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Original Article

Current and Future Challenges of Radiation Oncology in Iran: A Report from the Iranian Society of Clinical Oncology

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Abstract

Aims: Growth of the cancer incidence rate in Iran has been very high in recent years. Therefore, the Iranian health care system should be prepared for the treatment of a huge number of patients in the foreseeable future. One of the most important treatment options for cancer is radiation. However, there is no comprehensive information on infrastructure for radiation oncology in this country.
Materials and methods: In 2015, a questionnaire was designed by the Iranian Society of Clinical Oncology (ISCO) and all radiation oncology centres in the country were visited to determine four important components of radiation oncology services, including facilities, equipment, personnel and patients.
Results: In 2015, 94 radiotherapy centres were identified in Iran. Sixty-one centres were fully operational, six centres were commissioning, 26 centres were under construction and one was inactive. Among the fully operational radiotherapy centres, 54 offered three-dimensional conformal radiotherapy and two-dimensional radiotherapy, eight offered brachytherapy, two intensity-modulated radiotherapy, two intraoperative radiotherapy, ostereotactic radiosurgery, two hyperthermia and 59 chemotherapy. Moreover, the survey identified 110 linear accelerators, 25 cobalt-60, one gamma knife, 21 remote brachytherapy afterloaders and six orthovoltage units. Treatment planning equipment included 15 graphy simulators, 19 dedicated computed tomography simulators, 22 multileaf collimator and 12 electronic portal imaging devices. Moreover, in 2015, 243 clinical oncologists participated in the treatment of 42 350 cancer patients in need of radiotherapy, which is about one radiation oncologist for 175 patients. During 2010–2015, number of cobalt-60 reduced 70%, from 25 units to 8 units.
Conclusions: There is a significant gap between Iran's available facilities for radiation therapy and international standards. Moreover, during international economic sanctions against Iran this gap widened.

Key words: Economic sanctions; infrastructure; Iran; radiotherapy

Introduction

About 60% of the world's new cancer cases and 70% of the world's cancer deaths occur in developing countries [1]. In Iran, cancer is the third leading cause of death [2]. Although the age-standardised cancer incidence rate in Iran is lower compared with the global average rate (134 versus 188), the growth of cancer incidence in Iran has been very high in recent years [3–5]. In fact, the incidence of all types of cancer is significantly increasing [3,6–12] and health care systems should be prepared to offer sufficient cancer care in the near future.

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Radiotherapy is one of the most important treatment options for cancer. In fact, 50–70% of cancer patients require radiotherapy at some point during their treatment. This treatment is highly cost-effective compared with other treatment options, such as surgery and chemotherapy [13]. Among cancer specialists, clinical oncologists have carried out non-surgical treatment of cancer in Iran. Demand for radiotherapy treatment is steadily increasing because of its benefits and the growing number of patients who need such treatment. However, no comprehensive information about the infrastructure of radiation oncology, including equipment, personnel, patient load and geographic distribution exists in Iran. Therefore, the Iranian Society of Clinical Oncology (ISCO) proposed to conduct this national study.

Materials and Methods

In 2015, ISCO designed a national survey questionnaire examining nearly 400 variables. This questionnaire assesses 11 elements in radiation oncology facilities. The first element considers the general characteristics of a radiotherapy centre, including its status (active or not), staffing and patients. The studied centres were divided into four groups: (i) fully operational; (ii) commissioning, i.e. centres in which the accelerator is installed but does not admit patients; (iii) under construction, i.e. centres that are under construction, thus the accelerator is not installed; and (iv) non-operational, i.e. centres that were previously operational and equipped with cobalt-60.

The second element includes the linear accelerator (linac) of the centre. The third element includes the cobalt-60 system, as an older radiation treatment device that applies a cobalt-60 radioactive source. The remaining eight elements include as follows: (4) orthovoltage system, which is the oldest radiation treatment device; (5) simulators; (6) brachytherapy; (7) treatment planning systems (TPS); (8) other equipment and facilities in the wards; (9) treatment information; (10) chemotherapy and (11) other facilities and upgrade programmes.

In 2015, one clinical oncologist visited all radiation treatment centres in the country to collect data. For centres that were under construction, the data were gathered via e-mail and telephone calls. In the case of a low response or no response, multiple telephone calls and e-mails were used. If the response was not satisfactory, contact with regulatory authorities ensured a 100% response rate from all centres.

Results

Radiotherapy Facilities

This survey identified 94 radiotherapy centres in Iran in 2015. Sixty-one centres were fully operational, six centres were commissioning, 26 centres were under construction and one was inactive. These 94 centres had four types of management organisation. Eleven centres were charity based; 14 centres were teaching centres with public services managed by academic organisations; the rest were 28 public-service centres and 41 private centres. The fully operational centres included eight charity-based centres, 13 teaching centres, 18 public service centres and 22 private centres. It should be noted that among 61 fully operational centres, 54 centres provided external beam radiotherapy with or without brachytherapy and seven centres provided only brachytherapy. Furthermore, 43 (80%) fully operational external beam radiation treatment centres had chemotherapy facilities. Overall, 59 of 94 radiation oncology centres (including fully operational, commissioning, under construction) provided chemotherapy treatment as well. Therefore, some of these 59 centres did not have an active linac.

In terms of functionality, among fully operational radiotherapy centres, 54 centres offered three-dimensional conformal radiotherapy (3DCRT) and two-dimensional radiotherapy, eight offered brachytherapy, two offered intensity-modulated radiation therapy (IMRT), two offered intraoperative radiation therapy, one offered stereotactic radiosurgery, two offered hyperthermia and 51 offered chemotherapy.

Considering the geographical distribution of facilities, significant differences emerged between provinces. For example, Tehran had 26 fully operational centres, whereas nine provinces, including Ilam, Lorestan, Ghazvin, Semnan, Khorasan-e-Shomali, Kohkiloyeh-va-Boyerahmad,Bushehr, Khorasan-e- Jonobi, Sistan-va-Balochestan, had no fully operational centre (Figure 1).

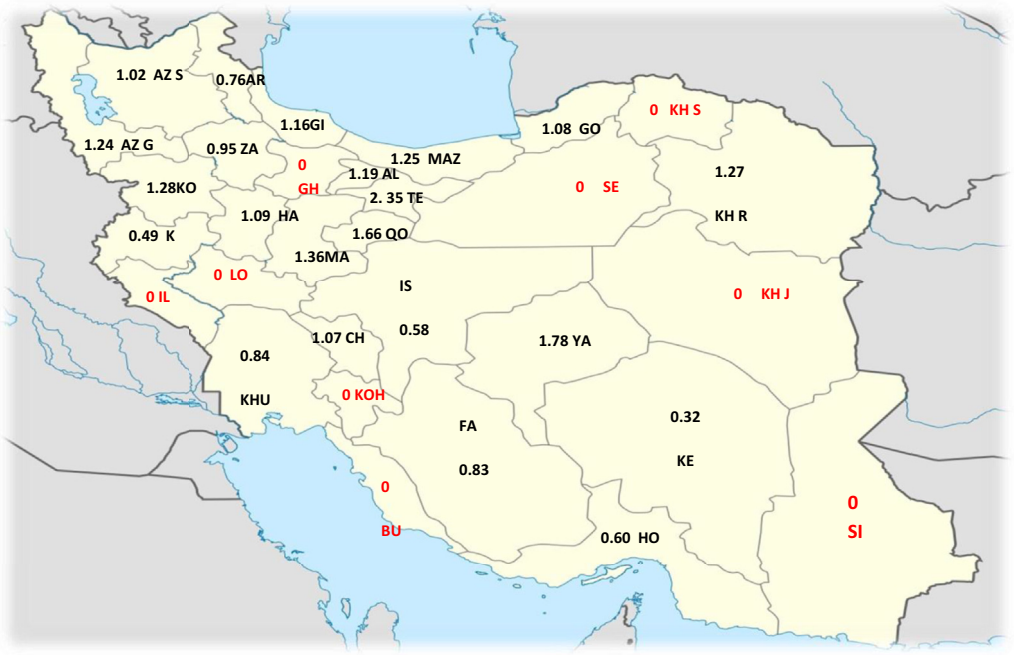
Figure 2 shows the radiation oncology centres that had physiotherapy, palliative medicine, nutrition counselling and other sections that help rehabilitation, management of complications and better care.

Equipment

During 2010–2015, the number of fully operational linacs increased from 32 to 77 units, representing a 130% increase, whereas installed cobalt-60 units decreased from 25 units to 8 units, which is a 70% decrease (see Table 1) [14]. At the end of 2015, there were 110 linacs, 25 cobalt-60, one gamma knife, 21 brachytherapy afterloaders and six orthovoltage units. Among these, fully operational units included 77 linacs, eight cobalt-60, one gamma knife, eight brachytherapy afterloaders and two orthovoltage units. Moreover, during the survey period, there were 19 brachytherapy centres with 21 brachytherapy afterloaders. From these 21 systems, nine were low dose rate and 12 were high dose rate. The source in seven was iridium-192, in seven was cobalt-60, in five was cesium-137 and in two was iridium-192 and cobalt-60. In terms of treatment plan equipment, there were 15 plain simulators, 19 dedicated computed tomography simulators, 22 multileaf collimators, 12 electronic portal imaging devices and 52 treatment planning software.

Staffing

The number of clinical oncologists in Iran increased from 147 to 243 between 2010 [14] and 2015, which is an increase



Population/province: 3,892,407 /**Az**arbayjane **s**harghi 3,217,514 /**Az**arbayjane **g**harbi 1,302,701 /**Ar**dabil 5,093,089 /**Is**fahan 2,519,078 /**Al**borz 580,722 /**IL**am 1,075,120 /**Bu**shehr 12,720,950 /**Te**hran 933,864 /**Ch**armahal o Bakhtiari 690,588 /**Kho**rasane **j**onobi 6,262,380 /**Kho**rasane **R**azavi 902,473 /**Kh**orasane **s**homali 4,732,099 /**Khu**zestan 1,059,425 /**Za**njan 659,198 /**Se**mnan 2,644,639 /**Si**stan o baloochestan 4,802,728 /**Fa**rs 1,255,615 /**Gh**azvin 1,200,682 /**Gho**m 1,561,671 /**Ko**rdestan 3,068,409 /**Ke**rman 2,032,527 /**K**ermanshah 690,588 /**Koh**kiloye boyerahmad 1,852,032 /**Go**lestan 2,589,706 /**Gi**lan 1,828,489 /**Lo**restan 3,209,666/**Maz**andaran 1,475,348 /**Ma**rkazi 1,647,995 /**Ho**rmozgan 1,836,337 /**Ha**madan 1,122,206 /**Ya**zd

Fig 1. Number of MV machines per 1 000 000 population in 31 provinces of Iran, at the end of 2015.

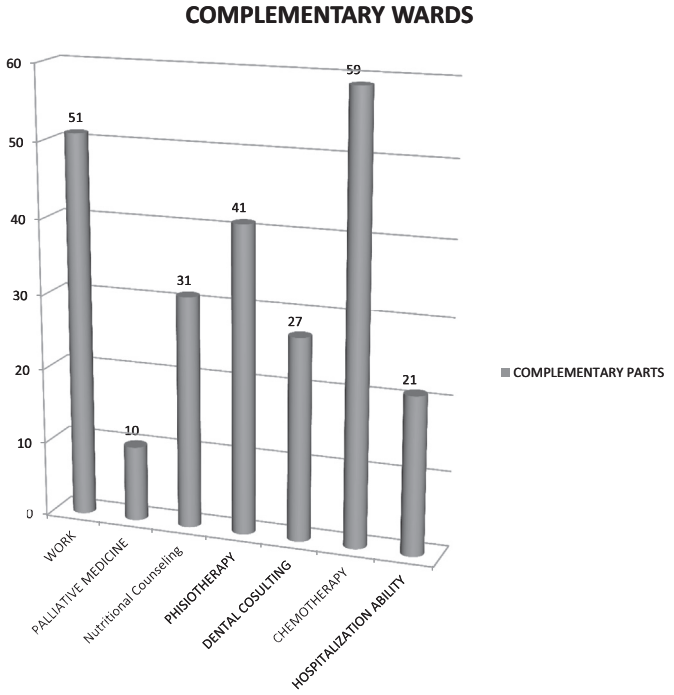


Fig 2. Radiotherapy centres in terms of having complementary wards.

of 63%. Moreover, the number of postgraduate trainees in clinical oncology increased from 45 to 65, which is an increase of 44%. Table 2 describes the number and type of personnel working in radiotherapy centres in 2010 and 2015.

Patients

Overall, 42 350 cancer patients (including primary cases and retreatment) received radiotherapy in 2015. Figure 3 illustrates the curative/palliative treatments as percentages of the total.

Discussion

Cancer is the third main cause of death in Iran [15]. The number of new cancer cases in Iran in 2015 was at least 100 000 [16], based on ministerial statistics and GLOBOCAN data. The rate of radiotherapy utilisation in cancer patients is 50% (50% * 100 000 = 50 000) and 10% of these patients need re-radiotherapy (10% * 50 000 = 5000) [17]. Therefore, the total number of patients needing radiotherapy was expected to be about 55 000 in 2015.

However, in 2015, 42 350 patients were treated with radiotherapy. This is 77% of the expected radiotherapy

Table 1
Treatment equipment of radiotherapy centres in 2010 [19] and 2015

Treatment modalities	Year		
	2010	2015	
	Operational	Operational	Commissioning, being set up or inactive
Linea accelerator	32	77	33
Cobalt 60	25	8	10
Orthovoltage	2	2	4
Brachytherapy	10	7	12
Gamma knife	1	1	0
Hyperthermia	0	2	0

cases. This difference could be the result of several factors. First, the current low cancer incidence rates in Iran may indicate that fewer patients are being treated than expected. In turn, low cancer incidence might be seen because of a lack of proper diagnosis. In fact, no comprehensive national cancer screening programme has been established for prostate, colorectal, cervical or breast cancer. Moreover, incomplete cancer registration would decrease the incidence rate. However, it seems that various factors, such as increasing life expectancy and unhealthy lifestyle, have led to the current highest growth in cancer incidence rate in the world [15].

It has been reported that about 40–50% of treatments performed in radiotherapy units have palliative purposes [18]. However, in Iran about 28% of radiotherapy treatments are palliative. This is about 12 000 of the 42 350 patients who received radiotherapy. In fact, it is possible that limited resources in the country with economic and management issues were dedicated to patients with better prognosis. Therefore, palliative purposes have not been a priority and this led to lower than expected palliative radiotherapy rates. Another possibility to explain the lower palliative rate is impaired insurance policies for radiotherapy in palliative cases. This leads to huge out of pocket expenses for palliative radiotherapy and could most probably result in issues of access to care. Finally, the waiting time to receive treatment in governmental centres is about 1–2 months. Thus, many patients who require palliative radiotherapy may die before receiving treatment.

The current study showed that the number of fully operational radiotherapy centres in Iran increased from 34 in 2010 to 61 in 2015, which included 54 centres that provided external radiotherapy and seven centres that provided only brachytherapy [14]. Therefore, the number of radiation oncology facilities increased by 80% between 2010 and 2015. In addition, at least 33 other radiotherapy centres are commissioning or under the construction, expecting to be fully operational in the next few years. Twenty-two private centres have only one machine, which is an expensive model of delivery of care associated with poor site specialisation.

For an Iranian population of about 80 million in 2015, there are 54 operational external beam radiotherapy centres. However, due to unequal geographical distribution, there is a large difference between the 31 provinces of Iran in equipment availability and ease of access to treatment (Figure 1). Currently, nine provinces with a population of 10 million do not have an active radiotherapy centre. On the other hand, some provinces, such as Tehran and Khorasan-e-Razavi, have the most facilities. The availability of facilities might be due to a high population in these two provinces, the structure of the population, the wealth of the provinces and political reasons. Considering that 33 external beam radiotherapy centres have been commissioned, 87 external beam radiotherapy centres would be active in Iran in the near future. Table 3 shows the expected number of linacs and staffing based on the World Health Organization (WHO), International Atomic Energy Agency (IAEA), European Society for Radiotherapy and Oncology (ESTRO) and American Society for Radiation Oncology (ASTRO) criteria [18–23].

Table 2
The number of staffs in radiotherapy centres in 2010 [19] and 2015

Staff	Year	
	2010	2015
Radiation oncologist	147	243
Medical resident	45	65
General practitioner	–	10
Nurse	–	143
Medical physicist	–	188
Radiation therapy technologist	–	384

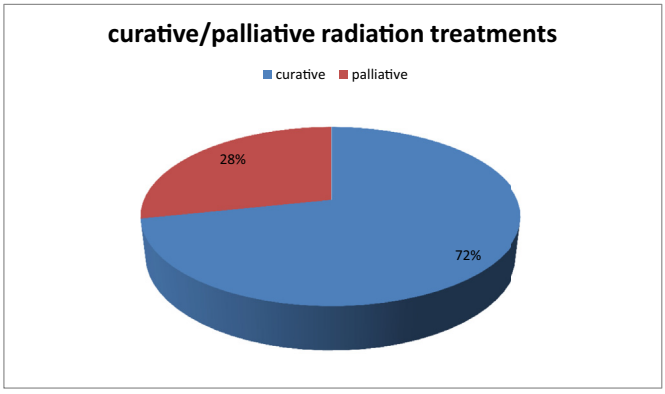


Fig 3. Pie chart for curative/palliative radiation treatments to express percentage of the total in 2015 in Iran.

Table 3
Various criteria, the population of Iran, number of radiotherapy patients, expected number of linear accelerators (linacs) and staffing

Criteria	Population-based	Patient-based	Linac	Radiation oncologist	Medical physicist	RTTs
WHO [25,29] [30]		–––	4/1 million population	4/1 million population	4/1 million population	8/1 million population
ESTRO-QUARTS or ESTRO-HERO [13,19]	–––	✓	1/450 patients/year, increasing complexity: 1/400–450 patients/year	1/250 patients/year, increasing complexity: 1/200–250 patients/year	1/450–500 patients/year	–––
IAEA [13,19]	–––	✓	1/200–500 patients/year depending on complexity	1/250–300 patients/year	1/300–400/patients/year	1/100–150 patients/year
ASTRO [26]	–––	✓	1/30 patients/day	1/200–250 patients/year 1/25–30 patients/day	1/400 patients/year	2/1 MV unit up to 25 patients/day; 4/1 MV unit up to 50 patients/day or 1 RTT/90 patients/year
Iran (current situation)	~80 000 000[†]	–––	77	243	188	384
Iran (expected) Based on WHO criteria	~80 000 000	–––	320	320	320	640
IRAN (expected) Based on IAEA criteria	–––––	42 350 (patients treated with radiotherapy in 2015)	85–212 (average 148)	141–169 (average 155)	106–141 (average 124)	282–424 (average 353)
		55 000[*] (patients who should be treated with radiotherapy in 2015)	110–275 (average 193)	183–220 (average 202)	138–183 (average 161)	367–550 (average 459)

WHO, World Health Organization; ESTRO, European Society for Radiotherapy and Oncology; IAEA, International Atomic Energy Agency; ASTRO, American Society for Radiation Oncology; RTT, radiation treatment technician.

[*] 55 000 radiotherapy patients, calculated from the total new cancer patient population of almost 100 000 annually in Iran.

[†] Population of Iran, 2015.

This study showed a rapid transition from cobalt-60 teletherapy units to high-energy linacs during the last 5 years. In fact, in 2012, international economic sanctions against Iran related to its nuclear programme endangered the supply of cobalt-60. Therefore, cobalt-60 teletherapy machines were replaced by linacs [14]. In 2010, 25 cobalt-60 machines were operational, whereas in 2015, only eight were active. In addition, these cobalt-60 machines are used solely for limited palliative treatments due to its low output and cobalt source. In fact, the Iran Ministry of Health, as the main provider of health care in Iran, purchased 30 linacs and installed the equipment at public centres during the 2010–2015 period. These linac machines have a low energy (6 MV); thus, they cannot be used in various types of treatment. In general, a radiotherapy centre should offer various treatment options to different patients. For instance, each centre would have low energy units and high energy units. Moreover, each centre should have at least two types of radiation, photon and electron. These different modalities are required to treat different cancers [23]. Therefore, the economic sanctions endangered access to care for patients required radiotherapy by restricting effective treatment options.

In this period, many new machines were purchased and some existing accelerators were upgraded with multileaf collimators and electronic portal imaging devices. Moreover, many clinics have installed computed tomography simulators and used treatment planning software. Consequently, various functions of linacs, such as dual energy, electron beam radiation, 3DCRT and IMRT have been optimised. Although the difference between existing facilities and international standards is still considerable, the ratio of the number of linac machines per 1 million population has improved remarkably, from 0.43 in 2010 to 0.99 in 2015, because of enormous investment in new accelerators [14]. Nonetheless, as shown in Figure 1, due to unequal distribution, this ratio is zero in nine provinces.

The WHO and IAEA recommend a standard of one MV linac per 250 000 inhabitants [19–21,25–28]. The current ratio is one linac per 1 018 964 inhabitants in Iran. However, this is a major improvement from 2010, when there was one linac per 2 326 001 inhabitants. The number of linac units does not meet the WHO criteria. In fact, 320 linac units are required for the Iranian population. This means that 243 linac units are still required to meet the current need. ESTRO-QUARTS and ESTRO-HERO guidelines recommend one linac per 400–450 patients [13]. Therefore, considering that at least 55 000 new patients need radiotherapy annually, 122–138 (average 130) linac machines are required. Therefore, Iran would need at least 53 more linac machines to meet the ESTRO criteria (Table 3). In addition, based on the IAEA standard, one linac per 200–500 patients is recommended, depending on the complexity of the treatment plan. This means that 110–275 (average 193) linac units are needed to serve the contemporary patient population. Thus, on average, 116 more linac units are required. Additionally, the introduction of new technologies will probably require more staff and more equipment in the field of radiotherapy.

The survey identified 19 brachytherapy centres with 21 remote afterloading systems, which are used for internal radiotherapy. However, a lack of sources of iridium-192 and cobalt-60 because of international sanctions led to the inactivity of 14 centres. In fact, the number of brachytherapy centres increased initially in the 2010–2015 period but then decreased from 19 in 2010 to seven in 2015 [14].

In terms of defining the treatment plan and using modern radiotherapy equipment, all radiotherapy centres in Iran can use 3DCRT; however, the use of IMRT is limited to two centres, intraoperative radiation therapy is used in only two centres and stereotactic radiosurgery is available in only one centre. Although Iran has made vast improvements in a short period in terms of equipment, these numbers are very low compared with the developed countries, like the USA and Canada [29,30]. This means that modern methods of radiotherapy are not accessible in Iran.

As mentioned above, in 2015, 243 radiation oncologists contributed to the treatment of 42 350 cancer patients. As shown in Table 3, the WHO's standard for radiation oncologist was 4 per 1 million population. In Iran, this ratio was 2 in 2010 and reached 3.1 in 2015. However, 320 clinical oncologists should be available to provide effective services to the entire population of the country. ESTRO-QUARTS and ESTRO-HERO recommend 1 radiation oncologist per 200–250 patients per year, whereas IAEA recommends 1 per 250–300 patients [13]. In Iran in 2015, this ratio was 1 radiation oncologist per 175 patients.

In 2015, 188 medical physicists with PhD or MSc degrees and 384 radiation treatment technicians (RTTs) worked in Iran. Based on the IAEA criteria, 1 medical physicist per 300–400 patients per year and 1 RTT per 100–150 are required [13]. This actual ratio was 1 medical physicist per 225 patients and 1 RTT per 110 patients. Therefore, the current number of radiation oncologists, medical physicists and RTTs seem to be sufficient and even higher than the standard for 42 350 patients. However, for the current 55 000 patients who should receive radiotherapy annually, the number of RTTs is insufficient and at least 75 additional RTTs should participate in the treatment of patients (Table 3).

In addition, the quality of training is an important issue. There are two problems in training competent staff in Iran. First, adequate clinical training for medical physicists is lacking and, second, academic training in dosimetry is insufficient. In fact, a medical physicist in Iran is busy with many tasks that could be better performed by dosimetrists or physician's assistants, such as computer treatment planning, routine daily checks and monitoring unit calculations.

Conclusion

This first comprehensive study of radiotherapy facilities in Iran showed a large gap between available facilities for radiation therapy in Iran and international standards, especially in advanced technologies, such as IMRT, tomotherapy and Stereotactic Body Radiation Therapy (SBRT) CyberKnife. Moreover, international economic sanctions against Iran widened this gap. Additional studies are

necessary to evaluate the patterns of choosing radiation therapy in cancer patients as well as policies to determine the distribution of radiation oncology centres in the country.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.clon.2017.12.021.

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