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

C. Pulcini[1], F. Wencker[2], N. Frimodt-Møller[3], W. V. Kern[4], D. Nathwani[5], J. Rodríguez-Baño[6], G. S. Simonsen[7], V. Vlahović-Palčevski[8] and I. C. Gyssens[2,9] for the ESGAP Curriculum Working Group

1) *Service de Maladies Infectieuses, CHU Nancy and EA 4360 Apemac, Université de Lorraine, Université Paris Descartes, Nancy, France,* 2) *Department of Medicine, Radboud University Medical Center and Department of Medical Microbiology and Infectious Diseases, Canisius Wilhelmina Hospital, Nijmegen, The Netherlands,* 3) *Department of Clinical Microbiology, Rigshospitalet (Copenhagen University Hospital), Copenhagen, Denmark,* 4) *Center for Infectious Diseases and Travel Medicine, Department of Medicine, University Hospital, Freiburg, Germany,* 5) *Infection Unit, Ninewells Hospital and Medical School, Dundee, United Kingdom,* 6) *Unidad Clínica de Enfermedades Infecciosas, Microbiología y Medicina Preventiva, Hospitales Universitarios Virgen Macarena y Virgen del Rocío, y Departamento de Medicina, Universidad de Sevilla, Sevilla, Spain,* 7) *Department of Microbiology and Infection Control, University Hospital of North-Norway and Research group for Host-Microbe Interactions, Faculty of Health Sciences, UiT—The Arctic University of Norway, Tromsø, Norway,* 8) *Department of Clinical Pharmacology, University Hospital Rijeka and Department of Pharmacology, University of Rijeka Medical Faculty, Rijeka, Croatia and* 9) *Hasselt University, Hasselt, Belgium*

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.

Keywords: Antibiotic stewardship, curriculum, education, medical school, medical student, questionnaire
Original Submission: 24 July 2014; **Revised Submission:** 15 November 2014; **Accepted:** 15 November 2014
Editor: M. Paul
Article published online: 22 November 2014

Corresponding author: C. Pulcini, CHU de Nancy, Hôpitaux de Brabois, Service de maladies infectieuses et tropicales, 54511 Vandœuvre-lès-Nancy cedex, France
E-mail: celine.pulcini@univ-lorraine.fr

Introduction

Several international surveys have identified areas of lack of confidence and gaps in antibiotic prescribing knowledge, and

http://dx.doi.org/10.1016/j.cmi.2014.11.015

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), Interne 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

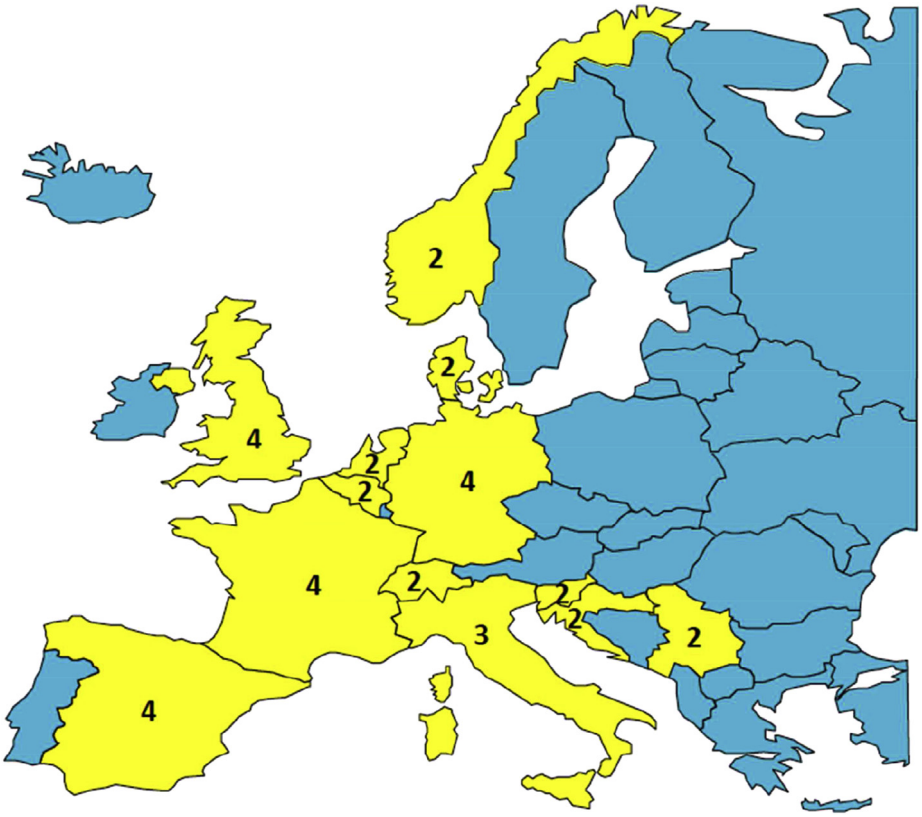

FIG. 1. Map of surveyed European countries indicating (in yellow) number of participating medical schools for each surveyed country.

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

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

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

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

independent). 'Lack of time' was cited as the main barrier, related to the fact that curriculum policies were quite constrained and rigid (Supplementary Table S1). 'Lack of collaboration' with organ specialists was also reported by one interviewee, as was 'lack of a national programme that integrates prudent antimicrobial use principles.'

Association among curriculum, antibiotic use and/or rates of bacterial resistance

There was no 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), 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, prevalence 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 formats. The in-depth interviews revealed that these initiatives could be traced back to motivated individuals within the university 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 European 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 interviews provided information on the reasons for these gaps: organ specialists teaching about most frequent infections such as pneumonia and urinary tract infections without real coordination with infectious diseases specialists or clinical microbiologists, 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 curriculum. Interactive teaching formats were used as frequently as passive formats: clinical case discussions (69%), small group discussions (93%) and role-play (21%) vs. lectures (69%). In terms of barriers to antibiotic resistance teaching, inadequate time allocation 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 efforts have been targeted at professionals (mostly medical doctors) after their training and at the adult public. In the past few years, some progress has been made in educating schoolchildren [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

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

	Mean teaching score [a]	2012 Overall outpatient antibiotic use DDD/ 1000 inhabitants/day [b]	2012 Total (inpatient + outpatient) antibiotic use DDD/ 1000 inhabitants/day [b]	2012 Methicillin-susceptible *S. aureus* [c] (%)	2012 Third-generation cephalosporins-susceptible *E. coli* [c] (%)	2012 Fluoroquinolone-susceptible *E. coli* [c] (%)	2012 Macrolide-susceptible *S. pneumoniae* [c] (%)	2012 Susceptibility score [d]
Association between teaching score and variable presented as heading of column (linear regression)		p 0.40	p 0.27					p 0.097
Association between national programme and variable presented as heading of column (nonparametric Mann-Whitney test)	p 0.35	p 0.87	p 0.44					p 0.062
Data available for all 13 included countries								
Belgium	94.5	29.76	31.5	83.4	92.1	76.6	74.6	326.7
Croatia[e]	84.0	21.72	23.7	78.7	91.7	82.8	89.6	342.8
Denmark[e]	112.5	16.43	18.2	98.7	91.1	84.6	94	368.4
France	82.75	29.68	31.8	80.8	89.3	79.2	71.1	320.4
Germany	92.75	14.87	No data	84.6	90.9	78.3	92.6	346.4
Italy	71.33	27.56	30.0	64.8	72.9	57	65.8	260.5
Netherlands	84.5	11.34	12.3	98.7	93.5	83.8	95.6	371.6
Norway[e]	97.5	16.92	18.4	98.7	94.6	87.9	94.7	375.9
Serbia	103	No data	25.5	No data	No data	No data	No data	—
Slovenia	103	14.30	15.9	89.7	89.7	78.3	78.8	336.5
Spain	100.5	20.87	No data	75.8	86.1	65.3	73.6	300.8
Switzerland	85	8.5	No data	89.8	91.6	79.2	82.4	343.0
United Kingdom[e]	101.5	20.06	No data	86	86.5	83.1	93.2	348.8

[a]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).
[b]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., Clin Microbiol Infect* 2011; 17: 855–861 [30]. Only 2007 and 2011 data were available for Switzerland and Serbia, respectively.
[c]Sources of information: ESAC-net data; Swiss Centre for Antibiotic Resistance (http://www.anresis.ch).
[d]Susceptibility score was calculated by adding up the four 2012 selected prevalence rates (%). Maximum score was 400 and reflected lowest prevalence of bacterial resistance.
[e]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

This work was supported by the European Society of Clinical Microbiology and Infectious Diseases Study Group for Antibiotic Policies (ESGAP), with a small unrestricted grant. JRB receives funding for research from Ministerio de Economía y Competitividad, Instituto de Salud Carlos III, cofinanced by the European Development Regional Fund "A Way to Achieve Europe" ERDF, Spanish Network for the Research in Infectious Diseases (REIPI RD12/0015). VVP receives funding for research from University of Rijeka under the project number 13.06.1.2.23. All authors report no conflicts of interest relevant to this article.

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.

Acknowledgements

The ESGAP Curriculum Working Group includes the following investigators who facilitated or coordinated the survey in their country and/or filled in the questionnaire for their medical school: Belgium (I. C. Gyssens, F. Jacobs, W. Peetermans), Croatia (I. Francetić, V. Vlahović-Palčevski), Denmark (N. Frimodt-Møller, N. Høiby, M. Kilian), France (F. Ader, C. Cazorla, M. Etienne, C. Pulcini), Germany (G. Fätkenheuer, W. V. Kern, M. W. Pletz, B. Salzberger), Italy (B. Cacopardo, M. Mikulska, C. Mussini, G. Orlando, S. Stefani), The Netherlands (I. C. Gyssens, S. H. Lowe, J. L. Nouwen), Norway (J. E. Afset, K. Bergh, F. Müller, G. S. Simonsen), Serbia (B. Carevic, O. Horvat, S. Jankovic), Slovenia (B. Beović, J. R. Gorisek), Spain (R. Canton, M. C. Fariñas, F. Gudiol, J. R. Paño Pardo, J. Rodríguez Baño), Switzerland (S. Harbarth, G. Zanetti) and the United Kingdom (G. Barlow, N. Brown, B. Healy, D. Nathwani).

Presented in part as an oral presentation (O020) at the European Congress of Clinical Microbiology and Infectious Diseases (ECCMID, Barcelona, May 2014), as a poster (M-03) at the Journées Nationales d'Infectiologie (French Infectious Diseases Society, Bordeaux, June 2014) and as an oral presentation (82°) at the RICAI (Réunion Interdisciplinaire de Chimiothérapie Anti-infectieuse, Paris, November 2014).

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

[1] Abbo LM, Cosgrove SE, Pottinger PS, Pereyra M, Sinkowitz-Cochran R, Srinivasan A, et al. Medical students' perceptions and

knowledge about antimicrobial stewardship: how are we educating our future prescribers? Clin Infect Dis 2013;57:631–8.
[2] Dyar OJ, Howard P, Nathwani D, Pulcini C. Knowledge, attitudes, and beliefs of French medical students about antibiotic prescribing and resistance. Med Mal Infect 2013;43:423–30.
[3] Dyar OJ, Pulcini C, Howard P, Nathwani D. European medical students: a first multicentre study of knowledge, attitudes and perceptions of antibiotic prescribing and antibiotic resistance. J Antimicrob Chemother 2014;69:842–6.
[4] Minen MT, Duquaine D, Marx MA, Weiss D. A survey of knowledge, attitudes, and beliefs of medical students concerning antimicrobial use and resistance. Microb Drug Resist 2010;16:285–9.
[5] Afzal Khan AK, Gausia Banu, Reshma KK. Antibiotic resistance and usage—a survey on the knowledge, attitude, perceptions and practices among the medical students of a Southern Indian teaching hospital. J Clin Diagn Res 2013;7:1613–6.
[6] Huang Y, Gu J, Zhang M, Ren Z, Yang W, Chen Y, et al. Knowledge, attitude and practice of antibiotics: a questionnaire study among 2500 Chinese students. BMC Med Educ 2013;13:163.
[7] Humphreys H, Dillane T, O'Connell B, Luke LC. Survey of recent medical graduates' knowledge and understanding of the treatment and prevention of infection. Ir Med J 2006;99:58–9.
[8] Ibia E, Sheridan M, Schwartz R. Knowledge of the principles of judicious antibiotic use for upper respiratory infections: a survey of senior medical students. South Med J 2005;98:889–95.
[9] Wright EP, Jain P. Survey of antibiotic knowledge amongst final year medical students. J Antimicrob Chemother 2004;53:550–1.
[10] Thriemer K, Katuala Y, Batoko B, Alworonga JP, Devlieger H, Van Geet C, et al. Antibiotic prescribing in DR Congo: a knowledge, attitude and practice survey among medical doctors and students. PLoS One 2013;8:e55495.
[11] Mattick K, Kelly N, Rees C. A window into the lives of junior doctors: narrative interviews exploring antimicrobial prescribing experiences. J Antimicrob Chemother 2014;69:2274–83.
[12] Pulcini C, Williams F, Molinari N, Davey P, Nathwani D. Junior doctors' knowledge and perceptions of antibiotic resistance and prescribing: a survey in France and Scotland. Clin Microbiol Infect 2011;17:80–7.
[13] McLellan L, Tully MP, Dornan T. How could undergraduate education prepare new graduates to be safer prescribers? Br J Clin Pharmacol 2012;74:605–13.
[14] Dellit TH, Owens RC, McGowan Jr JE, Gerding DN, Weinstein RA, Burke JP, et al. Infectious diseases society of America and the society for healthcare epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. Clin Infect Dis 2007;44:159–77.
[15] Davey P, Brown E, Charani E, et al. Interventions to improve antibiotic prescribing practices for hospital inpatients. Cochrane Database Syst Rev 2013;4:CD003543.
[16] Pulcini C, Gyssens IC. How to educate prescribers in antimicrobial stewardship practices. Virulence 2013;4:192–202.
[17] Ohl CA, Luther VP. Health care provider education as a tool to enhance antibiotic stewardship practices. Infect Dis Clin North Am 2014;28:177–93.
[18] Davey P, Hudson S, Ridgway G, Reeves D. A survey of undergraduate and continuing medical education about antimicrobial chemotherapy in the United Kingdom. British society of antimicrobial chemotherapy working party on antimicrobial use. Br J Clin Pharmacol 1993;36:511–9.
[19] Davenport LA, Davey PG, Ker JS. An outcome-based approach for teaching prudent antimicrobial prescribing to undergraduate medical students: report of a working party of the British society for antimicrobial chemotherapy. J Antimicrob Chemother 2005;56:196–203.
[20] Davey P, Garner S. Professional education on antimicrobial prescribing: a report from the specialist advisory committee on antimicrobial resistance (SACAR) professional education subgroup. J Antimicrob Chemother 2007;60(Suppl. 1):i27–32.
[21] Shankar R, Bajracharya O, Jha N, Gurung S, Singh K. Teaching medical students to use antibiotics rationally in a medical school in Nepal. Educ Med J 2011;2:WMC002329.
[22] Malterud K. Qualitative research: standards, challenges, and guidelines. Lancet 2001;358:483–8.
[23] Malterud K. Systematic text condensation: a strategy for qualitative analysis. Scand J Public Health 2012;40:795–805.
[24] McNulty CA, Lecky DM, Farrell D, Kostkova P, Adriaenssens N, Koprivova Herotova T, et al. Overview of e-Bug: an antibiotic and hygiene educational resource for schools. J Antimicrob Chemother 2011;66(Suppl. 5):v3–12.
[25] Laxminarayan R, Duse A, Wattal C, Zaidi AK, Wertheim HF, Sumpradit N, et al. Antibiotic resistance—the need for global solutions. Lancet Infect Dis 2013;13:1057–98.
[26] Brennan N, Mattick K. A systematic review of educational interventions to change behaviour of prescribers in hospital settings, with a particular emphasis on new prescribers. Br J Clin Pharmacol 2013;75:359–72.
[27] McNulty CA, Cookson BD, Lewis MA. Education of healthcare professionals and the public. J Antimicrob Chemother 2012;67(Suppl. 1):i11–8.
[28] Nathwani D, Sneddon J, Malcolm W, Wiuff C, Patton A, Hurding S, et al. Scottish antimicrobial prescribing group (SAPG): development and impact of the Scottish national antimicrobial stewardship programme. Int J Antimicrob Agents 2011;38:16–26.
[29] Versporten A, Bolokhovets G, Ghazaryan L, Abilova V, Pyshnik G, Spasojevic T, et al. Antibiotic use in eastern Europe: a cross-national database study in coordination with the WHO Regional Office for Europe. Lancet Infect Dis 2014;14:381–7.
[30] Achermann R, Suter K, Kronenberg A, Gyger P, Mühlemann K, Zimmerli W, et al. Antibiotic use in adult outpatients in Switzerland in relation to regions, seasonality and point of care tests. Clin Microbiol Infect 2011;17:855–61.