THE IMPACT OF THE TYPES OF MICROORGANISMS ISOLATED FROM BLOOD AND WOUNDS ON THE RESULTS OF TREATMENT IN BURN PATIENTS WITH SEPSIS

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Despite development of combustiology, infections continue to be the most important cause of death among patients with burns. Sepsis is the most severe clinical presentation of infection in patients after thermal injuries who require immediate treatment. Early diagnosis and proper treatment of sepsis are important in the clinical management that is often hampered for multiple reasons, e.g. impaired patient immunity, problems with microorganisms with multi-antibacterial drug resistance.

The aim of the study was to assess effect of type of a microorganism isolated from blood and wound on results of treatment of sepsis in patients with burns.

Material and methods. Effect of type of microorganisms isolated from blood and wound on the result of treatment of sepsis was studied in 338 patients hospitalized immediately after an injury in Centre for Burn Treatment in Siemianowice Śląskie in years 2003 – 2004 (at the age of 18 – 96 years, 66 women and 272 men). Clinical symptoms of generalized infection were found in all study subjects. The study group was divided into two subgroups: cured patients and patients who died of sepsis. The following parameters were assessed in both subgroups: type of microorganism isolated from blood, type of microorganism isolated from wound as well as occurrence of the same and different infections of blood and burn wound.

Results. Positive blood cultures were found in 165 patients (48.8%), 106 (64.2%) were cured, 59 (35.8%) died. The most commonly isolated microorganisms in cured patients were Gram(+) Staphylococcus epidermidis MRSE (19.81%) and Staphylococcus aureus MRSA (18.87%). Gram(–) intestinal rods were least commonly isolated from this group. The most commonly isolated microorganisms from blood of patients who were to die, included non-fermenting Gram(–) rods Acinetobacter baumanii (35.59%) and Pseudomonas aeruginosa (22.03%). Mixed bacterial flora was found in the blood of 22.03% patients. Among patients who were to die, the same microorganisms were found in the blood and in the wound in 32.2% of patients, while this rate was 17.92 in cured patients. The most commonly found bacteria in the blood and burn wound in the cured patients included Staphylococcus aureus MRSA (31.58%) and Staphylococcus aureus (21.05%). In the group of patients who were to die, the most common bacterial isolated simultaneously from the blood and burn wound included Acinetobacter baumanii (47.37%) and Pseudomonas aeruginosa (36.84%).

Conclusions. 1. The patients with thermal injuries are at higher risk of death in the event of sepsis caused by Gram(–) bacteria versus Gram(+) bacteria. 2. Infection of blood and burn wound caused by the same bacteria Pseudomonas aeruginosa and Acinetobacter baumanii increases the risk of death due to sepsis in patients with burns following thermal injuries.

Key words: burns, sepsis, burn wound infections, blood infection
The reasons why infection is a significant factor that complicates the management of burn patients include the decreased immunity following the burn injury, the presence of multiple gateways for infection and the multidrug resistance of the offending microorganisms (1). Exposure of large areas of subcutaneous tissue, impairment of both local and systemic defences, the presence of exudate or necrotic debris in the wound, subcutaneous thrombosis and the resulting ischaemia and hypoxia of the burned surface all promote a rapid growth of bacteria in the wound already in the first few days. In the first week post-injury the burn wound is colonised by gram-positive cocci, i.e. Staphylococcus aureus or Streptococcus pyogenes. From the beginning of week two a shift in the type of colonising flora to Gram-negative microorganisms is observed (2). When the number of microorganisms in the burn wound becomes sufficiently high as a result of proliferation, invasion of deeper tissues begins. If the microorganisms enter lymphatic or blood vessels (following a surgical intervention – demarcation of necrotic debris colonised by microorganisms), sepsis may develop, which considerably worsens the prognosis, particularly if caused by a multidrug resistant Gram-negative flora.

Sepsis is the most severe clinical form of infection in burn patients and requires immediate treatment. Mortality rates in patients with bloodstream infection managed at teaching hospital departments may reach 20-50%. The difficulties in establishing the diagnosis of sepsis in thermal injury patients also stem from the presence of systemic inflammatory response syndrome (SIRS) whose manifestations are very similar to those of sepsis (3-7). The key to a successful antibiotic therapy in sepsis is the isolation of the causative factor from the blood (blood cultures). In the recent decade or two, many improvements have been made in blood culture procedures, shortening of the time to detection and identification of the pathogens (8, 9). Not all of the difficulties encountered by clinicians could, however, be eliminated. There is an increasing prevalence of sepsis caused by multiple microorganisms in burn patients (mixed or alternating infections). Positive blood cultures in cases of clinically confirmed sepsis continue to account for a mere 40-80% of all cultures. In most cases, bacteria are only transiently present in the blood, which reduces the chances of blood culture positivity. The presence of a transient bacteraemia, which the body is capable of fighting, is not synonymous with the diagnosis of sepsis. Microbiological evaluation of blood samples may yield false negative results if blood is sampled outside the period of microorganism seeding and false positive ones if the samples are contaminated with microorganisms that colonise the patient’s skin (10).

A positive result often arrives at the ward too late anyway, hence the necessity to initiate empirical antibiotic therapy in thermal injury patients if sepsis is being suspected. Such empirical therapy should include at least one agent showing activity against the probable pathogens. The selection of antibiotics to be included in the empirical regimen should be based on multiple patient-related factors (general condition, including – among others – renal function, concentration of albumins as carriers of antibacterial drugs) and the familiarity with data on susceptibility of microorganisms specific for the department in question providing treatment to burn patients (11, 12, 13).

There are reports confirming that failure to institute antimicrobial treatment sufficiently early adversely affects the outcomes of treatment and increases mortality in burn patients (14, 15). Gram-positive microorganisms: Staphylococcus aureus and Staphylococcus epidermidis, are most commonly isolated from blood from burn patients (based on our own experience).

Non-fermenting Gram-negative bacilli: Pseudomonas aeruginosa and Acinetobacter baumannii, are another group of microorganisms isolated from burn patients’ blood. These microorganisms are particularly dangerous due to the lipopolysaccharide (LPS) incorporated in their cell walls. In severe infections, the presence of LPS-producing bacteria in the blood poses a significant threat to the patient’s life.

Pseudomonas aeruginosa is an opportunistic microorganism which causes infections in immunocompromised patients. Mortality rates in sepsis caused by Non-fermenting gram-negative range from 38% to 96% and exceed those in sepsis caused by other Gram-negative rods (16). Many factors are responsible for the virulence of Pseudomonas aeruginosa, including: proteases, cytotoxins, phospholipases,
Capsular polysaccharides and LPS, which facilitate colonisation, penetration and survival despite host defences (17, 18).

The aim of the study was to determine the impact of the types of microorganisms isolated from blood and wounds on the result of treatment in burn patients with sepsis.

MATERIAL AND METHODS

We retrospectively analysed hospital notes of 388 patients admitted directly after sustaining a thermal injury to the Centre for Burn Treatment in Siemianowice Śląskie, Poland, between 2003 and 2004. The age of the patients ranged from 18 to 96 years (mean age: 44 years) and the study population consisted of 272 men and 66 women. All the patients had clinical manifestations of systemic infection, which was defined as the presence of at least two of the following clinical abnormalities: a body temperature greater than 38°C or less than 36°C, a heart rate greater than 90 beats per minute, a respiratory rate greater than 20 breaths per minute or a PaCO₂ of less than 32 mm Hg, a white blood cell count greater than 12,000/mm³ or less than 4,000/mm³ or the presence of more than 10% of bands in differential blood cell count. A total of 2456 blood samples were collected in all the patients (fig. 1).

The collected blood was analysed with BACTEC 9050 and after an additional sample was obtained it was cultured on standard media. When the bacterial strain had been identified, its susceptibility was tested using the disk diffusion method. At the same time, swabs were collected from the burn wounds and the material was transferred onto Stuart transport media and then cultured on appropriate media. The isolated microorganisms were characterised qualitatively and semi-quantitatively with their growth being rated as modest (+), abundant (++) and very abundant (+++). Identification of strains was followed by sensitivity testing.

From day one following the burn injury all the patients received co-amoxiclav preventively at a daily dose based on age, body mass and co-morbidities. In patients who developed clinical manifestations of sepsis despite the prophylactic antibiotic therapy, blood cultures were obtained. If the blood cultures came back negative, empirical therapy was given and if no clinical improvement was seen within 72 hours, further blood cultures were obtained, collecting the blood just before administration of the next dose of the antibiotic. If the blood

![Fig. 1. The structure of the patients included in the retrospective analysis](image)
Microorganisms isolated from blood and wounds in burn patients with sepsis

cultures came back positive, the patient was switched to an antibiotic the cultured strains had been shown to be susceptible to. In mixed blood infections, synergic combinations of antibiotics were given.

The study population was divided into two subgroups:
- cured patients,
- patients who died from sepsis or its sequelae.

The following were assessed in both subgroups:
- type of microorganism isolated from the blood,
- type of microorganism isolated from the burn wound,
- simultaneous presence of the same microorganisms in the blood and in the burn wound.

The subgroups of cured patients and patients who died from sepsis were also analysed in terms of the types of microorganisms isolated from the blood and the burn wound as follows:
1. Pseudomonas aeruginosa,
2. Acinetobacter baumannii,
3. Staphylococcus aureus,
4. Methicillin-resistant Staphylococcus aureus (MRSA),
5. Methicillin-resistant Staphylococcus epidermidis (MRSE),
6. Klebsiella pneumoniae,
7. Proteus mirabilis,
8. Enterococcus faecalis,
9. Enterobacter cloacae,
10. Candida albicans,
11. Streptococcus pneumoniae,
12. Escherichia coli,

The statistical analyses were conducted using Microsoft Excel and Statistica for Windows ver. 7.0.

The statistical analysis of the data involved the calculation of the percentage of cured patients and the percentage of deceased patients, followed by the calculation of the percentages of individual parameters, such as the type of microorganisms isolated from the blood and the burn wound and the outcomes of sepsis in terms of cure or death.

The relationships between the investigated parameters were assessed using Pearson’s chi-square test of independence. For small samples the adjusted chi-square test of independence with Yates’ correction was used. In addition, in order to assess significant differences between the frequencies (expressed as percentages) of individual parameters in the subgroups the test for two structure indices for large and small samples was used.

RESULTS

In the subgroup of cured patients, Gram-positive microorganisms, namely MRSE (19.71%) and MRSA (18.87%), were most commonly isolated from the blood, while Gram-negative enterobacteria were the least common isolates: Proteus mirabilis (0.94%) and Enterobacter cloacae (0.94%). No Klebsiella pneumoniae was identified in the blood from this subgroup of patients.

In the subgroup of deceased patients, non-fermenting Gram-negative rods were most commonly isolated from the blood: Acinetobacter baumannii (35.59%) and Pseudomonas aeruginosa (22.03%). Mixed flora was also commonly isolated from the blood of these patients (22.03%).

The least common isolates were Enterococcus faecalis (1.69%), Candida albicans (1.69%) and Streptococcus pneumoniae (1.69%). Blood cultures in none of these patients revealed Klebsiella pneumoniae, Enterobacter cloacae or Escherichia coli.

In all the patients (those cured and those deceased), mixed bacterial flora (i.e. more than one microorganism) was most commonly isolated (42.4% and 45.1% in cured and deceased patients, respectively). In the subgroup of cured patients, MRSA together with Pseudomonas aeruginosa accounted for 16.04% of all the pathogens isolated from the wounds.

In the subgroup of patients who died as a result of sepsis, Acinetobacter baumannii was present in burn wounds in 22.1% of the patients and Pseudomonas aeruginosa in 18.6% of the patients. In these patients, Staphylococcus aureus together with MRSA were isolated from the wounds in 5.1% of the patients.

Another criterion against which all the patients in both subgroups were analysed was the simultaneous presence of the same versus different microorganisms in the blood and in the burn wound. In both subgroups of patients, the presence of different microorganisms in the blood and in the burn wound was observed more commonly. IN the group of deceased
patients, the presence of the same microorganisms in the blood and in the burn wound was more common than in the group of cured patients (32.20% versus 17.92%).

In the subgroup of cured patients, simultaneous presence of MRSA (31.58%) and Staphylococcus aureus (21.05%) was most common in the blood and in the burn wound.

In the subgroup of deceased patients, simultaneous presence of Acinetobacter baumannii (47.37%) and Pseudomonas aeruginosa (36.84%) was most common in the blood and in the burn wound.

Type of microorganisms and the outcome of sepsis (cure/death)

We examined the relationship between the type of microorganisms isolated from the blood and their impact on the outcome of sepsis in terms of cure or death.

Using the chi-square test we found a statistically significant relationship between the type of microorganisms and the outcome of sepsis ($\chi^2=29.96$, p<0.05).

In addition, based on the test for two structure indices at the significance level of $p<0.05$, it could be concluded that the highest death rate was present if Gram-negative microorganisms are isolated from the blood and the highest cure rate was observed in Gram-positive sepsis (tab. 1).

An analysis of the most common gram-positive and Gram-negative microorganisms present in the blood

Staphylococcus aureus

When we analysed the relationship between one of the Gram-positive microorganisms most commonly isolated from the blood, namely Staphylococcus aureus, and the outcome of treatment we concluded, using the test for two structure indices, that cure was significantly more common than death if Staphylococcus aureus was isolated from the blood. At the same time, there were significantly more deaths if microorganisms other than Staphylococcus aureus were isolated from the blood (tab. 2).

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>n</th>
<th>Outcome</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>cure</td>
<td>death</td>
<td></td>
</tr>
<tr>
<td>Gram-negative*</td>
<td>64</td>
<td>28</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>frequency (%)</td>
<td>43.7</td>
<td>56.2</td>
</tr>
<tr>
<td>Gram-positive**</td>
<td>71</td>
<td>62</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>frequency (%)</td>
<td>87.3</td>
<td>12.7</td>
</tr>
<tr>
<td>Mixed infection***</td>
<td>27</td>
<td>14</td>
<td>13</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>frequency (%)</td>
<td>51.8</td>
<td>48.2</td>
</tr>
<tr>
<td>Fungi</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>frequency (%)</td>
<td>66.7</td>
<td>33.3</td>
</tr>
</tbody>
</table>

* Pseudomonas aeruginosa, Acinetobacter baumannii, Klebsiella pneumoniae, Proteus mirabilis, Escherichia coli, Enterobacter cloacae
** Staphylococcus aureus, Staphylococcus epidermidis, methicillin-resistant Staphylococcus aureus (MRSA), methicillin-resistant Staphylococcus epidermidis (MRSE), Enterococcus faecalis, Streptococcus pneumoniae
*** Co-existence of Gram-positive and Gram-negative microorganisms

<table>
<thead>
<tr>
<th>Staphylococcus aureus</th>
<th>n</th>
<th>Outcome</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Present in the blood</td>
<td>14</td>
<td>14</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Absent in the blood</td>
<td>151</td>
<td>92</td>
<td>59</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Staphylococcus aureus</th>
<th>n</th>
<th>Outcome</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Present in the blood</td>
<td>14</td>
<td>14</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Absent in the blood</td>
<td>151</td>
<td>92</td>
<td>59</td>
<td></td>
</tr>
</tbody>
</table>
Methicillin-resistant Staphylococcus aureus (MRSA)

When we analysed the relationship between methicillin-resistant Staphylococcus aureus (MRSA) present in the blood and the outcome of treatment we concluded, using the test for two structure indices, that cure was significantly more common than death if MRSA was isolated from the blood. At the same time, there were significantly more deaths if microorganisms other than MRSA were isolated from the blood (p<0.05) (tab. 3).

Acinetobacter baumannii

The analysis of the relationship between the presence of Acinetobacter baumannii in the blood and the outcome of sepsis in terms of cure or death demonstrated the presence of a statistically significant relationship ($\chi^2=9.16$, p<0.05). Deaths were significantly more common than cures if Acinetobacter baumannii was isolated from the blood (tab. 4).

Pseudomonas aeruginosa

There was a statistically significant relationship between the presence of Pseudomonas aeruginosa in the blood and the outcome of sepsis in terms of cure or death ($\chi^2=8.47$, p<0.05). Deaths were significantly more common than cures if Pseudomonas aeruginosa was isolated from the blood (tab. 5).

Infection of the blood and burn wound caused by the same microorganism and the outcome of sepsis

When we analysed the relationship between the outcome of treatment and the presence of infection caused by the same versus different microorganisms we found a statistically significant relationship ($\chi^2=12.03$, p<0.05). Cures

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**Table 3.** Presence of methicillin-resistant Staphylococcus aureus (MRSA) in the blood and the outcome of treatment in the group of patients with microbiologically confirmed sepsis

<table>
<thead>
<tr>
<th>Methicillin-resistant Staphylococcus aureus (MRSA)</th>
<th>n</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present in the blood</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>number (n)</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>frequency (%)</td>
<td></td>
<td>90,9</td>
</tr>
<tr>
<td>Absent in the blood</td>
<td>143</td>
<td></td>
</tr>
<tr>
<td>number (n)</td>
<td></td>
<td>86</td>
</tr>
<tr>
<td>frequency (%)</td>
<td></td>
<td>60,1</td>
</tr>
</tbody>
</table>

**Table 4.** Presence of Acinetobacter baumannii in the blood and the outcome of treatment in the group of patients with microbiologically confirmed sepsis

<table>
<thead>
<tr>
<th>Acinetobacter baumannii</th>
<th>n</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present in the blood</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>number (n)</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>frequency (%)</td>
<td></td>
<td>43,2</td>
</tr>
<tr>
<td>Absent in the blood</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>number (n)</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>frequency (%)</td>
<td></td>
<td>70,3</td>
</tr>
</tbody>
</table>

**Table 5.** Presence of Pseudomonas aeruginosa in the blood and the outcome of treatment in the group of patients with microbiologically confirmed sepsis

<table>
<thead>
<tr>
<th>Pseudomonas aeruginosa</th>
<th>n</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present in the blood</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>number (n)</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>frequency (%)</td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Absent in the blood</td>
<td>145</td>
<td></td>
</tr>
<tr>
<td>number (n)</td>
<td></td>
<td>99</td>
</tr>
<tr>
<td>frequency (%)</td>
<td></td>
<td>68,3</td>
</tr>
</tbody>
</table>
were significantly more common than deaths in the group of patients in whom the microorganisms found in the blood were different from those found in the burn wound (tab. 6).

Based on the relationship between death or cure and the presence of infection of the blood and burn wound caused by the same versus different microorganisms we analysed this relationship between the most commonly isolated Gram-positive and Gram-negative microorganisms.

The analysis of the impact of infection of the blood and burn wound caused by Pseudomonas aeruginosa and isolation of different microorganisms from the burn wound and blood on the result of treatment demonstrated the existence of the relationship ($\chi^2=10.6, p<0.05$). If Pseudomonas aeruginosa was isolated both from the blood and from the burn wound, deaths were significantly more common than cures. At the same time, deaths were significantly more common in patients with the burn wound and blood infected with Pseudomonas aeruginosa than in patients in whom the microorganisms isolated from the blood were different from those isolated from the burn wound (tab. 7).

When we analysed the impact of infection of both the burn wound and blood caused by Acinetobacter baumannii and the isolation of different microorganisms from the burn wound and blood on the result of treatment we found a significant relationship ($\chi^2=10.83, p<0.05$). If Acinetobacter baumannii was isolated both from the blood and from the burn wound, deaths were significantly more common than cures. At the same time, deaths were significantly more common in patients with the burn wound and blood infected with Acinetobacter baumannii than in patients in whom the microorganisms isolated from the blood were different from those isolated from the burn wound (tab. 8).

When we analysed the impact of infection of both the burn wound and blood caused by MRSA and the isolation of different microorganisms from the burn wound and blood on the result of treatment we found, based on the test for two structure indices ($p<0.05$), that cures were significantly more common than deaths if MRSA was isolated both from the burn wound and from the blood. At the same time, cures were significantly more common in patients with both the burn wound and blood infected with MRSA than in patients in whom the microorganisms isolated from the blood were different from those isolated from the burn wound (tab. 9).

<table>
<thead>
<tr>
<th>Table 6. Infection of the blood and burn wound caused by the same versus different microorganisms and the outcome of treatment in the group of patients with microbiologically confirmed sepsis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection type</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Infection of the burn wound and blood caused by different microorganisms</td>
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<tr>
<td></td>
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<tr>
<td>Infection of the burn wound and blood caused by the same microorganism</td>
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</table>

<table>
<thead>
<tr>
<th>Table 7. Infection of both the blood and the burn wound caused by Pseudomonas aeruginosa versus infection caused by different microorganisms and the outcome of treatment in the group of patients with microbiologically confirmed sepsis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection type</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Infection of the burn wound and blood caused by different microorganisms</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Infection of the burn wound and blood caused by the same microorganism</td>
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</table>
Early detection of sepsis and its microbiological confirmation remain the principal object of care in the management of burn patients. These efforts are aimed at implementing optimal antimicrobial treatment, which may determine the prognosis (19-23).

We analysed the clinical material of the Centre for Burn Treatment in Siemianowice Śląskie, Poland, and based on this analysis we attempted to determine the impact of the types of microorganisms isolated from the blood and the burn wound on the outcome of treatment in burn patients with sepsis, treating survival as treatment success and death as treatment failure. When we analysed the patients with microbiologically confirmed sepsis we found that Gram-positive sepsis was significantly more common in the subgroup of subsequently cured patients.

We found a statistically significant relationship between the presence of sepsis caused by Staphylococcus aureus and the outcome of treatment and between the presence of sepsis caused by MRSA and the outcome of treatment. In the case of both these microorganisms, there were significantly more cures than deaths. This is associated with multiple factors. These sepses develop at a later stage, i.e. beyond two weeks following the burn injury, when the patient’s immune system is capable of tackling the infection. Secondly, these sepses affect patients with a less severe burn injury. Thirdly, the Gram-positive microorganisms that cause these sepses do not possess such potent virulence factors as Gram-negative microorganisms. Fourthly, more extensive treatment options are available for Gram-positive bacteria than for multidrug resistant gram-negative rods, such as Pseudomonas aeruginosa or Acinetobacter baumannii (24, 25).

The lower number of sepses and deaths reported in other studies (22) may be associated with the fact that gram-positive bacteria were the only pathogens investigated with MRSA being the most numerously represented. It is believed that burn units are the main source of MRSA infections (25-29).

Our study did not confirm this, as the numbers of MRSA strains isolated from the burn wound and from the blood were not the highest. More than 50% of all the microorganisms isolated and responsible for sepsis were non-fermenting Gram-negative rods. According to other authors, Pseudomonas aeruginosa, commonly recognised as a microorganism that colonises burn wounds and causes sepsis in burn patients, has recently become less preva-
lent due to the use of effective and targeted antibiotics (30-33).

We observed a relationship between the presence of sepsis caused by Pseudomonas aeruginosa and the result of its treatment: deaths were significantly more common than cures if Pseudomonas aeruginosa was isolated from the blood, similarly to the study by Abdolaziz Lari et al. (21). This may be associated with the occurrence of sepsis caused by Pseudomonas aeruginosa resistant to multiple antibiotic classes.

In the case of another non-fermenting rod, Acinetobacter baumannii, which was often isolated from the blood and burn wounds in the patients included in our study, we found a statistically significant relationship between the occurrence of sepsis caused by this microorganism and the outcome of treatment. These findings are consistent with studies that show an increased number of cases of sepsis caused by Acinetobacter baumannii and an increased number of deaths from this cause.

Sepses caused by Acinetobacter baumannii along with all their consequences, including the increased mortality, may be associated with many factors.

Acinetobacter baumannii is a residual and endemic microorganism at our facility, particularly at the intensive care unit. These data are consistent with those by other authors, who demonstrated an increased number of sepses caused by Acinetobacter baumannii and an increased death rate due to this cause (22, 34-37).

Severely burned patients have multiple gateways for infection and often require mechanical ventilation, which is associated with a moist environment resulting from the humidification of oxygen delivered to the airways. This promotes proliferation of this microorganism as well as other procedures, such as central vein cannulation, urinary bladder catheterisation etc. Right from admission, our patients were preventively given a broad-spectrum antibiotic, which may induce the emergence of multidrug resistant strains in the hospital setting. In the presence of the above factors, which are accompanied by infection of the burn wound with the same microorganism, the prognosis as to survival in patients with sepsis caused by Acinetobacter baumannii is poor.

Another reason why the sepses caused by the non-fermenting Gram-negative rods Pseudomonas aeruginosa and Acinetobacter baumannii in our material were associated with the greatest mortality could be the presence of lipopolysaccharide (LPS) in the outer membrane. The structure of this endotoxin shows a strong relationship with the virulence of the bacteria for reasons that include the different susceptibility to phagocytosis. In severe infections, in which the body is invaded by a large number of bacteria that proliferate rapidly and produce large quantities of LPS (through activation of macrophages), large quantities of proinflammatory mediators are formed.

As a result of excessive activation and overproduction of cytokines released by macrophages and monocytes activated through immune mechanisms by the endotoxin LPS the patients may develop septic shock, which is a direct threat to the patient’s life.

The burn wound is virtually a source of all the adverse health consequences, both local and systemic. The attempt made by us to analyse the situations in which isolation of the same pathogen from the burn wound and the blood may adversely affect the outcome of sepsis showed that there was a correlation between the result of treatment and the type of infection of the burn wound and the blood. There were significantly more deaths in patients with both sepsis and burn wound infection caused by Pseudomonas aeruginosa (62.1%) than in patients in whom the microorganisms isolated form the burn wound were different than those isolated from the blood (30.1%). We obtained similar figures when we analysed Acinetobacter baumannii (a mortality rate of 61.3% in patients with both sepsis and burn wound infection caused by Pseudomonas aeruginosa and 29.9% in patients in whom the microorganisms isolated form the burn wound were different than those isolated from the blood). These data indicate that in the case of non-fermenting Gram-negative rods the source of sepsis and death from this sepsis could be the burn wound alone.

Formation of a biofilm on the burn wound is responsible for the virulence of Pseudomonas aeruginosa (38, 39). Although biofilms are best known for their role in infections associated with the presence of foreign bodies in tissues and organs, recent studies have confirmed their essential role in the pathogenesis of burn wound infections.
In this study, the burn wound with biofilm cells persisting within its structure and possessing a quorum sensing system and a system for transmission of genotypic changes resulting from the action of antiseptic agents or antibiotics will always be a source of infections spreading all over the body that is impossible to eradicate (40, 41).

The hypotheses according to which sepsis originated from the burn wound are not confirmed by the results of the analysis of wound and blood infection by MRSA, in which cases cures were significantly more common than deaths if both blood and the burn wound were infected by MRSA. Based on this result one might believe that the source of blood infection and sepsis caused by MRSA is not always the burn wound alone but other factors may be present, such as indwelling vascular catheters (as confirmed by the data obtained by Appelgren et al.) (20). Infection of both the burn wound and blood by Pseudomonas aeruginosa or by Acinetobacter baumannii is associated with a higher mortality related to sepsis. Therefore, when selecting the antibiotic in patients without a microbiological confirmation of the presence of these pathogens in the blood and in the absence of septic manifestations in patients with wound infection with non-fermenting Gram-negative rods, it should be assumed that the sepsis is being caused by the same pathogen and an effective antibiotic should be started accordingly.

CONCLUSIONS

1. In patients after thermal injury the risk of death is greater with sepsis caused by Gram-negative bacteria than with sepsis caused by Gram-positive bacteria.
2. Infection of both the blood and the burn wound by Pseudomonas aeruginosa or by Acinetobacter baumannii increases the risk of death from sepsis in burn patients after thermal injury.

REFERENCES

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