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Analysis of radiology education in undergraduate medical doctors training in Europe

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ABSTRACT

Objectives: The purpose of the present study is to describe how undergraduate radiology teaching is organized in Europe and to identify important characteristics of undergraduate radiology curriculum.

Methods: An electronic survey on undergraduate teaching was distributed by the European Society of Radiology (ESR) to 38 national delegates of the ESR Education Committee.

Results: The “classic type” of radiology teaching method is more frequent than the “modular type”. In 38% of medical training centres the first experience with radiology is in pre-clinical years. The students enrolled in the fourth medical year experience the largest involvement in radiology education. The total number of teaching hours (mean 89 h, median 76 h) varies across the countries and differs depending on the radiological topic (mean across all topics 14.8 h, median 13). Written tests and oral exams were the most frequently used examination modes. Clerkships are reported as a key part of training.

Conclusion: This first international comparative study of undergraduate radiological curriculum in Europe identifies a large number of differences in curriculum content and teaching methods throughout Europe. More research is needed to establish the radiological educational competences resulting from these differing curricula's to improve and to standardize the teaching according to (inter)national and institutional needs.

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1. Introduction

Medical school educational programs and undergraduate training of radiology in particular are not standardized throughout Europe [1–3] and United States (US) [4,5]. The mandatory nature of a formal radiology curriculum [6–9] and the needs for a formal, clearly structured radiology curriculum [6,9–12] have been widely discussed in the medical literature. However, only a few US schools include radiology as a required course. Mostly radiology is presented as an elective course with additional sporadic exposure to imaging techniques during medical education [4,5,12]. This is in contrast to research pointing at the increasing interest for an integrated approach towards radiology education as well as towards the content of an innovative radiology curriculum [10,11,13–19]. This has led to recommendations as to new frameworks for radiology curriculum design; such as the one provided by the Royal College of Radiologist (UK) [20]. Research has also shown the benefits of incorporating evidence-based practice education in radiology [21,22]. A positive effect has been reported in the US of early expo-

sure to radiology in the early years of medical training or even in premedical years [11,19,23–25]. Lastly, radiology clerkship has been identified as an essential part of radiology curriculum. The educational benefits of different types of radiology clerkships point at improvement of students' knowledge and interpretation skills as well as students' satisfaction [8,26–29].

In view of developing a comprehensive strategy to develop undergraduate radiology education, it is critical to develop a thorough understanding of the broad curriculum content related to radiology, and to understand the instructional formats applicable to radiology education (teaching approaches, course set up, evaluation approaches, ...). Most research in this field originates from US based medical schools. Inclusive information about the current status of radiology teaching in Europe is lacking. Therefore, the present study describes how radiology teaching is set up in European medical schools to identify important characteristics of the European undergraduate radiological curriculum and the educational formats being adopted.

Considering this problem statement, the following research questions are formulated:

1. How is undergraduate teaching set up: what teaching methods are being used?

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2. In what year(s) of medical school do students study radiology?
3. What proportion of the curriculum focuses on radiology or radiology topics?
4. What type of staff is responsible for radiology education?
5. What radiology topics are examined and how are they being examined?
6. What is the nature and extent of radiology clerkships?
7. How many students are involved in radiology-related scientific work?
8. Is there an educational policy attracting students considering radiology as a career option?

2. Materials and methods

A questionnaire was developed under the umbrella of the Educational Committee of the European Society of Radiology (ESR). It was electronically distributed by European Society of Radiology (ESR) to 38 national member delegates of the Educational Committee. Each country was represented by one national delegate, who filled out the questionnaire about their own country, building on information obtained from their national educational board, radiology teaching staff, and chiefs of teaching hospitals. Responses were obtained from 34 respondents (89%) (Appendix A). The questionnaire (Appendix B) was developed to explore the duration of medical and radiology training, the curriculum content, the nature of instructional strategies, the human resources involved in radiology teaching, the assessment and evaluation approaches, the nature of clerkships in radiology departments, opportunities for students to participate in radiology research and the educational policy attracting students to consider radiology as a career option.

2.1. Statistical analysis

The questionnaire data were entered, and analyzed with SPSS version 15 software (Statistical Package for the Social Sciences, SPSS.; Chicago, IL, USA). Mainly descriptive statistics were applied and a variety of tools to develop graphical representations of the results. Answers to open-ended questions were answered in view of identifying key themes.

3. Results

3.1. How is undergraduate teaching set up: what teaching methods are being used?

The duration of medical undergraduate education in 29 out of the 34 countries (85%) is 6 years. In some countries medical undergraduate education only takes 5 years (IE, UK, SE) 7 years (BE) or 7.5 years (NO).

The average number of the students enrolled in the last year across all countries is 326. Countries such as BY, EE, TR and UA report more than 500 students being enrolled in last year medical education.

In our questionnaire, we focused on the nature of the building blocks in undergraduate medical education: “classic building blocks” in which radiology is studied and evaluated independently versus “modular building blocks” that integrate and assess radiology within thematic modules covering e.g., body systems (e.g. thorax, abdomen, nervous system, . . .) and focuses on a variety of medical perspectives (e.g. internal medicine, surgery, pharmacology, . . .). In more than half of the countries (ES, IT, CZ, GE, HR, PT, BA, GR, HU, RO, PL, SI, BY, ME, NO, BG, UA, LV, LU, FR) classic building blocks dominate the curriculum, in about 18% (AT, TR, IE, DK, UK, NL) modular building blocks dominate. In about 20% of the countries both classic and modular building blocks are combined in the undergraduate curriculum (IS, BE, SE, EE, LT, MK, DE).

3.2. In what medical school year(s) do students study radiology?

Twenty six percent of the countries (AT, NL, TR, LU, UK, FR, CZ, PL, RO) reported that students receive their first radiology experience in the first year of medical training. In countries such as BE, DE, IE, ES, SE, LT, DK, BG, HU (26%), radiology starts in the second year. Very different are about 18% of countries where radiology is only presented for the first time in the fourth year (GR, IS, HR, BA, SI, MK). In IT radiology is only part of the medical curriculum in the fifth year.

In five countries (AT, NL, TR, LU, UK) radiology is a consistent part of the medical curriculum in every medical training year. On average, the largest proportion of radiology is presented during the fourth in most countries (73.5%).

3.3. What proportion of the curriculum focuses on radiology or radiology topics?

The total number of the teaching hours focusing on radiology varies considerable between countries (mean 89 h, median 76 h, minimum 19 h, maximum 212 h). It also varies depending the radiology topic. The average number of teaching hours for each topic is 14.8 (median 13 h) with a minimum of 3 h and a maximum of 40 h. Some trends can be observed when focusing on the attention paid to particular radiology topics.

The topic “Radiology of diseases” receives most attention (mean 38.6 h; median 28 h), followed by “Radiology techniques” (mean 19.4 h; median 10 h), and “Radiology anatomy” (mean 18.6 h; median 12). The teaching hours for specific topics of radiological education for each country are summarized in Table 1. The table also documents separately outliers and extreme values.

A graphical overview of composition of the radiology curriculum in all countries is shown in Fig. 1. As mentioned earlier, specific trends can be observed across the countries. A large proportion of teaching hours related to radiology of diseases is typical in most countries. There are some exceptions. For example, in AT the number of radiology anatomy hours (30 h) and hands-on: interpretation skills (26 h) are higher as compared to radiology of diseases (16 h). In EE, the radiology curriculum pays much more attention to hands-on (interpretation skills) teaching hours (70), radiology anatomy (36 h) and radiology techniques (30 h). And in BE the proportion of attention paid to the following topics is balanced: radiology anatomy (30 h), radiology of diseases (30 h) and hands-on (30 h). It is remarkable that LT reports a significant higher number of hours spent in relation to for guidelines for appropriate use of radiology (50 h), hands-on: interpretation skills (40 h), and the same level of attention (20 h) to radiology diseases, radiology anatomy and radiology techniques. In the curriculum of FR, we observe higher proportion of time linked to interventional radiology (32 h). The information of HR, HU and LU contains missing data, and ES only reported quantitative data in relation to radiology anatomy (40 h) and radiology diseases (80 h). The information of DK and NO suggests that the focus was on the total number of hours, since next the down break to radiology topics reflects a completely balanced picture.

Next to the differences in proportional attention paid to radiology topics, it is interesting to note that the variation in topics is different across the countries. In the questionnaire, seven radiology topics were presented to be analyzed in view of the national undergraduate medical curriculum: radiology anatomy, radiology techniques, radiology of diseases, interventional radiology, radiation protection, guidelines for appropriate use of radiology and hands-on: interpretation skills. In 17 countries, such as MK, BA, GR, HU, LV, PT, CZ, IS, ME, IT, PL, BE, SE, AT, DE, LT, EE (55%), all topics seem to be part of the curriculum. The topic hands-on: interpretation skills is lacking in 10 countries (32%: IE, RO, TR, UK, BG, UA, ES,

Table 1
Proportion of the curriculum focusing on radiology topics in different European countries.

Radiological topic	Mean (SD) hours	Median hours	Min. hours	Max. hours	Interval	N countries answered		Outliers/extreme values (n)	N countries NOT answered
						<25% (n,%)	>75% (n,%)		
Radiology anatomy	16 (13.9)	12	2	52	2–4 h (n=6; 19%) DE GR IE IS MK SI	5–20 h (n=18; 58%) BA BY CZ DK FR HU IT LT LV ME NL PL PT RO SE TR UA UK	31	100 h (n=1) LU	2 HR RS
Radiology techniques	12.8 (10.0)	10	2	36	2–5 h (n=7; 23%) BA BE CZ GR IS MK NO	6–20 h (n=18; 60%) AT BG FR HU IE IT LT LV ME NL PL PT RO RS SI TR UA UK	30	76–100 h (n=3) BY ES LU	1 HR
Radiology of diseases	29.5 (17.8)	26	4	70	4–15 h (n=6; 20%) BA GR HU IE LV MK	16–41 h (n=17; 57%) AT BE BY CZ DK EE FR IS IT LT ME NL PL PT RO SE SI TR	30	100–250 h (n=2) GE LU	2 ES HR
Interventional radiology	4.0 (2.3)	4	1	8	1 h (n=3; 12.5%) BA BE RO	2–6 h (n=18; 75%) BG CZ EE GR HU IE IS IT LT LV ME MK PL PT RS SE SI TR	24	32–100 h (n=5) DK FR GE LU NO	5 ES HR NL UA UK
Radiation protection	2.7 (1.4)	2	1	6	1 h (n=5; 18%) CZ IS MK RO SI	2–4 h (n=20; 74%) BA BE BG BY DE EE GR HU IE IT LV ME NL NO PL PT RS TR UA UK	27	10–40 h (n=3) AT DK GE	4 ES FR HR LU
Guidelines for appropriate use of radiology	7.2 (5.8)	5	1	20	1–2 h (n=4; 17%)	3–10 h (n=15; 62%) 11–20 h (n=5; 21%)	24	35–52 h (n=3)	7
Hands-on: Interpretation skills	11.6 (11.5)	6	1	40	1–2 h (n=4; 20%) BA GR MK NL	BA BE CZ DE FR HU IS IT LV ME NL PL PT SE UA 3–22 h (n=12; 60%) 23–40 h (n=4; 20%)	20	DK LT NO 70 h (n=1)	BG ES GE HR RS SI UK 13
Total number of radiology teaching hours	89.2 (51.7)	76	19	212	19–43 h (n=6; 19%) MK BA GR HU IE LV	CZ FR HU IS IT LV ME PL PT RS SE SI 44–116 h (n=18; 58%) 117–212 h (n=7; 23%)	31	EE 300 h; 570 h (n=2) GE LU	BG BY DK ES GE HR IE LU NO RO TR UA UK 1 HR
Mean number of radiology teaching hours	14.8 (9.3)	13	3	40	3–6 h (n=8; 24%) BA GR HU IE LV MK PT SI	7–18 h (n=17; 52%) 19–40 h (n=8; 24%)	33		1 HR

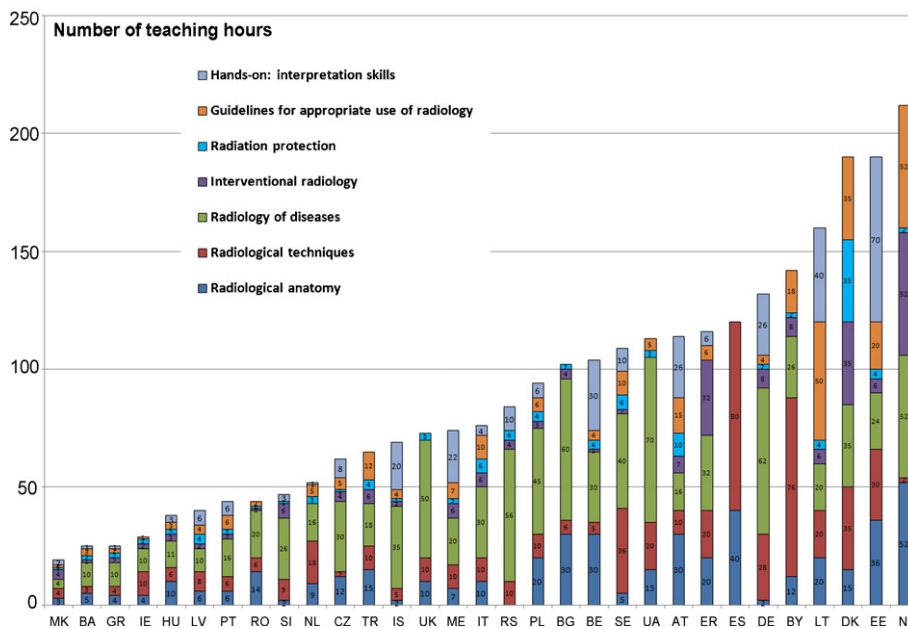


Fig. 1. An overview of the radiology curriculum contents in medical centers of Europe.

BY, DK, NO), the topic guidelines for appropriate use of radiology is lacking in 5 countries (16%: SI, UK, RS, BG, ES) and interventional radiology in 4 countries (13%: NL, UK, UA, ES).

The fourth year of medical training is reported to be the most important year for teaching all radiological topics except radiology anatomy and radiation protection that dominate the third year curriculum. In year 3 and/or 5, some countries also focus on radiology techniques (38.2%; 26.5% respectively), radiology of diseases (47.1%; 32.4% respectively), interventional radiology (23.5%; 32.4% respectively) and hands-on: interpretation skills (23.5%; 17.6% respectively). Guidelines for appropriate use of radiology is taught as well in the fifth (29.4%), third and sixth year (26.5%, equal for both years).

Countries teaching radiology in the first year pay great attention to topics as radiology anatomy (77.8%) and radiology techniques (55.6%).

In the second year, radiology anatomy is still a hot topic (80%), in the third year radiology of diseases becomes more important (84%), but not in BE, NO and SE. The topic radiation protection seems to be an essential part of the third year curriculum in most of countries (73.7%) with exception of AT (taught in year 4), FR and LU (do not taught at all), NL (taught in years 1 and 4) and TR (taught in years 2, 4, 5). In the fifth year, dominant topics are interventional radiology (68.8%) but not in CZ (taught in year 4), NL and UK (do not taught at all). In most countries, guidelines for appropriate use of radiology is a key topic in year 6 (81.8%) except GR (taught in year 5) and TR (taught in years 3, 4 and 5)

It has to be stressed that the comparison of teaching hours is somewhat marred by the lack of a standardized total number of teaching hours in each country. This makes it less easy to understand the relative value attached to specific topics in the broader context of the medical curriculum.

3.4. What type of staff is responsible for radiology education?

In most European medical training centers radiology topics are taught by more than two staff members (85%). The average total number of radiology-related teaching staff is 12. In countries such as ES and GR (6%), only a single specialized staff member is reported. Medical training centers in IE, SE, ME (9%) prefer two specialized teachers for radiology.

It is apparent that radiology topics in the medical training centres of Europe are preferably taught by general or specialized radiologists. Also other medical experts participate in the teaching process, with the exception of interventional radiology that is only taught by radiologists. Radiology anatomy is taught by anatomist (23.5%), as well as by radiology trainees (14.7%). Radiology techniques are also introduced by physicist (20.6%), radiology diseases by radiology trainees (11.8%), radiation protection by physicist (29.4%), guidelines for appropriate use of radiology by radiology trainees (11.8%) and clinicians (11.8%). Hands-on: interpretation skills are also introduced by radiology trainees (20.6%).

3.5. What radiology topics are examined and how are they being examined?

Radiology exams mostly focus at the same time on different radiology topics and as such as a part of a broader as part of larger exams (“modular” together with other disciplines) (44%). Exceptions are exams in relation to radiology techniques (38%), radiation protection examination (32%) and hands-on exams (18%), which are set up separately. Writing tests and/or oral examinations (65.6%;) are the most commonly used methods for student evaluation. Computer-based evaluation and/or Objective Structured Clinical Examination (OSCE) evaluation are also set up, but are not widely used (25% and 21.9%, respectively). In LV, LT, PL, GE, DK, SI, NL (22%) all assessment is based on written exams. In BA, HR, MK, NO, LU, CZ (19%) most exams are set up orally. In the following countries both types of exams are combined: ME, PT, HU, UA, IS, DE, RO, RS (25%). BE is special in this way that all radiology exams are set up via a computer. In TR, 86% of the exams is OSCE based; this is 14% in PC. In AT, GR and BY, a mixture of the different types of assessment approaches is adopted (written exam, oral exam, on PC and OSCE). Again, different assessment type combinations are observed in IE, FR, SE, UK, and IT.

PC based exams are mostly organized in relation to radiology of diseases (25%), radiology anatomy (18.8%), and for radiology techniques (15.6%). OSCE is only applied for radiology diseases (18.8%) and interventional radiology (15.6%) to a lesser extent for other topics (9.4% equal for radiology anatomy, radiology techniques, radiation protection and guidelines for appropriate use of radiol-

ogy). Interpretation skills (hands-on) are mostly examined orally (21.9%).

3.6. What is the nature and extent of radiology clerkships?

Clerkships are reported as a key part of undergraduate radiology teaching (88%; no answer for LU and PL), with the exception of UK and DK where no clerkships are scheduled, but where students have a possibility to participate in clinical-radiology conferences and multidisciplinary meetings.

The curriculum position and the duration of radiology clerkships varies across European countries. In none of the countries, clerkships or visits are reported during the second year. In NL and SE students already visit the radiology department in their first year. This visit helps them to observe daily practice in a radiology department. Students of the third (47%) and fourth (53%) year are increasingly involved in radiology clerkships for an average duration of 4 weeks (median 0.7 weeks) and 5 weeks (median 3.5 weeks) respectively. Countries such as MK, ME and RS report the longest clerkship period in the third year (24, 15 and 10 weeks). Countries such as HU, RO (14 weeks), GR (13 weeks) and NL (10 weeks) report the longest clerkships in the fourth year. In year 5, the longest clerkships is observed in GR (13 weeks) and IT (12 weeks). In year 6, the longest clerkship period is 16 weeks in DE. In a number of countries the radiology clerkship only takes only a single day (LV, EE, NO, AT, CZ) or two days (PT, BY, UA) during the entire medical training period.

The questionnaire did not focus on the type of the radiology clerkship. As a result, it is unclear whether there are required and/or elective clerkships. Additionally, little information was gathered about the tasks and responsibilities during the clerkships. The list of available information in this context contains: theory-based tasks such as reading, interpretation of images resulting from different radiological diagnostic modes: X-ray, MR exams, CT, etc., working cases (guided or unguided), observation of daily activities in the radiology department, taking part in routine clinical practices, or participating in conferences and/or multidisciplinary meetings.

3.7. How many students are involved in radiology-related scientific work?

Most institutions reported the opportunity to carry out the independent scientific work in radiology (85%, no answer for ES, HR, IS, EE, MK). The average number of students performing scientific work in radiology is 7, the median is 4. Involvement of a single student is reported in DK and NO. A maximal number of 28 students is reported in FR. Considering the fact that the average number of students in the national medical training centre is 326 (27 countries), the average percentage of students involved in the scientific radiology work is only about 4%.

3.8. Is there an educational policy attracting students considering radiology as a career option?

Forty-four percent (15 countries) indicate the presence of a policy attracting students to consider radiology as a career option. The following typical policies were used:

- facultative radiology courses;
- participation in scientific meetings;
- optional visits to the department;
- radiology brochures;
- scientific team working;

but also

- attracting students via interesting lectures and tutorials;
- presentation of the rapid developments in radiology and its importance in patient care.

4. Discussion

As stated earlier, medical educational programs lack uniformity [1–5,30]. Analysis of the descriptive results of the ESR questionnaire, results in a comparable picture about the big differences in the organization of the undergraduate radiology curriculum in Europe. The differences start with the length of the undergraduate medical study. In most European countries, a medical education program takes 6 years, in some countries only 5 or 7 years are required. This is a striking difference with US based medical schools where the undergraduate curriculum requires a 4-year program, based on 156 teaching weeks. This duration can be expanded with 2 to 3 years of “pre-med” courses [4,5]. European medical school duration is shorter than the program set up in the United Arab Emirates. Their 8-year program includes a compulsory 1-year internship [18]. It also has to be stressed that the size of training centre in Europe is very varied (average number in the last curriculum year is 326). Though the present study focuses on radiology undergraduate teaching, this information is important as a background to discuss the particular radiology education setting.

The findings of the present study confirm that radiology is taught via different types of medical undergraduate curricula, depending on the nature of the building blocks being used [16]: *The Conventional Medical Curriculum* based on the “classic building block”, the *PBL Problem Based Curriculum* based on “modular building blocks”, and the *Hybrid Medical Curriculum* that takes a position between the former two [31].

The Conventional Medical Curriculum mostly consists of a pre-clinical and a clinical part, where instruction is based on disciplines like anatomy, physiology, histology, internal medicine, surgery, pharmacology, and radiology. Assessment is linked to these individual disciplines and spread over one or more curriculum years. Radiology is usually presented and assessed in the clinical part where it is linked to the imaging of diseases. Radiology is sometimes also presented (as an extra) in anatomy course, with or without a specific evaluation part.

In Problem Based Curricula, the building blocks are part of both the pre-clinical and clinical part of the curriculum. Instruction is based on comprehensive “modules” covering systems or parts of the body like thorax, abdomen, musculoskeletal system, nervous system, urogenital system, etc. Usually these modules cover “the normal human” in the pre-clinical years and the “patient” in the clinical years. In the pre-clinical phase, disciplines – including radiology – are combined to develop an understanding of different healthy human system (e.g. the gastro-intestinal system), until the whole “healthy” body has been covered. In the clinical phase, additional disciplines like internal medicine, surgery, pharmacology, radiology, etc. are combined. Each module is closed with an examination that focuses on all the disciplines covered in a specific module. In this building block approach, radiology is hardly approached as a separate discipline and therefore relatively underrepresented in the exams. This can lead to students “skipping” radiology and radiology anatomy, unless specific radiology exams have been set up.

Our analysis results show that the “classic” type of undergraduate teaching is dominantly used in European medical centres. This neglects the findings from research showing that an integrated approach of radiological education leads to more effective radiological education and helps to develop a positive attitude towards

radiology. The latter has implications for their future career choice [11,13–15,17–19]. In the present study, only 18% of centres adopt a “modular building block” type of curriculum and about 20% adopt a combination of classic and modular building blocks in their curriculum, suggesting an orientation towards a Hybrid Medical curriculum.

Early exposure – in the pre-clinical training years – to radiology education is expected to result in a more positive perception of radiology, increased interest in radiology as a carrier option and a reduction of negative stereotypes about radiologist [11,19,23–25]. The results of the present study indicate that early exposure is found in most European medical curricula. In 78% of the medical curricula, the first experience with radiology is already in the pre-clinical phase. However, in a small number of countries, radiology is introduced rather late in the curriculum: the fourth or fifth year.

Lee et al. [9] from the University of British Columbia stress that students benefit more from radiology instruction during a first curriculum year. Important is their additional finding that all students participating in their study expressed a desire to opt for radiology as an elective course in their final training year (4-year medical curriculum). This implies that it is important to make radiology visible throughout the curriculum [7,18,20]. From our research we understand that only in 15% of countries radiology is a consistent part in every curriculum year. This questions the situation in countries where radiology is only taught during one single year of the entire medical curriculum. The fourth year of medical training is seems to be very important year for teaching radiology, radiology was present in most of countries.

The results of our study show that the number of radiology teaching hours varies largely between European countries (countries mean 89 h, median 76 h, min 19 h, max 212 h) and depends on the radiological topic (Table 1). This large fluctuation is similar to results from a study focusing on undergraduate nuclear medicine teaching in European universities [3]. An important question arises from our observations: what is the required optimal numbers of radiology teaching hours in order to develop sufficient radiology competences in medical undergraduates? Unfortunately it is difficult to develop a clear answer to this question. Though sufficient information about the critical contents of a radiological curriculum are found in the literature, as well as a variety of curriculum framework [10,16,20], less is known about the efficiency of radiology teaching in terms of teaching hours and proportion of the medical curriculum. Data from curricula in non-European countries can help to develop some benchmarks. A Canadian Undergraduate Radiology Survey reported an average of 19.9 h of radiology lectures and an average of 45.6 h of radiology-related small group sessions [9]. Gunderman et al. reported 165 h of focused radiology instruction next to clinical rotation at Indiana University [7]. In the integrated curriculum of the United Arab Emirates University [18] radiology is present in the whole curriculum (8 teaching modules).

In the present ESR questionnaire seven radiology topics were presented as critical components of a radiology curriculum: radiology anatomy, radiology techniques, radiology of diseases, interventional radiology, radiation protection, guidelines for appropriate use of radiology and hands-on: interpretation skills. It is a reassuring finding that in 55% of countries all topics are present in their radiology curriculum. Some radiology topics are less represented in the curricula: hands-on: interpretation skills, guidelines for appropriate use of radiology and interventional radiology. But, due to the nature of our questionnaire it might be possible that these topics are taught within the context of radiology of diseases.

The trends across the countries are also determined in our research: the topic radiology of diseases deserves the most teaching hours because of the involvement of different organ systems in

this topic, followed by radiological techniques due to wide spectrum of used imaging techniques and radiological anatomy. These topics are reported in all countries as a compulsory part of their curriculum. Moreover, radiological anatomy and imaging techniques (explanations of what is radiography, CT, ultrasound, MRI, angiography, interventional radiology and contrast media) in most of the countries incorporated in the pre-clinical part of the training because it is a required knowledge for feather radiology teaching, for example, for teaching of radiology of diseases which are taught mostly in the clinical part of the training.

As to human resources involved in radiology education, 85% of European training centres involve more than two radiology staff members, and is interesting to see that the country average is twelve staff members. This finding reflects the situation in the Canadian Undergraduate Radiology Program where on average 10.9 radiology staffs are involved in teaching activities [9]. In the literature the importance is stressed that radiology staff adopt a consistent educational approach: compatible teaching methods, clear learning objectives pursued throughout the different curriculum years and taking into account the progressive level in radiology competences of undergraduate students [7]. This is also recognized as critical to extend multidisciplinary collaboration within the teaching context [20]. In most European medical training centers, the radiology topics are mainly taught by general or specialized radiologists or radiology trainees. Radiology techniques and radiation protection are additionally taught by physics, radiology anatomy is especially taught by anatomist. The latter is not surprising and even preferred in the literature due to the close linkages and needed level of integration between these disciplines [15,17,32]. The fact that specialized radiologists are involved is also favored in the literature. Radiologist have proven to be successful radiology educators [12,18,24,33,34]. As professionals, radiologists are able to develop a deeper level of understanding in students to interpret radiology issues, to answer in-depth questions and to solve the clinical queries from a comprehensive patient perspective. We therefore agree with the statement of Gunderman et al. that: “Radiologists teach diagnostic imaging better than anyone else” [7]. But attention should be paid to the adequate level of radiology teaching. There is a risk that specialized radiologists teach at a too high level and prefer to focus on rare diseases and advanced techniques, thus forgetting about first line radiology.

The involvement of specialized radiologists is a point of concern in the literature [12,27]. Concerns are raised about actual staff participation and the reward system adopted for teaching activities in radiological departments in e.g., US medical schools. In the current system, an appropriate remuneration system is lacking. Moreover, in short-staffed departments, staff will be hardly geared to be involved in teaching activities when the workload gets higher and there is hardly sufficient time for teaching. Unfortunately, this situation seems to be mirrored in European schools where clinical activities compete with involvement in teaching activities. Our research has some limitations in this context, since questions were included about the balance between teaching and clinical work of radiologist staff or about the incentives and reward system to foster an educational orientation of radiology staff. This could be taken up in a future study.

As part of the instructional design, evaluation is an important component of the educational experience. Both teachers and students benefit when learning objectives are clearly defined, learning activities are clear structured and systematically evaluated [35]. Building on the findings of the present study, it is clear that radiology-related evaluation is high on the agenda of all institutions. Radiology seems to be dominantly evaluated as part of a broader examination. But, when radiology is entirely incorporated within a broader examination setting (e.g. linked to evaluation

related to thorax disease, internal medicine, surgery, pharmacology, pathology), a risk exists that radiology assessment is limited to a few number of the questions and that (some) students will hardly learn radiology. To ensure that students master radiology-related competences, a separate radiology examination is required.

Written tests and oral examinations were the most commonly used methods to set up student evaluation. It is striking that computer-based assessment PC or/and OSCE evaluation are not widespread. But, these results are similar to the assessment methods adopted by US medical schools [27,36]. The important advantage of PC is the possibility to make appropriate questions with different levels of difficulty and with a high quality of images. For example, the type of questions as: “click on this or that anatomic structure” or “give the name of the anatomic structure/pathology” or “what is differential diagnosis?” can be used for testing of image interpretations skills or knowledge of radiological anatomy or radiology of diseases. The type question as “choose most appropriate imaging technique to solve this clinical question. . .” can be used for testing of knowledge of radiological techniques or appropriate use of imaging techniques.

The research results demonstrate the importance of radiological clerkships in medical undergraduate teaching. In 88% of the European teaching centers an opportunity to be involved in radiological clerkship is provided. Next to the observation that this clerkship is mostly set up during the third or the fourth year, we observe a number of countries where the radiology clerkships is limited to a couple of days. In the questionnaire, we did not focus on the nature of the radiology clerkship, so it is less clear whether clerkships are set up as a required or elective curriculum component. Results from research related to radiology clerkships at teaching hospitals in the US [27] show that less than one third of medical schools include required radiology clerkships in their program. These clerkships have a median length of 3 to 4 weeks, depending on the number of fourth year students involved.

Differences in duration of clerkships between countries can be linked to different types of radiology clerkships and the curriculum year they are being organized. This can also explain the different planning of observational visits versus active radiology clerkships throughout the medical curriculum.

The educational impact of different types of radiology clerkships has clearly been established. Researchers refer to an impact on knowledge of imaging modalities, interpretation skills and attitudes towards radiology [8,13,26,28,29,37,38]. Also, clerkships can be helpful to induce the interest for radiology among students, and the possibility to be involved in related scientific work. According to the Bologna declaration (The Bologna Declaration of June 1999, Prague communiqué of May 2001, Berlin communiqué of September 2003) scientific research is a key characteristic of the academic higher education curriculum. It is therefore encouraging that all institutions involved in the present study reported opportunities for students to carry out independent scientific work in the radiology field. As expected, the percentage of students interested in this area is rather low (4%).

There are several limitations to the present study. First, we have to point at the impact of response bias that is typical for survey-based studies. Though our response rate of 89% is acceptable, we nevertheless have to consider that only one representative of each country filled out the survey. This can be questioned considering the differences in country size, volume of the national health care system, and the number of medical training centers in a country. This implies that it was possible to determine between-country variation, but not the potentially large within-country variation.

Second, due to the nature of our study, analysis of the data was restricted to an exploration of quantitative data. No inferential statistical tests have been carried out. Thus, in future studies, it is

advisable to involve more training centers for each country to get a clearer and more complete picture about radiological education across different training centres in Europe.

Thirdly, the quantitative results show some strikingly large differences, for example, the differences in teaching hours related to radiology teaching. This implies that a focus on means and the median is less relevant. Future studies should focus on these large differences and set up analysis of outliers and extreme values. As suggested in the results section, some survey data suggest that respondents might have interpreted questions in a particular way (mixing up total hours spent on radiology teaching and hours devoted to specific radiology topics). A cross-validation of the data by adding e.g., qualitative interviews could help to develop a more in-depth and controlled picture. Additionally, analysis results could be fed back to respondents for cross-checking.

The future research could also take an inventory of the teaching activities during clerkships and staff participation on it, and used rewards systems across Europe. These topics were not intended in this research but will be very useful for better understanding of curricular difference and institutional needs across the European countries. In addition, the student perspective could be considered by involving representative samples of students in the study. This would help to develop a picture of student perspectives on radiology teaching.

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Appendix A. List of countries in the “ESR survey on undergraduate teaching”

AT	Austria
BA	Bosnia and Herzegovina
BE	Belgium
BG	Bulgaria
BY	Belarus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FR	France
GE	Georgia
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IS	Iceland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
ME	Montenegro
MK	Macedonia
NL	Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
SE	Sweden
SI	Slovenia
TR	Turkey
UA	Ukraine
UK	United Kingdom

*Leave blank if there are **no** exams of the topic*

- Radiological anatomy S D O W PC Osce
- Radiological techniques S D O W PC Osce
- Radiology of diseases S D O W PC Osce
- Interventional radiology S D O W PC Osce
- Radiation protection S D O W PC Osce
- “guidelines” S D O W PC Osce
- “hands-on” S D O W PC Osce
- other + specify S D O W PC Osce

Comments :

6. “Practical sessions” – “Sign-off sessions” - “Clerckship”:

Do students visit the department? Yes No

If Yes, in which year(s) and how long? (day, week, month)

- Y 1 :
- Y 2 :
- Y 3 :
- Y 4 :
- Y 5 :
- Y 6 :
- Y 7 :

Which tasks do they perform ? :

7. How many students perform independent scientific work in radiology (~ 20 week

period according to Bologna declaration) . Number of students per year : (Mean; range)

8. Is there a policy to attract students to consider radiology as career option:

Yes No

Specify:.....

9. Please provide any additional comments regarding undergraduate radiology teaching and radiological involvement in undergraduate medical teaching :

References

[1] Isherwood I. Radiologic education in Europe – New challenges and new opportunities. *Investigative Radiology* 1993;28:S94–5.

[2] Pruszyński B. Selected problems of undergraduate and postgraduate education in radiology in Eastern-Europe. *Investigative Radiology* 1993;28:S97–8.

[3] Lass P, Scheffler J. Undergraduate teaching of nuclear medicine in European universities. *European Journal of Nuclear Medicine and Molecular Imaging* 2003;30(7):1018–23.

[4] Barzansky B, Jonas HS, Etzel SI. Educational programs in US medical schools, 1998–1999. *JAMA – Journal of the American Medical Association* 1999;282(9):840–6.

[5] Barzansky B, Etzel SI. Educational programs in US medical schools, 2003–2004. *JAMA – Journal of the American Medical Association* 2004;292(9):1025–31.

[6] Afaq A, McCall J. Improving undergraduate education in radiology. *Academic Radiology* 2002;9(2):221–3.

[7] Gunderman RB, Siddiqui AR, Heitkamp DE, Kipfer HD. The vital role of radiology in the medical school curriculum. *AJR American Journal of Roentgenology* 2003;180(5):1239–42.

[8] Scheiner JD, Novelline RA. Radiology clerkships are necessary for teaching medical students appropriate imaging work-ups. *Academic Radiology* 2000;7(1):40–5.

[9] Lee JS, Aldrich JE, Eftekhari A, Nicolaou S, Muller NL. Implementation of a new undergraduate radiology curriculum: experience at the University of British Columbia. *Canadian Association of Radiologists Journal* 2007;58(5):272–8.

[10] Smith WL, Kathol M, Franken EA, Albanese M. Curriculum topics in radiology education. *Investigative Radiology* 1987;22(6):521–3.

[11] Ekelund L, Elzubeir M. Diagnostic radiology in an integrated curriculum: evaluation of student appraisal. *Academic Radiology* 2000;7(11):965–70.

[12] Samuel S, Shaffer K. Profile of medical student teaching in radiology: teaching methods, staff participation, and rewards. *Academic Radiology* 2000;7(10):868–74.

[13] Shaffer K, Ng JM, Hirsh DA. An integrated model for radiology education: development of a year-long curriculum in imaging with focus on ambulatory and multidisciplinary medicine. *Academic Radiology* 2009;16(10):1292–301.

[14] Allen SS, Roberts K. An integrated structure-function module for first year medical students: correlating anatomy, clinical medicine and radiology. *Medical Education* 2002;36(11):1106–7.

- [15] Collins J, Dotti SL, Albanese MA. Teaching radiology to medical students: an integrated approach. *Academic Radiology* 2002;9(9):1046–53.
- [16] Collins J, Reddy GP, Mullan BF, et al. A curriculum in cardiothoracic radiology for medical students, with goals and objectives. *Academic Radiology* 2001;8(12):1247–51.
- [17] Collins JP. Modern approaches to teaching and learning anatomy. *BMJ* 2008;337:a1310.
- [18] Ekelund L, Lanphear J. Diagnostic radiology in an integrated curriculum: experience from the United Arab Emirates. *Academic Radiology* 1997;4(9):653–6.
- [19] Jafri NF, Wu P, Stanfield L, Slanetz PJ. Use of radiologic imaging to enhance physical diagnosis instruction in the preclinical curriculum. *Academic Radiology* 2008;15(7):942–7.
- [20] Available from: <http://www.rcr.ac.uk/content.aspx?PageID=703>. The Royal College of Radiology (RCR), Radiology for Medical Students, London.
- [21] van Beek EJR, Malone DE. Evidence-based practice in radiology education: why and how should we teach it? *Radiology* 2007;243(3):633–40.
- [22] Black WC, Jadad AR, Jarvik JG, et al. Evidence-based radiology: a new approach to the practice of radiology. *Radiology* 2001;220(3):566–75.
- [23] Branstetter BF, Faix LE, Humphrey AL, Schumann JB. Preclinical medical student training in radiology: the effect of early exposure. *AJR American Journal of Roentgenology* 2007;188(1):W9–14.
- [24] Branstetter BF, Humphrey AL, Schumann JB. The long-term impact of preclinical education on medical students' opinions about radiology. *Academic Radiology* 2008;15(10):1331–9.
- [25] Donnelly LF, Racadio JM, Strife JL. Exposure of first-year medical students to a pediatric radiology research program: is there an influence on career choice? *Pediatric Radiology* 2007;37(9):876–8.
- [26] Chen MY, Ott DJ, Richards B. Impact and value of junior rotation in radiology. *Investigative Radiology* 1990;25(10):1153–5.
- [27] Barlev DM, Lautin EM, Amis ES, Lerner ME. A survey of radiology clerkships at teaching hospitals in the United-States. *Investigative Radiology* 1994;29(1):105–8.
- [28] Chew FS, Relyea-Chew A. Distributed web-supported radiology clerkship for the required clinical clerkship year of medical school: development, implementation, and evaluation. *Academic Radiology* 2002;9(6):713–20.
- [29] Relyea-Chew A, Chew FS. Dedicated core clerkship in radiology for medical students development, implementation, evaluation, and comparison with distributed clerkship. *Academic Radiology* 2007;14(9):1127–36.
- [30] Ischerwood I, Tessier PJ, Thomsen HS. Developments in radiological education in Europe. *European Radiology* 1993;3:481–4.
- [31] Schwartz PL, Loten EG. Influence of type of curriculum on students' perceptions of the medical course: a compilation of results from the cognitive behavior survey, attitudes toward social issues in medicine survey, and learning environment questionnaire. *Teaching and Learning in Medicine* 2004;16(2):123–32.
- [32] Singh RK, McCoubrie P, Burney K, Miles JA. Teaching medical students about radiation protection-what do they need to know? *Clinical Radiology* 2008;63(12):1344–9.
- [33] Bui-Mansfield LT, Chew FS. Radiologists as clinical tutors in a problem-based medical school curriculum. *Academic Radiology* 2001;8(7):657–63.
- [34] Gunderman RB, Wilson PK. Viewpoint: exploring the human interior: the roles of cadaver dissection and radiologic imaging in teaching anatomy. *Academic Medicine* 2005;80(8):745–9.
- [35] Blane CE, Calhoun JG, Maxim BR, Martel W, Davis WK. Systematic evaluation and increased structure in a radiology elective. *Investigative Radiology* 1985;20(3):242–5.
- [36] Kassebaum DG, Eaglen RH. Shortcomings in the evaluation of students' clinical skills and behaviors in medical school. *Academic Medicine* 1999;74(7):842–9.
- [37] Chew FS. Distributed radiology clerkship for the core clinical year of medical school. *Academic Medicine* 2002;77(11):1162–3.
- [38] Scheiner JD, Noto RB, McCarten KM. Importance of radiology clerkships in teaching medical students life-threatening abnormalities on conventional chest radiographs. *Academic Radiology* 2002;9(2):217–20.