EXTERNAL BEAM RADIOTHERAPY FACILITIES IN UKRAINE. TRENDS AND CHALLENGES

V.P. Starenkiy[1], O.O. Petrichenko[2], L.O. Averyanova[3]*
[1]State Institutoin "Grigoriev Institute for medical Radiology NAMS of Ukraine", Kyiv, Ukraine;
[2]National Academy of Medical Science of Ukraine, Kharkov, Ukraine;
[3]Kharkiv National University of Radio Electronics, Kharkov, Ukraine
[*]E-mail: imr@ukr.net

The most important aspects of technological support of the radiation therapy of Ukraine are considered in accordance with the requirements of the IAEA. The reasons that influence the availability of radiotherapy for cancer patients in Ukraine are analyzed taking into account the experience of Grigoriev Institute for Medical Radiology of the National Academy of Medical Sciences of Ukraine.

PACS: 87.56.-v; 87.56.bd; 87.55.Qr

INTRODUCTION

The beam sources of radiation are applied in medicine from the first years of the accelerators emergence. Now it is impossible to imagine modern oncology without these technologies. But existence and maintenance of appropriate equipment requires a high level of the financial and technological support. The level of radiation technologies development directly reflects the level of scientific and technical development and economic conditions in any country [1 - 3]. The current situation in the world on this subject is shown in Fig. 1.

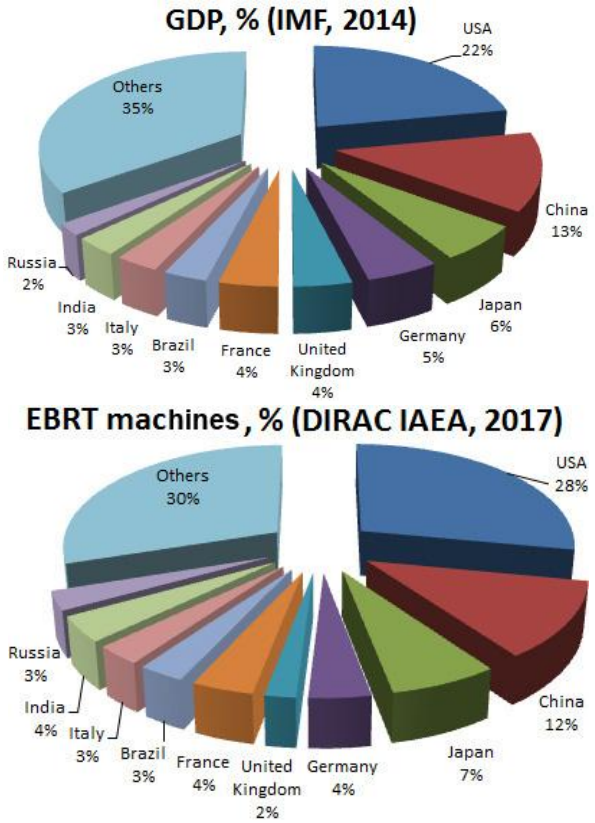

Fig. 1. Interrelation between GDP and number of EBRT equipment in the world

The analysis of interrelation GDP level (the IMF, 2014) and external-beam radiation (EBRT) equipment in the world (DIRAC IAEA) has shown that 67.9% of the world park of EBRT equipment are concentrated in 10 most powerful countries with the greatest GDP (65.2% of world GDP). Direct compliance between the GDP level and the number of EBRT equipment is obvious.

According to guidelines of IAEA it's enough to have 4 MV EBRT machines per 1 million of population for sufficient availability of radiation treatment [4]. The main types of megavoltage radiotherapy equipment currently are medical 6…18 MeV linear accelerators of electrons (linacs) and Co-60 machines. According to actual data of IAEA DIRAC Database there are more than 11648 linacs, 2156 Co-60 machines and 138 particle accelerators in use worldwide.

Global trends indicate decrease of quantity of Co-60 machines and more wide use of linacs. EBRT linacs are more flexible in use and allow implement new technologies with high accuracy of dose delivery – IMRT, IGRT, ARC, tomotherapy, stereotaxic radiosurgery. But on the other hand linacs can be operated only by very qualified specialists, in good technological conditions. Thus this equipment and requirements for its maintenance are much more complex than for previous simple Co-60 machines. Linac-based technologies can be used successfully if enough of resources for all workflow. Linacs are integrated into RT network and operate under control of modern computer systems with support of built-in imaging systems. Of course old Co-60 machines have significant drawbacks and limitations for RT. That is why ratio "linacs to Co-60 machines" can be used as indicator of technological level of radiotherapy and effectiveness of cancer patient's care. For high developed regions (North America and Western Europe) the average ratio "linacs vs Co-60 machines" is near 96 to 4%, for Eastern Europe and North Asia – 60 to 40% respectively.

1. DEVELOPMENT OF EBRT IN UKRAINE

Ukraine is classified by DIRAC IAEA as Low Middle Income country with level of availability 2.6 EBRT machines per 1 million of population. Now Ukraine has 58 RT centers. As of the beginning of 2017 there were 80 Co-60 machines and 25 linacs in use in Ukrainian hospitals, ratio "linacs vs Co-60 machines" is 24 to 76%. It indicates significant technological problems in Ukrainian radiation medicine.

Use of 125 EBRT machines cover only 65% needs of Ukrainian population in radiation treatment.

During all years of existence of independent Ukraine use of Co-60 machines was predominant in radiotherapy

centers (Fig. 2). Even now we can't overcome the problem of inaccessibility of modern linacs for wide clinical use in Ukraine [5]. Among used Co-60 machines 35% of them require immediate replacement of Co-60 source with simultaneous procedural service for the further use, 16% machines are in use more than 30 years.

Since 2014 Ukraine has lost control over 13 EBRT machines in occupied part of Donbass and 5 machines in Crimea (totally 17% of Ukrainian EBRT machines). So the catastrophic shortage of the RT equipment in Ukraine is obvious.

The main reason for this situation is the shortage of state and regional financial resources on maintenance of high technologies in health care. In case of enough financial resources the installation of the newest EBRT systems in Ukraine can be done as quickly as in Poland or Turkey where state programs of global RT upgrade were implemented under supervision of appropriate European institutions.

As for efficient radiological staff Ukraine still has good personnel opportunities, scientific and educational support. Especially it is really to implement this technology in Kharkiv region thanks to comprehensive support of National Science Center Kharkiv Institute of Physics and Technology, Karazin Kharkiv National University, Kharkiv National University of Radio Electronics.

Just Kharkiv has rich experience in development and application of particle accelerators. The first in Ukraine in-room medical linac was mounted in 1991 in Kharkiv Grigoriev Scientific Research Institute for Medical Radiology. Both 15 MeV photon and 10…15 MeV electron beams were available for clinical use (Fig. 3).

Linac LUEV-15 M1 was developed and produced in NIIEFA (Yefremov Scientific Research Institute of Electrophysical Equipment). It allowed conventional 2D RT with high clinical capacity (up to 15 sec per patient). Several medical scientific research projects have been successfully performed during operation of LUEV-15 M1 in Kharkiv Institute for Medical Radiology.

The results of these researches proved that use of 15 MeV photon beam for radical RT of lung cancers allow to improve results of treatment (90.4% of cases) and considerably reduce negative side effects in comparison with effects reached after treatment with use Co-60 machine (gamma radiation 1.25 MeV) [6]. Therefore clinical use of high energy linac for elimination of growth of some forms of tumors was justified and successful. But this technology was limited in use because maintenance of equipment was very complicated. It caused by complexity of linac design, primitive control, low reliability, quick hardware obsolescence and insufficient technical support. Problems of post-soviet disintegration of technological infrastructure in 1990th caused closure of short period of use of soviet linacs in Ukraine.

The next attempt of returning of linacs to Ukrainian oncology centers was done in 2000th (Fig. 4). Thanks to experience and knowledge gained in previous years Ukrainian technicians and radiologists have overcome difficulties of installation and start of new generation of linac-based EBRT equipment.

Fig. 2. Co-60 machine ROCUS-AM in treatment room of Kharkiv Grigoriev Scientific Research Institute for Medical Radiology, since 1990

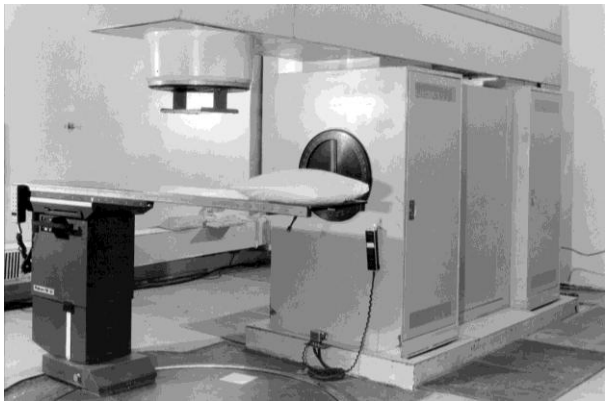

Fig. 3. Linac LUEV-15 M1 in treatment room of Kharkiv Grigoriev Scientific Research Institute for Medical Radiology, since 1991

Fig. 4. Linac Varian Clinac 600C in treatment room of Grigoriev Institute for Medical Radiology NAMS of Ukraine, since 2010

Now all main linac-based EBRT equipment developers – Varian, Elekta, Accuray and Siemens – are presented in Ukraine (Fig. 5). Distribution of working EBRT linacs in Ukraine by key linac manufacturers is shown on Fig. 5,a. For comparison the global distribution of EBRT linacs worldwide is shown on Fig. 5,b.

General correspondence between these two diagrams indicates that Ukraine follow global trends of EBRT linac market on qualitative structure. But quantitatively we have lack of this modern equipment in all regions of Ukraine except for Kyiv. All newest equipment (Figs. 6,b,c) is installed in private centers thus now it isn't available for ordinary patients.

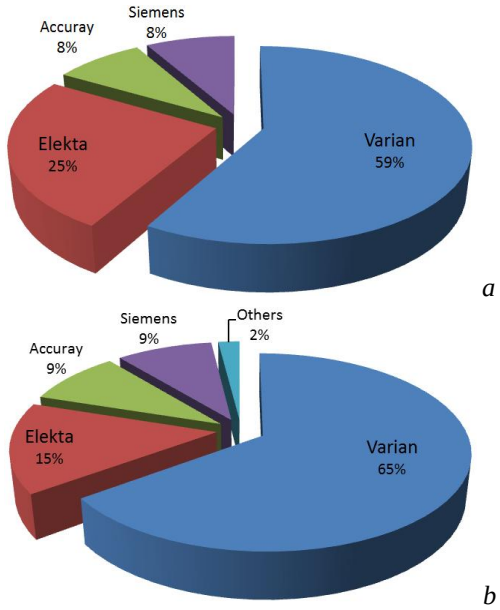

Fig. 5. Distribution of EBRT linacs by manufacturers: a – in Ukraine (DIRAC IAEA); b – worldwide (Zacks Small-Cap Research, 2016)

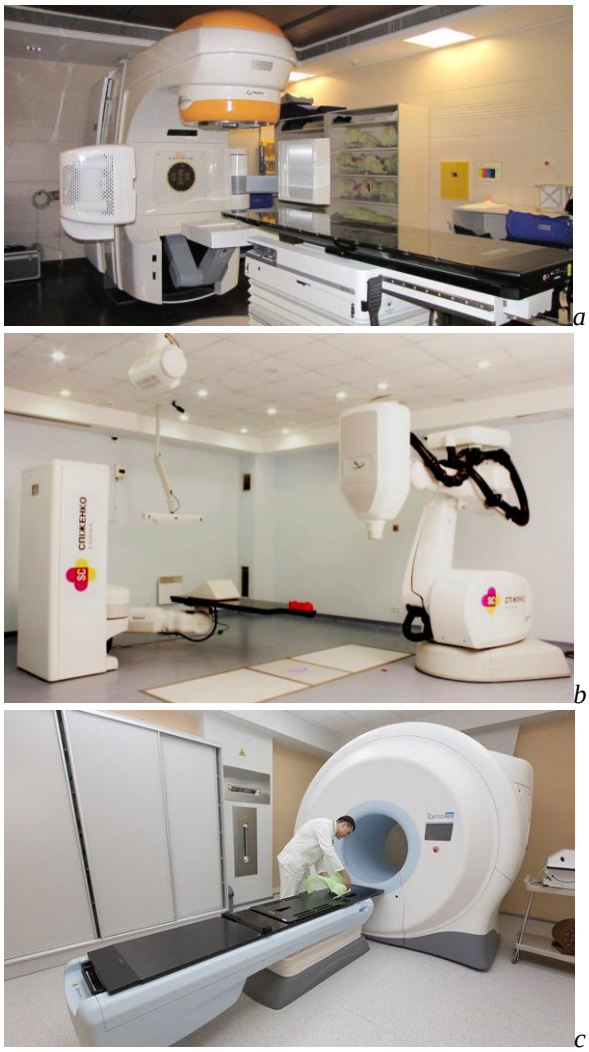

Fig. 6. New generation of RT linacs in Ukraine: a – Varian Novalis TX in Clinical Hospital "Pheopaniya", Kyiv, since 2011; b – Accuray CyberKnife G4 in Cyber Clinic of Spizhenko, Kapitanovka, since 2009; c – Accuray Tomo HD in Ukrainian Center of Tomotherapy, Kropyvnytskyi, since 2015

2. IAEA GUIDELINES FOR UKRAINIAN EBRT SERVICE

According to Recommendations of IAEA [7] basic radiation therapy services at a minimum should be made available to all patients with cancer who need them. Ukraine must overcome 35% shortage of EBRT equipment in the next years. During this process all installed and working megavolt EBRT equipment (both Co-60 machines and linacs) must cover needs of Ukrainian patients without stops and failures. It is necessary to overcome disproportions in distribution of the equipment between regions. Radiation treatment has to become more available for population of Ternopil, Chernovtsi, Vinnytsia and Mykolaiv regions (level of EBRT equipment less than 25%); Lviv, Ivano-Frankivsk, Odessa, Kharkiv regions (level of EBRT equipment is near 30%). All working Co-60 machines must be recharged by new Co-60 sources according to technical requirements and be in use till the new linacs will be installed.

Ukraine must implement modern education and training programs to enable good quality radiation therapy services. Of course it is necessary to provide adequate salary levels to retain staff of existing RT departments and grow new generation of specialists for maintenance of the newest smart EBRT systems.

Implementation of adequate QA/QC program for EBRT is necessary condition for improvement of RT service in Ukraine.

Ukrainian RT specialists must clearly define which cancer outcomes are expected to be improved by the introduction of advanced technologies.

As an example it's necessary to consider daily capacity of every EBRT machine according with the chosen technology (E.V. Titovich, I.G. Tarutin, 2014):

- 2D RT needs 15 min per patient;
- 3D CRT needs 20 min per patient;
- IMRT needs 25 min per patient;
- IGRT needs 35 min per patient;
- SRT needs 40 min per patient.

During two-shift working day RT department can treat no more than 38 patients with use of 100% high-tech EBRT or 64 patients if rate of high-tech EBRT is 60% or 100 patients if rate of high-tech EBRT is only 20%. Thus no need to use only advanced technologies of EBRT for ordinary clinical cases. The specialists of Grigoriev Institute for Medical Radiology NAMS of Ukraine proposes as desirable to equip Ukrainian RT centers by 60% of conventional low-energy EBRT linacs, by 30% of upgraded Co-60 machines and only by 10% of high-tech, high-energy EBRT linacs and radiosurgery equipment. It corresponds to actual structure of cancer incidence in Ukraine.

CONCLUSIONS

The main actual aspects of technical equipment of external-beam radiation therapy in Ukraine were discussed. Existing EBRT facilities were analyzed from the point of view of real needs of Ukrainian radiation oncology and some recommendations for improvement of RT service in Ukraine are proposed.

REFERENCES

1. Mei Ling Yap, Eduardo Zubizarreta, Freddie Bray, Jacques Ferlay, and Michael Barton. Global Access to Radiotherapy Services: Have We Made Progress During the Past Decade? // *Journal of Global Oncology*. 2016, v. 2, № 4, p. 207-215. DOI: 10.1200/JGO.2015.001545
2. S. Grover, M.J. Xu, A. Yeager, L. Rosman, R.S. Groen, S. Chackungal, D. Rodin, M. Mangaali, S. Nurkic, A. Fernandes, L.L. Lin, G. Thomas, A.I. Tergas. A systematic review of radiotherapy capacity in low- and middle-income countries // *Frontiers in Oncology*. 2015, Jan. 22, p. 4380.
3. V. Levin, H. Tatsuzaki. Radiotherapy services in countries in transition: gross national income per capita as a significant factor // *Radiother. Oncol.* 2002, v. 63, № 2, p. 147-50.
4. International Atomic Energy Agency. Vienna. Planning National Radiotherapy Services: A Practical Tool // *IAEA Human Health Series.* 2010, № 14. STI/PUB/1462, (ISBN: 978-92-0-105910-9), 83 p.
5. V.P. Starenkiy, L.L. Vasyliev, I.O. Samofalov. The Problems and Perspectives of Megavoltage Photon Beam Radiotherapy in Ukraine // *Problems of Atomic Science and Technology. Ser. "Nuclear Physics Investigations"*. 2016, № 5(105), p. 94-97.
6. V.P. Starenkiy. Comparative assessment of gamma-radiation and linear accelerator braking radiation efficacy for treatment of patients with lung cancer // *Thesis for academic degree of Candidate of Science (Medicine) in speciality 14.01.23 - radiodiagnosis, radiotherapy.* Kyiv Research Institute of Radiology and Oncology, Kyiv, 1998, 20 p.
7. E.K. Salminen, K. Kiel, G.S. Ibbott, et al. International Conference on Advances in Radiation Oncology (ICARO): Outcomes of an IAEA Meeting. *Radiation Oncology (London, England)*. 2011; 6:11. doi:10.1186/1748-717X-6-11.

Article received 09.10.2017

ДИСТАНЦИОННАЯ ЛУЧЕВАЯ ТЕРАПИЯ В УКРАИНЕ. ТЕНДЕНЦИИ И ПРОБЛЕМЫ

В.П. Старенький, А.А. Петриченко, Л.А. Аверьянова

Наиболее важные аспекты технологической поддержки лучевой терапии в Украине рассматриваются в соответствии с требованиями МАГАТЭ. Обстоятельства, влияющие на доступность радиотерапии для онкопациентов в Украине, анализируются с учетом опыта Института медицинской радиологии им. С.П. Григорьева Национальной академии медицинских наук Украины.

ДИСТАНЦІЙНА ПРОМЕНЕВА ТЕРАПІЯ В УКРАЇНІ. ТЕНДЕНЦІЇ ТА ПРОБЛЕМИ

В.П. Старенький, О.О. Петриченко, Л.О. Авер'янова

Найбільш важливі аспекти технологічної підтримки променевої терапії в Україні розглядаються відповідно до вимог МАГАТЕ. Обставини, що впливають на доступність радіотерапії для онкопацієнтів в Україні, аналізуються з урахуванням досвіду Інституту медичної радіології ім. С.П. Григор'єва Національної академії медичних наук України.