The role of antibiotic stewardship in limiting antibacterial resistance among hematology patients

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Haematologica has published European guidelines for empirical and targeted antibacterial therapy for febrile neutropenic patients in the era of emerging resistance (ECIL-4). Indeed, collateral damage by broad-spectrum antibiotic therapy includes selection of multidrug resistant pathogens, and increased predisposition to infection by fungi and Clostridium difficile. Antibiotic resistance has become a major public health concern, with fears expressed that we will soon run out of antibiotics.1

This is critically important for the management of hematologic cancer patients who receive consecutive courses of immunosuppressive treatments, resulting in varying degrees and durations of neutropenia. During immunosuppressive therapy, many patients will develop fever and are prescribed antibiotics for prevention or treatment of infection.

Several recent studies have shown an increasing prevalence of multidrug resistance among Gram-negative pathogens in hematology patients. In one recent prospective observational study, the only independent risk factors for the acquisition of multiresistant pathogens were prior antibiotic exposure (OR 3.57; 95% CI: 1.63-7.80) and urinary catheterization (OR 2.41; 95% CI: 1.01-5.74).2

The use of broad-spectrum antibiotics also is a well-known risk factor for invasive fungal infection in hematology patients. Chronic disseminated candidiasis in patients with acute leukemia and/or bone marrow transplantation has been independently associated with the use of quinolone antibiotics in particular,3 and a recent observational study showed that 92% of patients with candidemia had received broad-spectrum antibiotics.4 Important risk factors for C. difficile-associated disease in hematology patients include the number and duration of antibiotics received, with particular risk attached to certain classes, such as cephalosporins.5

For all these reasons, it is becoming more and more necessary to optimize antibiotic use in hematology patients, and to deploy antimicrobial stewardship strategies that have shown benefit in other categories of patients. Key components of stewardship include: i) de-escalation of broad empirical regimens once the pathogen is identified; ii) dose optimization in critically-ill patients;6 and iii) the long tradition of prudent antibiotic use in Northern European countries which is reflected in their low resistance rates, as shown in, for example, the European Antimicrobial Resistance Surveillance Network EARS-Net.7

Antimicrobial stewardship aims to limit the unnecessary use of broad-spectrum antibiotics and involves a continuous effort by healthcare institutions to optimize antimicrobial use in hospitalized patients. Its targets are to improve outcomes, ensure cost-effective therapy, and to reduce adverse effects of antimicrobial use, including resistance.1

Control of infection is closely related to antimicrobial stewardship programs, as it aims to prevent the spread of the resistant organisms, when these are selected locally or patient transfers. The successful implementation of antimicrobial stewardship and infection control programs complement each other in limiting the number of infections caused by multidrug-resistant organisms.

Infection control strategies found their way into hematology many years ago, and guidelines in this field are published elsewhere.7 The most important measures in hematology are: i) enforcement of hand hygiene by using alcohol-based hand-rubs; ii) standard barrier precautions; iii) enforcement of isolation criteria for patients colonized or...
infected with multidrug-resistant organisms, e.g. methi-
cillin-resistant *Staphylococcus aureus* (MRSA) or Extended-
Spectrum Beta-lactamase (ESBL)-producing organisms; iv) co-
horting of infected patients; v) the use of single rooms for
hematologic stem cell transplant (HSCT) recipients; and
vi) High-Efficiency Particulate Air (HEPA) filtration for al-
logeneic HSCT recipients. Antiseptics with alcohol-based
hand-locks is the single most effective hygienic measure in
healthcare institutions and has led to a reduction in overall
nosocomial (hospital-acquired) infection and MRSA trans-
mission.11

There are several key aspects to implementing antimic-
trobial stewardship for hematologic cancer patients. These
require collaboration between the hematologist/occlo-
gist, the microbiology laboratory, hospital pharmacy and
an infectious diseases (ID) consultation service.

4) Local surveillance of antibiotic resistance, antibiotic con-
sumption and patient outcomes, including monitoring reports.

Local surveillance in hematology/occology centers
should be carried out, with a review of the situation twice
yearly. It includes data on the identity and resistance pat-
terns of blood isolates. Indicator organisms, or a ‘top 10’
list of relevant pathogens should be defined. These are
likely to include the Gram-negative bacteria, *Escherichia
coli*, *Klebsiella*, *Pseudomonas aeruginosa*, *Enterobacter*, *Serratia*, and *Acinetobacter*, and the Gram-positives *S. aureus*, coagu-
lase-negative staphylococci, *Enterococcus* and alpha-
hemolytic streptococci. In addition, antibiotic consump-
tion should be monitored, preferably as Defined Daily
Dosages (DDD)/100 patient days or Days on Therapy
(DOT) to allow for comparisons with other centers.12 The
DOT unit is particularly useful for pediatric populations.

Policy decisions need also to be made: i) whether or not
to use antibiotic prophylaxis in certain categories of
patients; ii) the need and frequency of surveillance cultures
to detect colonization, especially when antibiotic prophy-
laxis is used.10 Good surveillance data allow for fast and
targeted adaptation of empirical regimens and/or prophy-
laxis.13 Resistance patterns of colonizing microorganisms
are often, but not always, indicative of the resistance pat-
terns of subsequent blood isolates in these patients.

Microbiological investigation of likely infections should
always be carried out, irrespective of what is known or
suspected from previous surveillance cultures. In addition,
outcome data for bacteremic patients (ICU stay, total
length of stay, total and attributable mortality) of the
hematology unit should also be collected to determine
and review the coverage and adequacy of the local empirical
antibiotic regimens. Colonization with resistant organ-
isms should impact the choice of empirical therapy regi-
mens only if these organisms have caused significant mor-
bidty and mortality in previous hematology patients.

**Table 1. Principles of antimicrobial stewardship for hematology patients.**

- The initiation of empirical antibiotic treatment should be prompted by fever and clinical signs, and not by C-reactive protein or other biomarkers, as stud-
ies of these have shown inconsistent results, antibiotics should not be initiated on the basis of colonization by resistant organisms.
- Empirical antibiotic treatment should never be started or changed before taking at least two blood cultures, along with relevant specimens from the clin-
ically-suspected sites of infection.
- Risk stratification (low/high risk) for infection should be undertaken according to the Multinational Association for Supportive Care in Cancer (MASCC)
score, and should be considered in the empirical therapy algorithm.
- The spectrum of initial empirical therapy should, at the very least, cover common virulent *Enterobacteriaceae* (*Escherichia coli* and *Klebsiella pneumo-

**Table 2. Summary of antimicrobial stewardship recommendations for hematology patients.**

1. Produce epidemiological data on blood isolates and colonization cultures (especially if prophylaxis is used) on a regular basis.
2. Record infection-related outcome data (length of stay; infection-related mortality).
3. Discuss microbiology; antibiotic use and outcome data in a local multidisciplinary working group/policy committee consisting of hematologists/ID physi-
cians/microbiologists/ID pharmacists.
4. Develop multidisciplinary protocols and algorithms on diagnosis, treatment and prophylaxis of fever during neutropenia, including on duration of therapy
for the inpatient as well as outpatient management.
5. Provide ID training for hematologists and clinical hematology training for ID physicians/microbiologists and pharmacists.
laboration with ID specialists and medical microbiologists and updated to reflect changes in bacterial antimicrobial susceptibilities in the unit.

Once the local surveillance data are available, they should be used to develop or adapt local protocols and algorithms. A few important principles to be considered are listed in Table 1.

3. Swift reporting of positive clinical cultures and implementation of rapid techniques for bacterial identification and resistance patterns by the microbiology laboratory to control the duration of treatment and to facilitate reassessment of the antibiotic therapy.

The speed of communicating microbiological results to the clinicians by the laboratory is paramount for prompt adaptation of antimicrobial regimens. Re-assessment of the clinicians by the laboratory is paramount for prompt adaptation of antimicrobial regimens. Re-assessment of empirical antimicrobial therapy with the help of the microbiological results after 2-3 days allows for de-escalation to targeted, narrower-spectrum antibiotics appropriate to the susceptibilities of the pathogens isolated. A clinical example of de-escalation strategy is shown in the Appendix and illustrates how de-escalation works in an individual patient. For details and background of the prophylaxis strategy in this example, see the method section of the publication by Slobbe et al.

Experience in the Netherlands has shown that broad-spectrum empirical therapy in neutropenic fever can also be replaced by narrower-spectrum oral agents, mitigating selection for resistance. De Marie et al. and Cornelissen et al. reported that intravenous (i.v.) antibiotics could be discontinued early in febrile patients with persistent neutropenia who received decontamination or oral regimens (neomycin/polymyxin B or co-trimoxazole or ciprofloxacin and an antifungal drug). Fifteen years later, Slobbe et al. showed that, for the same category of high-risk patients, it was safe to discontinue empirical imipenem for fever after 72 h if, following a standardized protocol, no infectious etiology was documented. In the ECIL-4 guideline on empirical therapy, the suggested duration of antimicrobial therapy is 72 h in stable patients who are afebrile for more than 48 h and have no microbiological or clinical documentation of infection (see Averbuch et al. in this issue of Haematologica).

It should be stressed that, in the series described by Slobbe et al., empirical antibiotics were stopped after 72 h for patients on fluoroquinolone prophylaxis with meticulous clinical and microbiological follow up, including twice-weekly surveillance cultures and protective isolation with alternative prophylactic oral antibiotics. If surveillance cultures detected ciprofloxacin-resistant Gram-negative bacteria, although prophylaxis with quinolones exerts a significant selection pressure for colonization and infection by fluoroquinolone-resistant organisms, a recent Cochrane review confirmed earlier meta-analyses that the reduction in mortality and infection rates in high-risk patients still outweighs the risk of resistance, the costs and occasional adverse events. Nevertheless, quinolone prophylaxis should be employed only in selected high-risk patients, not in all neutropenic patients.

4. Optimization of dosing regimens using pharmacodynamic principles.

Individualization of antibiotic regimens according to: i) minimal inhibitory concentration (MIC) data for the causative pathogen in the individual or on local surveillance data; and ii) patients’ characteristics, can optimize treatment outcomes. This should benefit neutropenic patients who have a malfunctioning immune system, and particularly high-risk patients and those whose pathogens have only borderline antibiotic susceptibility. Several pharmacological issues should be taken into consideration. In particular, high-risk hematologic patients have large volumes of distribution and/or capillary leak syndrome and/or a more rapid...
clearance of certain drugs. In general, higher doses are needed to obtain adequate serum concentrations, and individual pharmacokinetic variability is high. For some classes of antibiotics, few pharmacokinetic data are available for patients with fever and neutropenia. However, dosing regimens may be predicted from other categories of patients with large volumes of distribution such as ICU patients with critical illness.24

Three patterns of antibiotic activity are important to consider when defining the optimal dosage of different antibiotic classes:25
- concentration-dependent killing is seen for aminoglycosides, with a considerable post-antibiotic effect;
- beta-lactam antibiotics display time-dependent killing with little or no post-antibiotic effect;
- quinolones and vancomycin have activity related to the Area Under the time Concentration Curve (AUC):MIC ratio, reflecting both the serum peak and the time above MIC.

In the case of beta-lactams with short half-life, optimization of dosing may be obtained by extending the infusion time prolonging the period that the free-drug levels remain above the MIC. Recent retrospective studies support this optimized dosing in critically-ill patients, with relevant data available for piperacillin-tazobactam, cefazidime, ceftazidime and meropenem. The choice of continuous versus extended infusion of beta-lactams should be guided by the stability of the drug at room temperature.21

Aminoglycoside dosing is optimized via the administration of large (once daily) doses up to 7 mg/kg for gentamicin and tobramycin and up to 20 mg/kg for amikacin, aiming at a serum peak/MIC ratio of 8-12 (individual MIC or local data), which also minimizes nephrotoxicity.21 Active therapeutic drug monitoring27 should be performed to avoid toxic drug levels arising via accumulation. Optimization of vancomycin dosing is achieved by using a loading dose (up to 35 mg/kg) and ensuring optimal trough levels of approximately 15 mg/L, either by twice-daily administration or continuous infusion, in order to achieve an (AUC):MIC ratio of more than 400, which correlates with positive outcomes in patients with MRSA bacteremia.20 Nephrotoxicity of vancomycin, which mainly occurs if they are combined with other nephrotoxic drugs, should be monitored.21

5. Frequent multidisciplinary rounds.

Clinical rounds, including discussion of patient histories and interactive, bedside education on antimicrobial drug use and infection control, are recommended. A summary of recommendations is presented in Table 2.

In conclusion, antimicrobial stewardship is crucial in the era of growing microbial resistance. Although not yet broadly introduced in hematology centers, it is warranted by the resistance crisis and the scarce development of new antibiotics, in particular those with new targets or mechanisms of action or with activity versus Gram-negative pathogens. Already, resistance developments are jeopardizing the improved outcomes for hematology patients that have been achieved by medical advances over the last decade. Antimicrobial stewardship aims to diminish unnecessary antibiotic exposure and to minimize collateral damage by broad-spectrum antibiotics. Infection control measures are complementary, to prevent the spread of resistant pathogens. De-escalation strategies have been successfully used in other areas of medicine, including the ICU, to decrease selection pressure by prolonged unnecessary regimens of broad-spectrum antibiotics. Their multidisciplinary implementation in hematology is much to be welcomed.

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