Health and Technology (2021) 11:963–969
https://doi.org/10.1007/s12553-021-00591-1

ORIGINAL PAPER

Collaborative networking and support for medical physics development in low and middle income (LMI) countries

Slavik Tabakov[1,3] · **Magdalena Stoeva**[2,3]

Received: 11 August 2021 / Accepted: 19 August 2021 / Published online: 9 September 2021

Abstract

Medical physics is one of the key aspects of contemporary medicine, primarily focused on the safe and effective use of medical imaging and radiotherapy equipment. The number of medical physicists and their activities are directly related to the national/regional healthcare provision. The distribution of the medical physics workforce however is still very uneven—more than 70% of all medical physicists are in North America and Europe, serving the healthcare provision of about 1 billion people. The remaining 30% of medical physicists serve the healthcare provision of the rest of the world—serving about 6.5 billion people. A number of activities were taken by various teams and organisations to address this issue. The increase of quality of healthcare and the effectiveness of medical technology usage, lie in adequate education and training for medical physicists and engineers, who are the front-liners when it comes to dealing with technology in healthcare. To help LMI countries professional growth in the field of medical physics and technology, we developed an education and capacity building strategy, based on the revolutionary application of digital resources combined with experience sharing through large international network.

Keywords Medical physics · Medical engineering · IUPESM · Low and middle income countries · Education and training

Medical physics is one of the cornerstones of contemporary medicine. The number of medical physicists and their activities in one country are directly related to the healthcare provision in the country. The work of these specialists is most often related to the safe and effective use of medical imaging and radiotherapy equipment. As per the UNSCEAR 2008 Report [1], the annual number of medical radiation uses in the world are:

- 3.143 million diagnostic medical examinations (X-ray);
- 32.7 million nuclear medicine procedures;
- 7.5 million radiation oncology treatments.

Each one of the equipment associated with these millions of procedures has been assessed, quality controlled and maintained by medical physicists and biomedical engineers.

✉ Magdalena Stoeva
ms_stoeva@yahoo.com

[1] King's College London, London, UK

[2] Medical University of Plovdiv, Plovdiv, Bulgaria

[3] International Union for Physical and Engineering Sciences in Medicine (IUPESM), York, UK

The distribution of the medical physics workforce is still very uneven—more than 70% of all medical physicists are in North America and Europe, serving the healthcare provision of about 1 billion people. The remaining 30% of medical physicists serve the healthcare provision of the rest of the world—serving about 6.5 billion people [2]. A number of activities were taken by various teams and organisations to address this issue—on the first place we shall mention the International Atomic Energy Agency (IAEA) and the International Organization for Medical Physics (IOMP) with all its National member societies. These activities are most often targeting the Low-and-Middle Income (LMI) countries, where the number of medical physicists per capita is very small. When the activities described in this paper were initiated at the beginning of the 1990s all medical physicists in the world were about 12,000, now these are about 30,000 in over 80 countries [3].

A very important set of activities in this period were associated with the international recognition of the profession. The International Union for Physical and Engineering Sciences in Medicine (IUPESM) was formed specifically to serve this objective. It started its activities in 1980 as a Union of the International Organization for Medical Physics

(IOMP) with the International Federation for Medical and Biological Engineering (IFMBE) [4]. Following long and important discussions, IUPESM was accepted in 1999 as the 27th Scientific Union member of International Council of Scientific Unions (ICSU—now International Science Council, ISC). This major success was a true recognition for the scientific fields of medical physics and biomedical engineering. In 2012 IUPESM achieved recognition of the professional occupations of medical physicists and biomedical engineers, including these in the International Standard Classification of Occupations (ISCO) of the International Labour Organization (ILO). Alongside with this, both IFMBE and IOMP were accepted as Non-governmental Organisations (NGO) to the World Health Organisation (WHO).

In parallel with these very important high-level arrangements in the profession, a number of activities were initiated by various institutions and teams of specialists. These were naturally related to the establishment of educational courses in medical physics and engineering. An important set of such activities were associated with the countries in Central and Eastern Europe, which traditionally had good University education in medical engineering and could easily use this background to build medical physics University programmes. A Network was set up in 1993 which triggered the organisation of the First European Conference on Education in Medical Radiation Physics in Budapest 1994 [5]. One of the main objectives of the Conference was to establish the status and needs of education and training in Medical Radiation Physics in Central/Eastern European countries;

Following this a project was made and submitted to the European Commission (EC) for financial support (with partners from UK, Bulgaria, Italy and Ireland). This resulted in the establishment of the first International Centre for Education on Radiation Physics in Medicine (ERM) in the Medical University of Plovdiv, Bulgaria [6]. The detailed curricula and educational materials developed there were later used to support the establishment of MSc courses in medical physics in Latvia, Estonia, Lithuania, Czech Republic, Hungary, Belarus, Macedonia, Georgia, Malaysia, Thailand, Jamaica, Zimbabwe (many of these with IAEA support). The three Baltic countries developed also join MSc courses in medical physics and biomedical engineering, subject to a separate EC project [7].

These activities continued with the development of the first e-learning materials in the profession (also with the support of EC)—the project EMERALD with members from the UK, Sweden, Italy and Portugal. The international project EMERALD developed medical physics training tasks, based on the concept "learning through examples". These were supported by the development of the first educational Image Database (IDB) with images of: Equipment and its components; Block diagrams and graphs; QC procedures and measuring equipment; Test objects and image quality examples; Typical clinical images and artefacts, etc. (Figs. 1, 2). The organization of images in the IDB followed the organization of the Training tasks. The volume of the IDB was about 1400 images [8].

Initially the IDB was developed using CD-ROMs as media carriers. An unique feature of these CD-ROMs at the time was that the EMERALD Consortium published these with ISBN numbers (as books). When this was made in 1997 electronic books did not exist and the first three in the world CD-ROM Image databases with ISBN were [9]:

- Atlas of Pathology: Urological Pathology CD-ROM, Springer-Verlag, ISBN 3540146571 (published on 30 Dec 1997)
- EMERALD Image Database, Training Courses in Medical Radiation Physics CD-ROM, King's College London, ISBN 1870722035 (published on 19 February 1998)
- Developmental Psychology Image Database CD-ROM, McGraw-Hill, ISBN 0072896914 (published on 30 April 1998)

In 1999 the team of EMERALD project (with additional members from France, Czech Republic, Bulgaria and Ireland) developed the first educational web site in the profession now www.emerald2.eu which included the training tasks and the IDB in an original and user friendly setting [10]. The first materials on this web site included materials on Physics and equipment of: X-ray Diagnostic Imaging, Nuclear Medicine and Radiotherapy. In 2005 this web site was opened for free use by all colleagues in LMI countries (now is free for all).

Specific development of medical physics education for LMI countries was made through the International Centre for Theoretical Physics (ICTP) in Trieste, Italy, which operates under the aegis of the IAEA and UNESCO. In 1988 ICTP organised the first College on Medical Physics and since then is one of the most oversubscribed regular activities of the ICTP. Currently the College is held for 3 weeks, bi-annually (Fig. 3). The College curriculum is based on

Fig. 1 The first CD with EMERALD Image Database

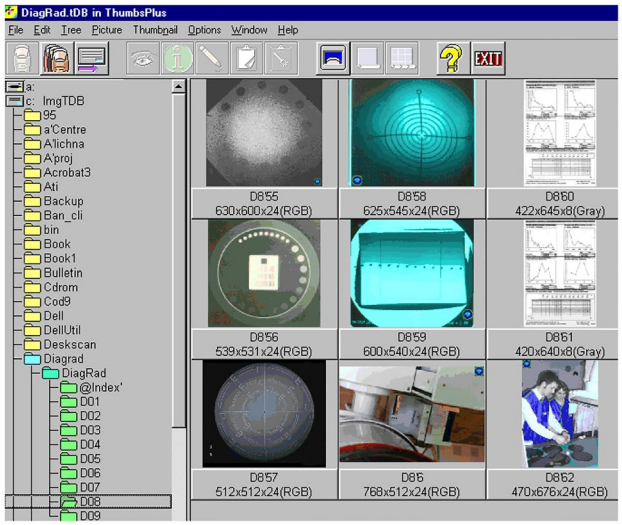

Fig. 2 The interface of the image database with thumbs (slides) for easy finding of each image. The Folders with images correspond to the Workbook chapters—a sample from the hard drive source

medical imaging physics and related radiation safety. In 2001 the College was modified to allow forming a cohesive teaching entity "Train-the-Trainer", adapted for colleagues from LMI countries [11]. This included a major objective of the College—to develop the participants as educators who can create effective medical physics programs in their countries. The emphasis of the College is on medical imaging and related radiation safety. Additionally each participant receives free educational materials (including the EMERALD and Sprawls materials) and instruction on the process of the development of appropriate educational programs for their countries [12, 13].

The ICTP College on Medical Physics unveiled a problem for the education in many countries—most of the textbooks and teaching materials were in English language, but many Universities required education to be delivered on their own language. This was not easy as most of the terminology in the profession was on English. This led to the need of development of a Scientific Dictionary of Medical Physics. This Dictionary was initiated by the project EMIT (a continuation of EMERALD), which also added medical physics training tasks in the fields of Ultrasound and Magnetic Resonance Imaging. This international project was highly praised and in 2004 was awarded with the EC Leonardo da Vinci Award [14].

The Dictionary was made with original methodology and a specific web site was made for its (currently associated with the Encyclopaedia of Medical Physics—www.emitel2.eu). The Scientific Dictionary was translated free by many senior colleagues from many countries, some of these—attendees of the ICTP College on Medical Physics. The project attracted over 200 specialists from 32 countries. Currently the Scientific Dictionary is translated in 31 languages (from English) and cross translates medical physics terms between any of its languages: Arabic, Bengal, Bulgarian, Chinese, Croatian, Czech, English, Estonian, Finnish, French, Georgian, German, Greek, Hungarian, Italian, Japanese, Korean, Latvian, Lithuanian, Malaysian, Persian, Polish, Portuguese, Romanian, Russian, Slovenian, Spanish, Swedish, Thai, Turkish, Ukrainian and Vietnamese [15]. The web site of the Scientific Dictionary is free for all and has thousands of visits per month.

The ICTP activities in the field of medical physics included also joint activities with the IAEA and in 2015 it started two new major activities—an ICTP School on Medical Physics for Radiation Therapy and an MSc programme Master of Advanced Studies in Medical Physics—a collaborative arrangement of the ICTP and the University of Trieste with the strong support of the Italian Association of Medical Physics (AIFM)—Fig. 4. Each year between 20 and 30 students from LMI countries graduate the unique MSc, some with additional support form IAEA and other institutions. Many of the graduates have become strong supporters for the development of the profession in their own countries and institutions [16].

The dynamics of the science of medical physics and the need of specific international guidance for the teaching content of various courses led to the need of development of the first e-Encyclopaedia of Medical Physics. This is the largest project in the profession, including over 150 specialists from 30 countries. The project was based on the Thesaurus of the Scientific Dictionary using also original methodology. It included many of the EMERALD materials and also materials from the educational website www.sprawls.org (developed by Prof. P Sprawls from USA and also a free online resource). The original web site of the Encyclopaedia (www.emitel2.eu) was specially made to be a user friendly reference resource with free access. The Web site includes about 4000 articles, supported with over 1000 images and diagrams. On the web site the e-Encyclopaedia is combined with the Scientific Dictionary (Fig. 5). The web site has thousands of visits per month globally [17].

The support for the colleagues in LMI countries triggered the formation in 2016 of a specific activity of the IOMP—an IOMP School. Its first run was at the International Conference on Medical Physics in Bangkok, 2016 and after this continues in various venues and with various topics. The pandemic situation in 2020 expanded this School as an online activity, which is now increasingly popular, especially among colleagues from LMI countries [18].

An important moment of the e-Encyclopaedia is that it was decided to include also materials from the field of biomedical engineering. This was based on the assessment at the ICTP College on Medical Physics that many colleagues from LMI countries perform also some duties of clinical

Fig. 3 ICTP colleges on medical physics—part of lecturers, supporters and students from 47 LMI countries, Trieste, 2016, 2018

engineering in their countries. The meetings of the ICTP College lecturers gathered feedback from the colleagues in many LMI countries and advised on the future activities in the respective LMI countries (Figs. 6, 7). This reflected in including materials related to medical equipment management in both—the College, and in the Trieste MSc on Advanced Studies in Medical Physics [19].

The collaborative activities between medical physicists and biomedical engineers led further to the creating of a sequel of IUPESM Workshops, supporting education/training activities in LMI countries and promoting the collaboration between these two sister specialities (Fig. 8). These activities are specially important for LMI countries, where the workforce is not sufficient and often specialists from one sub-part of the profession perform some duties related to the other sub-part of the profession [20].

The activities in support of medical physics development in LMI countries, described in this condensed material cover a period of almost 30 years. Alongside these, the projects of the IAEA are described in [21] and the activities of other Federation, Societies and Institutions are described in many of the free issues of the IOMP Journal Medical Physics International 2018–2021 (www.mpijournal.org). This Journal was established in 2013 specifically to provide platform for exchange of expertise in the field of education and professional development. The Journal is a free online resource, used regularly by all colleagues from LMI countries.

Fig. 4 First IOMP accredited alumni of MSc Advanced Studies in Medical Physics with supporting colleagues from AIFM, 2017

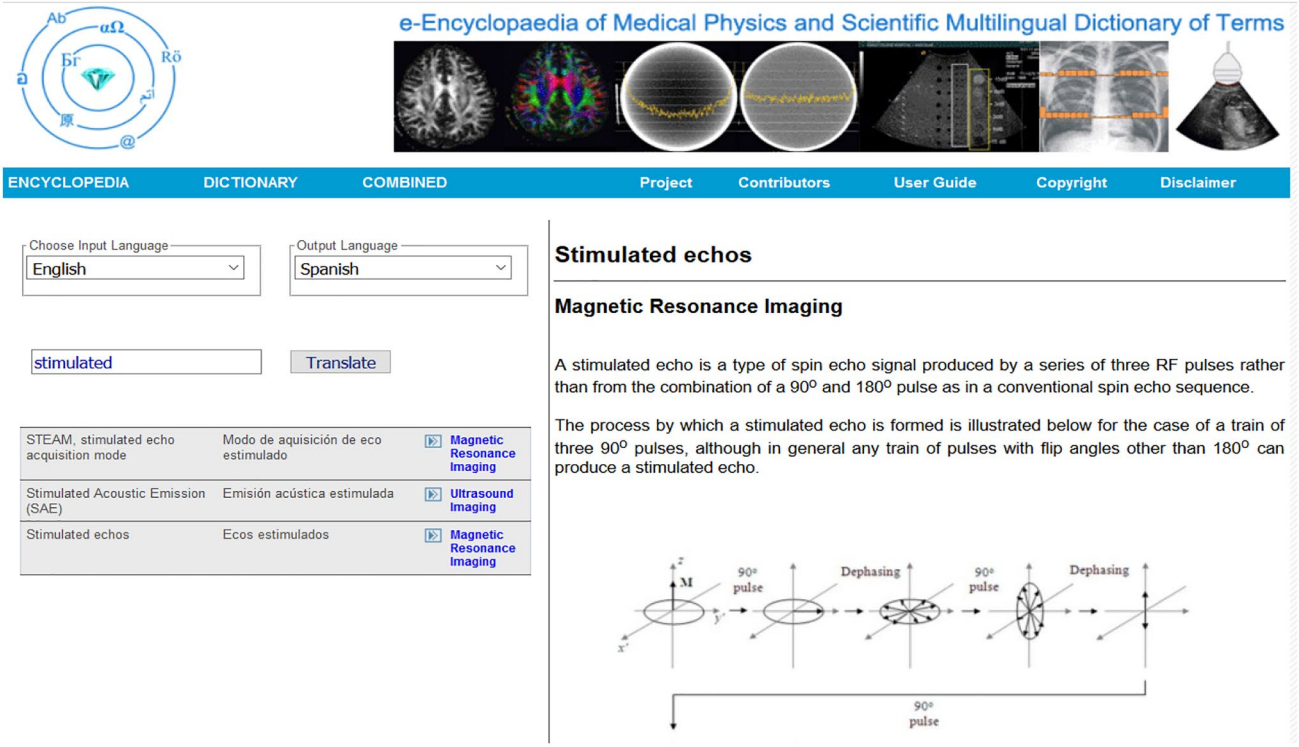

Fig. 5 Part of the interface of the Medical Physics e-Encyclopaedia and Scientific Dictionary—www.emitel2.eu

During these 30 years the growth of the profession per decade doubled and is now steadily moving toward the goal set by the WHO-supported projection of about 60,000 medical physicists globally by 2035 [22]. The stable growth of this workforce is especially important for the harmonious development of healthcare provision in LMI countries.

The described introduction of e-learning in the profession, initially targeting LMI countries, developed quickly into a steady trend in medical physics [23]. This built significant e-learning expertise and confidence in all educational courses in the profession, what appeared to be crucial during the time of the pandemic [24].

The map on Fig. 9 shows the places around the world where the described e-learning materials have been used, mainly by graduates of the ICTP College on Medical Physics, which now has students in over 80 LMI countries. Currently about 25% of all medical physicists from LMI countries are graduates of this College and use these materials. Many of these colleagues became leading specialists in their countries, opened Master-level and other courses what further supported the global growth of the profession.

For over 100 years medical physics has been dealing with radiation in medicine, saving millions of lives and contributing to better healthcare globally. Top-technology research and management in medical equipment, taken for granted in developed countries, present a huge challenge for LMI countries. The key to address this challenge and to increase quality of healthcare and the effectiveness of medical technology usage, lies in adequate education and training for medical physicists and engineers, who are the front-liners when it comes to dealing with technology in healthcare. To help LMI countries professional growth in the field of medical physics and technology, we developed an education strategy, based initially on the revolutionary application of digital and online resources through large international network. Our primary focus on collaborative networking

Fig. 6 Meeting at ICTP College with students from Africa, ICTP, 2016

Fig. 7 Meeting at ICTP College with students from Latin America, ICTP 2018

and experience exchange provides free and easy to access educational resources (through Emerald Network and others such activities). The Medical Physics College at ICTP, Trieste (operating under the aegis of UNESCO and IAEA) existed for 30 years and during the last 20 years focused its activities on education. Its Train-the-Trainer approach trained over 1200 medical physicists from 82 LMI countries. These activities form a significant part of the 60% increase of medical physics workforce during the past decades, which is vital contribution to contemporary healthcare. These activities supported with measurable effect the application of the increased amount of medical equipment and also supported the disaster preparedness and handling during the COVID-19 pandemic.

Fig. 8 IUPESM collaborative workshop in Asia, Taipei, 2019

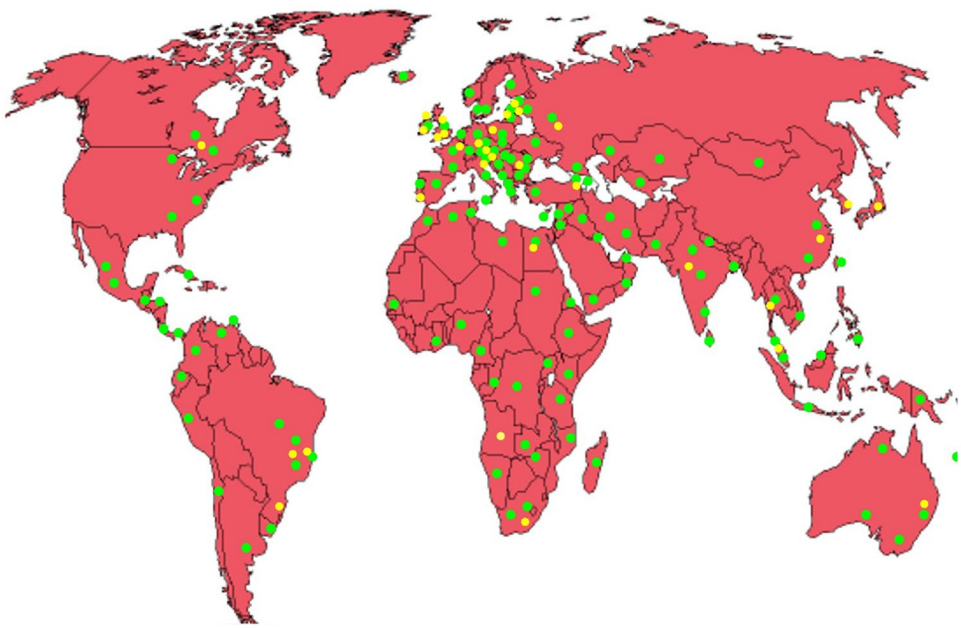

Fig. 9 Places around the world where the described e-learning materials have been used, mainly by graduates of the ICTP College on Medical Physics

Funding N/A.

Declarations

Conflict of interest Magdalena Stoeva is the Editor-in-Chief of Health and Technology, Slavik Tabakov is an Associate Editor in Health and Technology.

References

1. UNSCEAR. Sources and effects of ionising radiation. 2008. http://www.unscear.org/docs/reports/2008/09-86753_Report_2008_Annex_A.pdf.
2. Tabakov S. Global number of medical physicists and its growth 1965–2015. J Med Phys Int. 2016;4:78–81.
3. Tsapaki V, Tabakov S, Rehani M. Medical physics workforce: a global perspective. Phys Med. 2018;55(2018):33–9.
4. Goh J, Tabakov SD. 40 years IUPESM. Health Technol. 2020;10:1331–6. https://doi.org/10.1007/s12553-020-00493-8.
5. Roberts C, Tabakov S, Lewis C. Medical radiation physics: a european perspective. London: King's College London; 1995. ISBN 1 870722 02 7.
6. Tabakov S, Roberts C, Milano F, Sheahan N, Tabakova V, Velkova K, Litchev A, Stoilov G, Petrova G, Spassov G, Yaneva M, Michova L, Milieva E, Kostianev S, Boyadjiev N, Belev G, Balabanov N, Mitrkov M, Trindev P, Daskalov I, Pressianov D, Nencev M. Inter-university education centre and msc course in medical radiation physics and engineering. J Med Biol Eng Comput. 1999;37(s1):153–4.
7. Dekhtyar Y, Hinrikus H, Katashev A, Kingisepp A, Lukosevicius A, Meigas K, Oberg A, Soosaar A, Spigulis J, Tabakov S. Joint-baltic biomedical engineering and physics courses. J Med Biol Eng Comput. 1999;37(s1):144–5.
8. Strand S, Milano F, Tabakov F, Roberts C, Lamm I, Liungberg M, Benini A, da Silva G, Jonson B, Jonson L, Lewis C, Teixeira N, Compagnucci A, Ricardi L. EMERALD for vocational training and interactive learning. In: 18 symposium on radioactive isotopes in clinical medicine, Euroepan journal of nuclear medicine. Springer-Verlag; 1998, v.25, S.1, pp. 1–6.
9. Tabakov S. History of medical physics e-learning introduction and first activities. J Med Phys Int. 2018;6(SI1):82–109.
10. Jonson B-A, Tabakov S, Aitken V, Alquist M, Clarke G, Goss D, Giraud J, Jansson T, Lewis C, Ljungberg M, Strand S, Lamm I, Milano F, Noel A, Roberts C, Sherriff S, Simmons A, Smith P, Stahlberg F, Wirestam R. EMERALD and EMIT: worldwide computer aided education and training packages in medical physics. J CAL-laborate. 2005;13:10–5.
11. Bertocchi L. Medical physics at ICTP: the abdus salam international centre for theoretical physics, trieste (from 1982 to 2010). In: Tabakov S, Sprawls P, Krisanachinda A, Lewis C, editors. Medical Physics and Engineering Education and Training—part I; 2011. ISBN 92-95003-44-6, ICTP, Trieste, Italy.
12. ICTP College on Medical Physics Celebrating 30 years. (2018). http://www.emerald2.eu/mep/e-book-ictp/ICTP_College_on_Medical_Physics_Celebrates_30_years_s.pdf.
13. Sprawls P, Tabakov S. A model for effective and efficient teleteaching of medical physics. World Cong Med Phys Biomed Eng IFMBE Proc. 2009;25:221–2.
14. Tabakov S, Tabakova V. The pioneering of e-learning in medical physics. London: Valonius Press; 2015. http://www.emerald2.eu/mep/e-learning/Pioneering_of_eLearning_1_pw.pdf.
15. Tabakov S, Tabakova V, Stoeva M, Cvetkov A, Milano F, Strand S-E, Giraud J-Y, Lewis C. Medical physics thesaurus and international dictionary. J Med Phys Int. 2013;2:139–44.
16. Loreti G, Aslian H, Brito A, Delis H, Longo R, Padovani R. Evaluation of the impact of an international master of advanced studies in medical physics. World Congress on Medical Physics and Biomedical Engineering, Prague, Proceedings; 2018, pp. 361–362.
17. Tabakov S, Sprawls P, Milano F, Strand S-E, Lewis C, Stoeva M, Cvetkov A, Tabakova V, Damilakis J. Medical physics e-encyclopaedia and multilingual dictionary: upgrade and new developments. World Congress on Medical Physics and Biomedical Engineering, Toronto, Keynote speech, Proceedings; 2015. pp. 361–362.
18. All IOMP School activities. www.iomp.org/iomp-school/.
19. Tabakov S, Padovani R. MSc medical physics curriculum including clinical engineering elements, international clinical engineering and health technology management congress, Rome, Proceedings; 2019. http://www.icehtmc.com/.
20. Stoeva M, Lin KP. IUPESM (IFMBE & IOMP) activities and opportunities in the field of early career development, International Clinical Engineering and Health Technology Management Congress, Rome, Proceedings; 2019. http://www.icehtmc.com/.
21. Loreti G, Delis H, Healy B, Izewska J, Poli GL, Meghzifene A. IAEA Education and training activities in medical physics. J Med Phys Int. 2015;3:81–7.
22. Atun R, Jaffray DA, Barton MB, Bray F, Baumann M, Vikram B, Hanna TP, Knaul FM, Lievens Y, Lui TYM, Milosevic M, O'Sullivan B, Rodin DL, Rosenblatt E, Van Dyk J, Yap ML, Zubizarreta E, Gospodarowicz M. Expanding global access to radiotherapy. Lancet Oncol. 2015;16:1153–86.
23. Tabakova V. e-learning in medical physics and engineering. CRC Press; 2020. ISBN 978 13834732 8.
24. Ng KH, Stoeva M (Ed). Medical physics during the covid-19 pandemic. CRC Press; 2021. ISBN 978-0367693756.