soft infections, pointed out strains of *E. coli* showing resistance to ampicillin (96.15% in 2009 - 2010 and 100% in 2011 - 2013), ceftriaxone, ceftazidime and cefepime (each above 80%) [33]. In Japan, low rates of *E. coli* susceptibility were reported to sulbactam/ampicillin (69.7%), cefazolin (63.2%) and ciprofloxacin (73.0%) [43].

Overall, we report lower resistance rates for ampicillin, fluoroquinolones and cephalosporins. For *E. coli* infection, cephalosporines are widely used as a treatment in our hospital, therefore the high rates of resistance. Recent studies have noted a high percentage of gentamicin-resistant (> 60%), 3rd cephalosporin-resistant (> 50%) and fluoroquinolone-resistant (> 50%) *E. coli*, data also retrieved in our study, except the rates for gentamicin, which were lower, 41.17% [25, 30].

Acinetobacter baumannii proved a high level of resistance (100%) to amikacin, fluoroquinolones, carbapenems and cotrimoxazole (7/7 samples). Our alarming analysed data is confirmed by other 3 studies [6, 15, 24]. For instance, surveys from Pakistan and India revealed high resistance rates for *Acinetobacter* species, even pan-antibiotic [7, 42]. A particular aspect of our study is represented by the high sensibility of *Acinetobacter* to polymyxins (100%), in contradiction with a current rising trend of *Acinetobacter* colistin-resistant, with high mortality rates [18].

Acinetobacter baumannii is known to be resistant to most available antibiotics, probably due to its characteristic to survive on dry surfaces for weeks that promotes transmission from fomites [15]. Resistance to amino-glycosides is extensively evaluated in studies, showing 81% to amikacin and 86% to gentamicin [2]. We found alarmingly higher rates, 100% resistance to amikacin and 85.71% to gentamicin.

Analysing susceptibility/resistance rates for *Klebsiella pneumoniae*, the following concerning data about resistance was noted: amoxicillin/clavulanic acid

and ceftazidime 88.88% each, cefotaxime 66.66%, cefuroxime 100%, ampicillin 11.11%; amikacin showed 77.77% sensibility, ceftazidime/avibactam 55.55% sensibility and 88.88% for carbapenems. Other research detected resistance rates to amoxicillin and ampicillin of 100% each, ceftriaxone 90%, cefotaxime 70%, cefuroxime 60%, ceftazidime 80% with rates of success to gentamicin 60%, ciprofloxacin 80%, tetracycline 70% [15]. Rates of high resistance to ampicillin were also found, alongside sulbactam, ceftazidime and gentamicin (> 50% each) in Southern China, successfully treated with carbapenems [33].

Ampicillin-resistant *Klebsiella pneumoniae* is infrequent, whereas cefuroxime-resistant *Klebsiella* shows higher rates (which can be accountable for our single-dose intraoperative antibiotic prophylaxis, therefore the higher rates of resistance). Cefotaxime and ceftazidime resistance rates were far above 50% each in our study and literature. Susceptibility to carbapenems and aminoglycosides, also sustained by our research, represent a treatment pathway.

The second most prevalent pathogen analysed in our study was represented by *Pseudomonas aeruginosa*, with the following rates of resistance: piperacillin/tazobactam, ceftazidime and gentamicin 40% each, 73.33% for levofloxacin, 33.33% for amikacin and carbapenems. Our findings concur with many studies regarding the resistance to gentamicin and cephalosporins [25]. For instance, a recent research evaluated the rates of meropenem-resistant (24.4%), ceftazidime-resistant (18.9%), ciprofloxacin-resistant (31.7%), piperacillin/tazobactam-resistant (24.2%) and gentamicin-resistant (19.7%) *P. aeruginosa*, whereas the results in our study were significantly higher (meropenem 33.33%, ceftazidime 40%, 73.33% resistance for levofloxacin, piperacillin/tazobactam 33.33% and gentamicin 33.33%) [30].

33.33% of our *Pseudomonas aeruginosa* germs were MDR, a result consistent with recent studies. Due to MDR *P. aeruginosa* higher prevalence, antibiotics such as colistin are revived. Recent studies showed that colistin-resistant *P. aeruginosa* is emerging in different geographical regions due to different treatment strategies [23]. In our study, all *Pseudomonas aeruginosa* strains tested for colistin were susceptible.

Proteus mirabilis, known for HAI, was examined in 7 samples. Three of them were MDR and showed 100% susceptibility to ceftazidime and carbapenems, with 42.85% resistance to gentamicin. Resistance to gentamicin was also confirmed in other reports [44]. *Proteus mirabilis* is the 4th cause of urinary tract infections in women [38] and males [12], and like other germs, their resistance to antimicrobials increases drastically [37]. A recent study evaluated its resistance regarding forming biofilms – stable biofilms mean higher resistance [21]. Studies in Ghana have confirmed the resistance of *Proteus mirabilis* to cotrimoxazole (81%) and ampicillin (77%) [20], different data from ours: cotrimoxazole 71.42% and ampicillin 28.57%. Regarding ciprofloxacin-resistant *P. mirabilis*, a study revealed a rate of 40% [31]. We report significantly lower rates, of 14.28%.

Corynebacterium is an underappreciated pathogen that can be found in SSIs. As reviewed previously, it is associated with diabetic foot, also confirmed in our study (1 of 2 cases). This pathogen is known as "hard to grow" in laboratories and considered as a contaminated sample when associated with a diabetic foot. Many studies describe our previous understanding of which bacteria cause SSIs as faulty due to culture-based diagnosis limits, especially that they cannot identify biofilms. They raise the importance of modern molecular techniques and discover new *Bacteroides* as contributors to SSIs [8].

The literature describes *Staphylococcus* species as dominant in HAI [4, 25], but other bacterial pathogens are ready to overtake. Many hospitals developed measures to prevent colonization with preoperative "bundles", adapted to each surgical specialty and patient risk factors. This "bundle" method is a step to decrease SSIs, thus becoming a routine. For example, a colorectal "bundle" reduced SSIs from 4.9% to 1.6% after initialization [4].

The lower prevalence of MRSA in this study can be explained by the fact that hospitals differ in facilities and medical care. MRSA infections represent a considerable number of HAI, and literature suggested throughout time vancomycin and linezolid as leading empirical treatment, with favourable outcome [33]. The economic burden is instead appropriate. In 2009 a study underlined that the cost of the antibiotic represents in the case of linezolid ≈ 20% of the total and 11% in vancomycin cases [34]. In our study *Staphylococcus* MRSA was susceptible to vancomycin, gentamicin, levofloxacin and linezolid.

Table II

Gram-negative and Gram-positive germs distribution

Gram negative (67.39%)	**Gram positive** (32.60%)
Achromobacter xylosoxidans	*Corynebacterium striatum*
Acinetobacter baumannii	*Enterococcus faecalis*
Alcaligenes faecalis	*Enterococcus faecium*
Enterobacter cloacae	*Enterococcus* spp
Escherichia coli	*Staphylococcus aureus*
Klebsiella oxytoca	*Staphylococcus aureus* MRSA
Klebsiella pneumoniae	*Staphylococcus* spp
Morganella morganii	
Proteus mirabilis	
Pseudomonas aeruginosa	
Serratia marcescens	

The current literature reflects Gram-negative and anaerobic bacteria's predominance in SSIs [29, 35], also confirmed by our study. Table II presents the distribution of Gram-positive and negative germs from our research: 7 Gram-positive (30 isolates) and 11

Gram-negative (62 isolates). Gram-negatives can survive on fomites for months. *Acinetobacter* is found mainly in Intensive Care Units [22].

We report as the most effective antibacterial agents against Gram-positive: vancomycin, gentamicin and linezolid. This data was also confirmed by other studies [27]. 36/62 (58.06%) Gram-negative pathogens were MDR Colistin and relatively gentamicin and ciprofloxacin were effective antibiotics against Gram-negative pathogens associated with SSIs, consistent with other studies [15].

Gentamicin proved to be a relatively good option for some pathogens in our study (> 50% rate of susceptibility). We acknowledge a susceptibility rate of 58.82% for *E. coli* (10/17 samples), 92.85% for *Enterococcus faecalis* (13/14 samples), *Proteus mirabilis* (57.16%; 4/7), *Pseudomonas aeruginosa* (60%; 9/15), 100% to *Staphylococcus aureus*, *Staphylococcus aureus* MRSA and *Staphylococcus* spp. *Klebsiella pneumoniae* had a lower rate of susceptibility to gentamicin (33.33%; 3/9) and *Acinetobacter baumannii* proved highly resistant (85.71%; 6/7 samples). Safe to say, gentamicin is still a good option for Gram-positive germs, not so good on MDR germs and preferably not as the primary treatment on Gram-negative germs.

Carbapenems showed 100% resistance in the case of *Acinetobacter baumannii* (7/7 samples). Still, we report 100% susceptibility for *E. coli* (17/17 samples) and *Proteus mirabilis* (7/7), 88.88% for *Klebsiella pneumoniae* (8/9), 66.66% in the case of *Pseudomonas aeruginosa* (10/15). Data analysed suggest carbapenems as a valid option, even in some MDR germs infections, but fell as an option for *Acinetobacter baumannii*, as multiple studies raised awareness. For *Acinetobacter baumannii*, colistin represents in our study a stain of hope in treating this MDR germ infections, data consistent with other studies [1, 19]. Also, we found susceptibility in all samples of *Pseudomonas aeruginosa* tested for colistin.

Linezolid is a capable antimicrobial agent for MRSA and spp., *Staphylococcus aureus*, *Corynebacterium striatum*, *Enterococcus faecalis* and *Enterococcus* spp, which showed susceptibility in all samples tested in our study, consistent with the literature [27, 33].

Cephalosporines (different classes) proved a low rate of susceptibility for *E. coli* (11.76%) and *Klebsiella pneumoniae* (11.11%), but still susceptible for *Proteus mirabilis* (100%), *Serratia marcescens* (100%; 2/2 samples), *Morganella morganii* (1/1), *Pseudomonas aeruginosa* (60%; 9/15).

Ampicillin showed a low susceptibility rate in the case of *E. coli* (11.76%; 2/17 samples), but still represents an option in treating *Enterococcus faecalis* infections – 92.85% rate of susceptibility.

Fluoroquinolones tipped the scales toward resistance to many germs, including *Acinetobacter baumannii* (100%), *E. coli* (64.70%), *Klebsiella pneumoniae* (77.77%), *Proteus mirabilis* (57.14%), *Pseudomonas aeruginosa* (73.33%). It is still efficient against *Staphylococcus aureus* (100%).

Vancomycin was potent in all *Enterococcus faecalis*, *Corynebacterium striatum*, *Enterococcus faecium*, *Enterococcus* spp, *Staphylococcus aureus*, MRSA and spp. samples tested for antimicrobial susceptibility.

Table III presents the overall germs' susceptibility and resistance to antibiotics – a total of 90 cases, excluding the two germs with non-standardized antibiogram. Vancomycin, linezolid and ceftazidime-avibactam rank in the first place with 100% susceptibility, the last two with low testing rates. The successive positions are occupied by colistin (94.73%), ertapenem (92.10%), meropenem (78.33%) and amikacin (74.07%). Considering the percentage of tested/non-tested antibiotics for these pathogens, we cannot disregard gentamicin with only a 63.63% susceptibility rate. However, it was tested in all, but 2 of the 90 cases, which raises it among the top. Third-generation cephalosporins display an increasing resistance rate (68.96% for cefuroxime) and levofloxacin (60.60%) with a 74.44% testing quota.

The susceptibility for colistin (94.73%) and linezolid (100%) is very reassuring. Still, these were tested for few pathogens – 21.11% for colistin and 13.33% for linezolid. As described in the literature and stated in this study, they remain a successful HAI tool, as "last resort" antibiotics. We must not forget that the price of 1 vial of colistin is around 24$ [46], while an intravenous treatment course with linezolid is about $537 for a supply of 3000 mL [46].

Knowledge of bacterial patterns and their antibiotic susceptibility is required in each medical field. SSIs are a reality of many interventions, complicating the post-operative evolution and demanding a straightforward solution. The time-lapse between collecting the specimens from the surgical sites and obtaining the germ species and the antimicrobial pattern must be covered with a therapeutic agent. An efficient treatment involves comprehension of the local microbial resistance to antibiotics. To our understanding, this is the first study to analyse the spectrum and antibiotic susceptibility of germs colonizing surgical sites dehiscence in Romania.

Bacteria have the ability to form biofilms, and through it, can exert antimicrobial resistance alongside other mechanisms. It produces an extracellular polymeric matrix that encases surface-attached bacteria. This biofilm's main characteristic is the increased resistance towards a wide range of stressors (the immune system, disinfectants and antibiotics). An essential mechanism between biofilm bacteria and free-living planktonic bacteria is persistence – a transient tolerance state in which the antibiotic resilience is not genetic, but persists within a susceptible population [5, 28, 41].

Table III

The susceptibility profiles of the microorganisms studied

Antibiotics	Sensitive		Resistant		Not tested
	n	%	n	%	n (%)
Amikacin	40	**74.07%**	14	25.92%	36 (40%)
Amoxicillin-clavulanic acid	14	41.17%	20	**58.82%**	56 (62.22%)
Ampicillin	21	51.21%	20	48.78%	49 (54.44%)
Cefotaxime	2	14.28%	12	**85.71%**	76 (84.44%)
Ceftazidime	27	50%	27	50%	36 (40%)
Ceftazidime-avibactam	5	**100%**	0	0%	85 (94.44%)
Ceftriaxone	9	50%	9	50%	72 (80%)
Cefuroxime	9	31.03%	20	**68.96%**	61 (67.77%)
Ciprofloxacin	2	18.18%	9	**81.81%**	79 (87.77%)
Colistin	18	**94.73%**	1	5.26%	71 (78.88%)
Co-trimoxazole	26	49.05%	27	50.94%	37 (41.11%)
Ertapenem	35	**92.10%**	3	7.89%	52 (57.77%)
Gentamicin	56	63.63%	32	**36.36%**	**2 (2.22%)**
Imipenem	24	64.86%	13	35.13%	53 (58.88%)
Levofloxacin	26	39.39%	40	**60.60%**	24 (26.66%)
Linezolid	12	**100%**	0	0	78 (86.66%)
Meropenem	47	**78.33%**	13	21.66%	30 (33.33%)
Minocycline	5	71.42%	2	28.57%	83 (92.22%)
Moxifloxacin	0	0	2	100%	88 (97.77%)
Oxacillin	1	12.5%	7	87.5%	82 (91.11%)
Penicillin	0	0	2	**100%**	88 (97.77%)
Piperacillin-tazobactam	9	60%	6	40%	75 (83.33%)
Rifampicin	8	80%	2	20%	80 (88.88%)
Teicoplanin	19	100%	0	0	71 (78.88%)
Tetracycline	0	0	2	100%	88 (97.77%)
Tigecycline	10	76.92%	3	23.07%	77 (85.55%)
Tobramycin	3	50%	3	50%	84 (93.33%)
Vancomycin	26	**100%**	0	0	64 (71.11%)

Clinical diagnosis of SSIs is based on the signs of inflammation at the surgical site (*rubor*, *calor*, *tumor*, *dolor*) and sometimes *fluor* (discharge: pus, serous, non-purulent). If the *per primam* closure fails, the surgical site is dehiscent and prone to infection. The CDC (Centers for Disease Control and Prevention) defines SSIs as an infection within 30 days of surgical intervention [45].

Risk factors for SSI [4, 32, 45]: *Regarding the patient*: (i) Modifiable: glycaemic control and diabetic status, dyspnoea, alcohol and smoking status, obesity (BMI > 35 kg/m^2 or subcutaneous tissue more generous than 2 cm), immunosuppression; (ii) Non-modifiable: age, recent radiotherapy, history of skin and soft tissues infections, sex (males tend to have a higher risk [9]); *Regarding the procedure*: type of intervention, facility (inadequate ventilation, increased traffic in the operating room and inappropriate sterilization of equipment), longer duration of surgery [9, 11].

Long-term blood glucose control and SSIs risk were linked a long time ago, with conflicting results. Recent studies highlighted that glycated haemoglobin is not correlated with SSIs risk, as it was believed. Instead, perioperative hyperglycaemia is significant in diabetics or nondiabetics [4]: serum glucose 110 - 150 mg/dL lowers the risk for SSI.

Bacterial resistance is a significant health problem, with alarmingly increasing rates, especially comparing with the gradual decline in antibiotic discoveries, leading to an antimicrobial resistance crisis [13, 26]. Changes in financial models could translate better the scientific advances of antimicrobial agents into clinically approved antibiotics [17].

Discovering new antibiotics requires financial support and at the same time treating MDR germs implies another financial support. The void in antibiotic discovery should be filled by clinical trials for novel models of antimicrobial agents. As our study highlights, the necessity is overwhelming and treatment options are closing at an unexpected rate. We consider recommendable the current knowledge of SSIs' resistance patterns to ensure proper empirical treatment until the timely therapy according to germ's susceptibility.

Conclusions

E. coli is primarily responsible for SSIs; 76.46% are MDR pathogens. *Pseudomonas aeruginosa* ranked second, with 33.33% MDR strains. As expected, *Acinetobacter baumannii* analysed in our study demonstrated 100% MDR strains, but it displayed high susceptibility to colistin.

The most effective antibiotics *per* total number of germs are gentamicin (63.63%), carbapenems (ertapenem 92.10% and meropenem 78.33%) and amikacin (74.07%). They represent valuable treatments for *E. coli* and *Pseudomonas aeruginosa*.

Our study reflects a high number of MDR germs, as literature tries to raise awareness.

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Conflict of interest

The authors declare no conflict of interest.

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