European survey on principles of prudent antibiotic prescribing teaching in undergraduate students

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Abstract

We surveyed European medical schools regarding teaching of prudent antibiotic prescribing in the undergraduate curriculum. We performed a cross-sectional survey in 13 European countries (Belgium, Croatia, Denmark, France, Germany, Italy, Netherlands, Norway, Serbia, Slovenia, Spain, Switzerland, United Kingdom) in 2013. Proportional sampling was used, resulting in the selection of two to four medical schools per country. A standardized questionnaire based on literature review and validated by a panel of experts was sent to lecturers in infectious diseases, medical microbiology and clinical pharmacology. In-depth interviews were conducted with four lecturers. Thirty-five of 37 medical schools were included in the study. Prudent antibiotic use principles were taught in all but one medical school, but only four of 13 countries had a national programme. Interactive teaching formats were used less frequently than passive formats. The teaching was mandatory for 53% of the courses and started before clinical training in 71%. We observed wide variations in exposure of students to important principles of prudent antibiotic use among countries and within the same country. Some major principles were poorly covered (e.g. reassessment and duration of antibiotic therapy, communication skills). Whereas 77% of the respondents fully agreed that the teaching of these principles should be prioritized, lack of time, mainly due to rigid curriculum policies, was the main reported barrier to implementation. Given the study design, these are probably optimistic results. Teaching of prudent antibiotic prescribing principles should be improved. National and European programmes for development of specific learning outcomes or competencies are urgently needed.

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Keywords: Antibiotic stewardship, curriculum, education, medical school, medical student, questionnaire

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Introduction

Several international surveys have identified areas of lack of confidence and gaps in antibiotic prescribing knowledge, and
have shown that medical students perceive a need for further education on antibiotic prescribing [1–10]. Junior doctors feel unprepared for the complexity of antibiotic prescribing in daily practice [11–13].

Education is considered essential to influence prescribing behaviour and can provide knowledge that will enhance the acceptance of stewardship strategies [14]. However, most educational programmes have been and are still being conducted at the postgraduate level in healthcare institutions [14–17]. Changing practicing physician behaviour has proven difficult [15].

The World Health Organization (WHO) recently highlighted the importance of undergraduate training in prudent antibiotic prescribing (http://www.who.int/patientsafety/implementation/amr/publication/en/). Surprisingly, not much has been published on the content of this undergraduate training [16,18–21]. The few published articles, as well as informal contact with international colleagues, suggest that wide variations exist between countries, which could contribute to the observed differences in antibiotic use [18]. A thorough analysis of the situation is lacking. Therefore, we conducted a survey on a sample of medical schools in Europe to report on the teaching of prudent antibiotic prescribing in the undergraduate curriculum.

Material and methods

Study design
From April to June 2013 we performed a cross-sectional survey in 13 European countries (Belgium, Croatia, Denmark, France, Germany, Italy, Netherlands, Norway, Serbia, Slovenia, Spain, Switzerland, United Kingdom; Fig. 1). Our aim was to survey a sample of European medical schools regarding teaching of prudent antibiotic prescribing in the undergraduate curriculum. By undergraduate, we mean the bachelor and master years before the junior doctors start a foundation year (United Kingdom), Internes des Hôpitaux (France) or in other countries any specialized track, including general practice.

Participants
Proportional sampling was used resulting in the selection of two to four medical schools per country, according to the total number of medical schools in the country (two schools selected if the total number of medical schools was fewer than ten; three if the total number ranged between 10 and 19; four if the total number was 20 or more). One person from the European Society of Clinical Microbiology and Infectious Diseases Group Study Group for Antibiotic Policies (ESGAP) board’s network

FIG. 1. Map of surveyed European countries indicating (in yellow) number of participating medical schools for each surveyed country.

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was selected in each country to coordinate the survey in his or her country. Each coordinator helped us identify the other medical schools of the sample and referent persons willing to fill in the questionnaire. They were asked to also include faculty of medical schools who were not really involved in antibiotic stewardship activities to avoid any selection bias. The referent at each medical school identified the main lecturers in charge and invited each of them to fill in the questionnaire or parts of it. The referent filled in the final version questionnaire by integrating all information provided. Participation was voluntary and without compensation, except being cited as an investigator.

Questionnaire design
The standardized questionnaire (Supplemental Information) was based on a literature review and validated by a panel of experts through an informal consensual approach [16,19]. Ten lecturers from different medical schools participated in pilot testing. This led to further modifications to the questionnaire.

Data collection
The 57-point self-administered questionnaire (Word document) on principles of seven topics was sent by e-mail by the coordinator in each country to the lecturers in infectious diseases (ID), medical microbiology and/or clinical pharmacology. Further e-mail reminders were sent 3 and 6 weeks after the initial message if needed, resulting in two missing medical schools from the final proportional sample.

Statistical analysis
Categorical variables were presented as percentages and continuous variables as medians (with interquartile range). All analyses were done by SPSS (version 18).

In-depth interviews
To analyze the triggers to start teaching prudent antibiotic principles, as well as barriers, semistructured in-depth interviews were conducted by a student at two Dutch and two German medical schools. The duration of the interviews ranged between 15 and 45 minutes. The two medical schools of the particular country with the most contrasted survey’s results were chosen for the interviews to obtain a wide cross section. Standardized interview questions based on the survey results and validated by two experts were asked in face-to-face interviews, audiotaped and transcribed verbatim. The interview transcripts were then analyzed and categorized [22,23].

Association among curriculum, antibiotic use and/or rates of bacterial resistance
We performed analyses using a mean teaching score (at the country level) to investigate the association between the level of teaching of prudent antibiotic use as expressed by this score, and overall outpatient antibiotic use, total (all settings) antibiotic use and prevalence of resistance. We also looked for an association between the existence of national programmes for the teaching of prudent antibiotic use, and the teaching score, overall outpatient antibiotic use, total (all settings) antibiotic use and prevalence of resistance.

Results

Participants
Data were provided for 13 countries; 35 medical schools were included in the study (response rate: 35/37, 95%), all with questionnaires fully filled in. The duration of undergraduate medical training (preclinical and clinical years) in the 13 surveyed countries ranged from 5 to 7 years. The referents were infectious diseases specialists (26/35, 74%), clinical microbiologists (5/35, 14%) and clinical pharmacologists (4/35, 12%). Lecturers involved in prudent antibiotic prescribing teaching at each medical school were also ‘often or very much’ involved in antimicrobial stewardship activities in 77% of the cases.

Teaching principles for prudent antibiotic use in undergraduate curriculum
Prudent antibiotic use principles (i.e. antimicrobial stewardship learning outcomes) were taught in all but one medical school, but in only 4/13 (31%) countries in the framework of a national programme (Croatia, Denmark, Norway, United Kingdom). These principles of prudent antibiotic use had been taught for a median duration of 10 (interquartile range 5–13) years in the included medical schools. All medical students were targeted in 94% of the medical schools. The teaching was mandatory for 53% of the courses, and started before the medical students begin their clinical training in 71% of the medical schools. It was integrated with other related topics, such as immunology, microbiology, pharmacology and infection control, for 68% of the courses, and integrated in the clinical training and combined with the management of individual diseases/organ groups for 56%.

Interactive teaching formats were used less frequently than passive formats: clinical case discussions (85%), active learning assignments (50%), Web-based server software learning platform (29%), e-learning (21%), role-play (12%) vs. lectures (100%).

The extent of teaching regarding major principles for prudent antibiotic use is detailed in Table 1. Some important prudent antibiotic use principles were poorly covered—for example, the practical use of point-of-care tests, estimating the
shortest possible adequate duration of treatment, the reassessment of the antibiotic prescription at around day 3 and quality of care or communication skills principles. We observed wide variations in exposure of students to the selected principles of prudent antibiotic use among countries and within the same country.

A total of 77% of the respondents fully agreed that the teaching of these principles should be prioritized in the future, 63% totally agreed with teaching these prudent antibiotic use principles early in the curriculum (first, second or third year) and 71% with including these principles in basic microbiology and pharmacology (antibiotic) teaching.

In-depth interviews
The four in-depth interviews provided additional information and background on the topic, and again, respondents had frequently divergent views. Some illustrative statements are given in the supporting information (Supplementary Table S1).

At all four included medical schools, the trigger to start teaching on prudent antibiotic use principles had been a dedicated individual interested in and committed to antimicrobial resistance and stewardship topics (Supplementary Table S1). Nevertheless, the opportunities for implementation were disparate: complete restructuring of the curriculum at one medical school, and lecturers involved in antimicrobial resistance and stewardship activities becoming coordinators of subjects (e.g. infectious diseases) where those principles thematically fit in at two medical schools.

Several barriers were cited at two of the medical schools to integrate (more) topics on prudent antibiotic use principles in the medicine curriculum, whereas no barriers at all were experienced by the remaining two medical schools (country

### Table 1. Coverage of prudent antibiotic use principles in 34 of 35 surveyed medical schools reporting some teaching on these principles

<table>
<thead>
<tr>
<th>Principle</th>
<th>Mean (%) stated as:</th>
<th>Well covered</th>
<th>Partially covered</th>
<th>Not covered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic 1: Bacterial resistance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epidemiology of resistance, accounting for local/regional variations and importance of surveillance</td>
<td>60</td>
<td>31</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Factors associated with bacterial resistance in pathogens</td>
<td>63</td>
<td>34</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Extent, causes of bacterial resistance in commensals and the phenomenon of overgrowth</td>
<td>46</td>
<td>40</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Consequences of bacterial resistance for the patient</td>
<td>74</td>
<td>20</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Spread of resistant organisms</td>
<td>74</td>
<td>20</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Collateral damage/consequences of antibiotic use</td>
<td>63</td>
<td>28</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Lack of development of new antibiotics</td>
<td>49</td>
<td>31</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Topic 2: Diagnosis of infection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Recognizing clinical signs of infection</td>
<td>89</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Assessing the severity of infection/sepsis</td>
<td>83</td>
<td>14</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Interpretation of clinical and laboratory biological markers of inflammation</td>
<td>66</td>
<td>31</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Importance of taking microbiological samples before starting the antibiotic therapy</td>
<td>86</td>
<td>11</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Interpretation of basic microbiological investigations</td>
<td>68</td>
<td>26</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Practical use of point-of-care tests</td>
<td>40</td>
<td>49</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>Topic 3: Indications for antibiotic prophylaxis/curative therapy</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Clinical situations when not to prescribe an antibiotic:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Colonization vs. infection</td>
<td>71</td>
<td>26</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Viral infections</td>
<td>71</td>
<td>23</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Inflammation vs. infection</td>
<td>57</td>
<td>37</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Defining empiric/directed therapy and prophylaxis</td>
<td>86</td>
<td>11</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Indications for empiric/directed therapy</td>
<td>83</td>
<td>11</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Principles of surgical antibiotic prophylaxis</td>
<td>54</td>
<td>34</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td><strong>Topic 4: Initial empiric/directed therapy</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Best bacteriological guess for empiric therapy</td>
<td>60</td>
<td>37</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Documentation of an indication for antibiotics in the clinical notes</td>
<td>37</td>
<td>31</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Prescribing antibiotic therapy according to national/local practice guidelines</td>
<td>54</td>
<td>43</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Assessment of antibiotic allergy</td>
<td>49</td>
<td>40</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Choice of spectrum; criteria for selecting an antibiotic for empiric therapy</td>
<td>71</td>
<td>26</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Indications for combination therapy</td>
<td>60</td>
<td>34</td>
<td>6</td>
<td></td>
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<tr>
<td>Broad vs. narrow-spectrum antibiotics, and preferred choice of narrow-spectrum drugs</td>
<td>66</td>
<td>31</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Choosing the dose and interval of administration</td>
<td>37</td>
<td>60</td>
<td>3</td>
<td></td>
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<tr>
<td>Estimating the shortest possible adequate duration</td>
<td>34</td>
<td>57</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Recording (planned) duration or stop date</td>
<td>29</td>
<td>40</td>
<td>31</td>
<td></td>
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<tr>
<td><strong>Topic 5: Reassessment of antibiotic therapy</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Reassessment of the antibiotic prescription around day 3</td>
<td>54</td>
<td>26</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Streamlining/de-escalation once microbiological results are known</td>
<td>57</td>
<td>40</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Stopping the empiric antibiotic therapy around day 3 if the diagnosis of bacterial infection is ruled out or highly unlikely</td>
<td>43</td>
<td>40</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Intravenous-oral switch</td>
<td>57</td>
<td>37</td>
<td>6</td>
<td></td>
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<tr>
<td>Therapeutic drug monitoring to ensure adequate drug levels</td>
<td>49</td>
<td>31</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Assessment of clinical outcomes and reasons for failure of antibiotic treatment</td>
<td>43</td>
<td>46</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>Topic 6: Quality of care</strong></td>
<td></td>
<td></td>
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<tr>
<td>Audit and feedback assessing prescribing practice</td>
<td>11</td>
<td>46</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td><strong>Topic 7: Communication skills</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explaining to the patient the absence of an antibiotic prescription</td>
<td>23</td>
<td>31</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Education of patients regarding prudent antibiotic prescribing</td>
<td>20</td>
<td>31</td>
<td>49</td>
<td></td>
</tr>
</tbody>
</table>
activities. We acknowledge that the participating medical
lecturers were actively involved in antimicrobial stewardship
but probably due to some network effect, 77% of the surveyed
procedure was intended to limit any potential selection bias,
be generalizable to all European medical schools. Our sampling
large number of European countries, but our results might not
constrained curriculum.

ologists, as well as barriers of allocated time due to a rigid and
dinates with infectious diseases specialists or clinical microbi-
ders [24]. It is now crucial that academia and ministries of
start clinical practice. Up until now, most educational
effects have been targeted at professionals (mostly medical
dr after their training and at the adult public. In the past
eys, some progress has been made in educating school-
children [24]. It is now crucial that academia and ministries of
health and education jointly focus on an adapted undergraduate
medical/professional curriculum that teaches all necessary
principles of microbiology, infectious diseases and clinical
pharmacology, with emphasis on the principles of prudent
prescribing, using diverse interactive teaching formats
[16,17,25]. An integrated and contextualized approach is
needed, taking into account all the factors that may have an
impact on prescribing practices, related to the prescriber and

Association among curriculum, antibiotic use and/or
rates of bacterial resistance
There was no significant association, at the country level, be-
tween the level of teaching of prudent antibiotic use and either
prevalence of bacterial resistance (although there was a trend),
outpatient antibiotic use and total antibiotic use (Table 2).
There was also no significant association between the existence
of national programmes and either the teaching score, preva-
lence of bacterial resistance (although there was a trend),
outpatient antibiotic use and total antibiotic use (Table 2).

Discussion

This European survey showed wide variations among countries
and within the same country regarding the teaching of prudent
antibiotic prescribing principles, with some poorly covered
essential principles. The teaching mainly occurred as a result of
local academic initiatives and mostly used passive learning for-
mats. The in-depth interviews revealed that these initiatives
could be traced back to motivated individuals within the uni-
versity who were given the opportunity to expand the topic in
the curriculum. Here again, divergent situations were described
regarding the existence of barriers to implementation.

Our results are consistent with the recent findings of a Eu-
ropean survey of medical students [3]. As examples, gaps in
confidence regarding the duration of antibiotic treatment or
combination therapies were identified among medical students,
and our study showed that these topics were frequently
partially covered or not covered in medical schools. The in-
terviews provided information on the reasons for these gaps:
organ specialists teaching about most frequent infections such
as pneumonia and urinary tract infections without real coordi-
nation with infectious diseases specialists or clinical microbi-
ologists, as well as barriers of allocated time due to a rigid and
constrained curriculum.

Our multicentre study presents original findings covering a
large number of European countries, but our results might not
be generalizable to all European medical schools. Our sampling
procedure was intended to limit any potential selection bias,
but probably due to some network effect. 77% of the surveyed
lecturers were actively involved in antimicrobial stewardship
activities. We acknowledge that the participating medical
schools are quite certainly biased towards higher standards of
prudent antibiotic use teaching, and that, given the study design,
these results are probably optimistic. Moreover, because the
survey was not anonymous, socially desirable answers might
have been given, but the high frequency of topics reported as
partially or not covered argues against this hypothesis. Finally,
only four in-depth interviews could be conducted, limiting the
degree of data saturation.

We did not show any significant association, at the country
level, between the level of teaching of prudent antibiotic use
and either prevalence of bacterial resistance (although there
was a trend) or antibiotic use. However, we think that these
analyses are subject to the same selection bias we discussed
above; it is indeed quite difficult to definitely assess the teaching
score of a country in such a small number of medical schools.

A multicentre survey was conducted in 2011 in 15/132 medical
schools in five Asian countries (Malaysia, Thailand, Singapore,
Indonesia, the Philippines) (http://www.reactgroup.org/uploads/
react/resources/213/Education%20on%20antibiotic%20resistance
%20in%20medical%20and%20pharmacy%20schools.en.266.pdf).
Eighty-seven per cent of the schools documented that antibiotic
resistance–related topics were a compulsory part of their cur-
riculum. Interactive teaching formats were used as frequently as
passive formats: clinical case discussions (69%), small group dis-
cussions (93%) and role-play (21%) vs. lectures (69%). In terms of
barriers to antibiotic resistance teaching, inadequate time alloca-
tion for teaching was mentioned in 53% of the medical schools, lack
of interest from other faculty members in 79%, lack of integration
of teaching in the curriculum in 73% and lack of continuation during
students’ clinical training in 64%. Another study, from Nepal, in a
resource-limited setting obtained successful teaching through a
problem-based approach within clinical pharmacology teaching
using the WHO essential medicine prescribing approach [21].

Our data show that there is room for improvement in the
education of undergraduate medical students in the principles
that should provide a foundation for the knowledge that leads
to acceptable antimicrobial stewardship programmes when
doctors start clinical practice. Up until now, most educational

### TABLE 2. Association between (1) level of teaching of prudent antibiotic use principles (expressed as mean teaching score at country level) and antibiotic use/prevalence of resistance; and (2) existence of national programme and teaching score/antibiotic use/prevalence of resistance

<table>
<thead>
<tr>
<th>Country</th>
<th>Mean teaching score</th>
<th>2012 Overall outpatient antibiotic use DDD/1000 inhabitants/day</th>
<th>2012 Total (inpatient + outpatient) antibiotic use DDD/1000 inhabitants/day</th>
<th>2012 Methicillin-susceptible S. aureus (%)</th>
<th>2012 Third-generation cephalosporin-susceptible E. coli (%)</th>
<th>2012 Fluoroquinolone-susceptible E. coli (%)</th>
<th>2012 Macrolide-susceptible S. pneumonia (%)</th>
<th>2012 Susceptibility score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>94.5</td>
<td>29.76</td>
<td>31.5</td>
<td>83.4</td>
<td>92.1</td>
<td>76.6</td>
<td>74.6</td>
<td>326.7</td>
</tr>
<tr>
<td>Croatia</td>
<td>84.0</td>
<td>21.72</td>
<td>23.7</td>
<td>78.7</td>
<td>91.7</td>
<td>82.8</td>
<td>89.6</td>
<td>342.8</td>
</tr>
<tr>
<td>Denmark</td>
<td>112.5</td>
<td>16.43</td>
<td>18.2</td>
<td>98.7</td>
<td>91.1</td>
<td>84.6</td>
<td>94</td>
<td>368.4</td>
</tr>
<tr>
<td>France</td>
<td>82.75</td>
<td>29.68</td>
<td>31.8</td>
<td>80.8</td>
<td>89.3</td>
<td>79.2</td>
<td>71.1</td>
<td>320.4</td>
</tr>
<tr>
<td>Germany</td>
<td>92.75</td>
<td>14.87</td>
<td>No data</td>
<td>84.6</td>
<td>90.9</td>
<td>78.3</td>
<td>92.6</td>
<td>346.4</td>
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<tr>
<td>Italy</td>
<td>71.33</td>
<td>27.56</td>
<td>30.0</td>
<td>64.8</td>
<td>72.9</td>
<td>57</td>
<td>65.8</td>
<td>260.5</td>
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<tr>
<td>Netherlands</td>
<td>84.5</td>
<td>11.34</td>
<td>12.3</td>
<td>98.7</td>
<td>93.5</td>
<td>83.8</td>
<td>95.6</td>
<td>371.6</td>
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<tr>
<td>Norway</td>
<td>97.5</td>
<td>16.92</td>
<td>18.4</td>
<td>98.7</td>
<td>94.6</td>
<td>87.9</td>
<td>94.7</td>
<td>375.9</td>
</tr>
<tr>
<td>Serbia</td>
<td>103</td>
<td>No data</td>
<td>25.5</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>358.1</td>
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<td>Slovenia</td>
<td>103</td>
<td>14.30</td>
<td>15.9</td>
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<td>78.3</td>
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<td>Spain</td>
<td>100.5</td>
<td>20.87</td>
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<td>86.1</td>
<td>65.3</td>
<td>73.6</td>
<td>300.8</td>
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<td>Switzerland</td>
<td>85</td>
<td>8.5</td>
<td>No data</td>
<td>89.8</td>
<td>91.6</td>
<td>79.2</td>
<td>82.4</td>
<td>343.0</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>101.5</td>
<td>20.06</td>
<td>No data</td>
<td>86</td>
<td>86.5</td>
<td>83.1</td>
<td>93.2</td>
<td>348.8</td>
</tr>
</tbody>
</table>

For each participating medical school, replies regarding the teaching of 38 principles of prudent antibiotic prescribing were numerically categorized (1 if not covered, 2 if partially covered and 3 if well covered) and summed up (maximum score = 114). Mean score per country was calculated (sum of individual scores at each medical school, divided by number of surveyed medical schools in country).

Sources of information: ESAC-net data; Versporten A et al., Lancet Infect Dis 2014; 14: 381–387 [29]; Swiss Centre for Antibiotic Resistance (http://www.anresis.ch); Achermann R et al., Cm Microbial Infect 2011; 17: 855–861 [30]. Only 2007 and 2011 data were available for Switzerland and Serbia, respectively.

Susceptibility score was calculated by adding up the four 2012 selected prevalence rates (%). Maximum score was 400 and reflected lowest prevalence of bacterial resistance.

Countries with a national programme (Croatia, Denmark, Norway, United Kingdom).
his or her social context [11,13,17,26]. It seems obvious that antimicrobial stewardship is likely to be more successful when started much earlier, at the time when knowledge, attitude and behaviour of healthcare professionals are being shaped.

Recently, the importance of undergraduate training in prudent prescribing of antibiotics has become increasingly recognized in the United Kingdom, including Scotland. Major efforts were made to adapt and revise undergraduate education on antibiotics at the national level. In the United Kingdom, the Specialist Advisory Committee on Antimicrobial Resistance has proposed to undertake the development of learning outcomes, i.e. statements that indicate what a student should know, understand and be able to do by the end of an educational programme [27]. Learning outcomes were used to develop a coordinated student-centered teaching resource for prudent antimicrobial prescribing based on clinical scenarios (vignettes) [28]. This would provide a robust and transparent framework for curriculum development at all stages. Subsequently, the learning outcomes can be translated into competencies by the appropriate bodies [19,20]. The recent development of a competency framework in the United Kingdom on antibiotic stewardship is certainly a start in the right direction (https://www.gov.uk/government/publications/antimicrobial-prescribing-and-stewardship-competencies). In the United States, an Antimicrobial Stewardship Curriculum for Medical Students has been designed in conjunction with the U.S. Centers for Disease Control and Prevention and the Association of American Medical Colleges [17]. This learning material is freely available online for use by any medical school and consists of large-group presentations, with corresponding examination questions, as well as interactive small-group activities, with a facilitator guide [17]. However, competencies in antibiotic stewardship for medical students have not yet been established [17].

In conclusion, teaching of prudent antibiotic prescribing principles shows wide variations in European medical schools, and even in this optimistic scenario, major gaps were identified. National and European programmes for development of specific learning outcomes or competencies in prudent antimicrobial prescribing are urgently needed, targeting all healthcare professionals.

**Transparency declaration**

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**Authorship/Contribution**

CP and ICG designed the study and the questionnaire. FW performed the interviews. CP analysed the data and wrote the article with contributions from all authors.

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**Appendix A. Supplementary data**

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.cmi.2014.11.015

**References**


