Reports of Practical Oncology and Radiotherapy 25 (2020) 840–845

Available online at www.sciencedirect.com

Reports of Practical Oncology and Radiotherapy

journal homepage: http://www.elsevier.com/locate/rpor

Original research article

Radiation oncology in Mexico: Current status according to Mexico's Radiation Oncology Certification Board☆

Federico Maldonado Magos [a,*], Francisco Javier Lozano Ruíz [b], Sandra Ileana Pérez Álvarez [a], Onix Garay Villar [c], Cesar Cárdenas Pérez [a], María Yicel Bautista Hernández [d], Gabriela Núñez Guardado [e]

[a] *Instituto Nacional de Cancerología, Mexico*
[b] *Médica Sur, Mexico*
[c] *Centro Médico Nacional Siglo XXI IMSS, Mexico*
[d] *Hospital General de México "Dr. Eduardo Liceaga", Mexico*
[e] *Centro Médico Nacional 20 de Noviembre, Mexico*

ARTICLE INFO

Article history:
Received 15 January 2020
Received in revised form 29 April 2020
Accepted 1 June 2020
Available online 16 June 2020

Keywords:
Radiotherapy
Mexico
Census
Linacs
Brachytherapy
Density

ABSTRACT

Aim: Describe the results of the first national census of radiotherapy in Mexico in order to make a situational diagnosis of radiotherapy availability, offer more accurate information to radiation oncologists, and promote an adequate scientific based investment for the country.
Background: According to the Organisation for Economic Co-operation and Development (OECD), the density of radiotherapy (RT) machines per million habitants in Mexico is approximately 1.7–1.8. Other international organizations such as DIRAC-IAEA report 1.15 per million habitants. National organizations collect data indirectly and previous surveys had a low accrual rate (32.5%). Therefore, a precise census is required.
Material and methods: The Mexican Radiation Oncology Certification Board (CMRO for its acronym in Spanish) conducted a nationwide census from January through November 2019. Gathered information was combined with CMRO database for sociodemographic information and human resources.
Results: The study included 103 RT centers [95.1% answered the survey], with a median of 2 centers by state (ranging from 0 in Tlaxcala to 20 in Mexico City) and with a report of only 1 center in 11 states (34.4%). Fifty-six (54.3%) of the centers are public. Fourteen centers (13.6%) have residency-training programs. The total number of RT machines is 162 [141 clinical and linear accelerators (87%) and 21 radionuclide units (13%)] with a median of 3 machines by state (0 in Tlaxcala to 46 in Mexico City) and with ≤3 machines in 18 states (56.25%). The overall calculated density of RT machines per million habitants is 1.32, varying from 0 in Tlaxcala to 5.16 in Mexico City. The density of linear and clinical accelerators per million population is 1.19. The total number of brachytherapy units is 66, with a median of 1 center with brachytherapy unit per state and 29 states with ≤3 centers with a brachytherapy unit (90.6%). Thirty-seven brachytherapy units (56.1%) have automated afterload high-dose rate. The overall rate of brachytherapy units per million inhabitants is 0.55, varying from 0 in 5 states (15.6%), 0.1-0.49 in 8 states (25%), 0.5–0.99 in 13 states (40.6%), 1–1.49 in 5 states (15.6%) and 1.5–1.99 in Mexico City (3.1%). The Mexican CMRO has 368 radiation oncologists certified (99 women and 269 men), of whom only 346 remain as an active part of Mexico's workforce.
Conclusions: This is the first time the CMRO conducts a national census for a radiotherapy diagnostic situation in Mexico. The country currently holds a density of clinical and linear accelerators of 1.19 per million habitants. Brachytherapy density is 0.55 devices per million habitants, and 57% of radiotherapy centers have brachytherapy units.

☆ Article from the Special Issue on Advanced Techniques in Radiation Oncology in Mexico.

* Corresponding author.
E-mail address: dr.lozanoruiz@icloud.com (F. Maldonado Magos).

https://doi.org/10.1016/j.rpor.2020.06.002
1507-1367/

1. A perspective from Mexico

The United States of Mexico, usually known as Mexico, is a diverse and rich country not only by its people but by its enormous natural resources where 10%–12% of world biodiversity and over 12,000 endemic species are housed.[1] According to Mexico's National Institute of Statistics and Geography (INEGI), by 2015 Mexico had a population of over 119 million, with an estimated population of 129 million by 2019, distributed across 1.9 million km^2 with most of its population density in the central area. It is divided into 32 states, and within its large geographical territory (14th worldwide and 5th in America), 22% of the people live in rural communities of less than or equal to 2500 people. The country is the 11th most populated country in the world, its official language is Spanish along with more than sixty native indigenous languages.[2] According to the World Tourism Organization, Mexico is the most visited country in Latin America, and the 6th most visited in the world.[3] In macro-economic terms, Mexico is the 14th most powerful world economy and 11th in purchasing power parity, the second biggest economy in Latin America and the 4th in the continent and it is classified as an upper-middle-income country.[4] With a median age of 28 years and with 7.3% of its population composed of people aged 65 years or older, Mexico has an exceptionally young population for its economic capacities.[5]

INEGI reported cancer as the 3rd leading cause of death, only surpassed by cardiovascular disease and diabetes. In 2018, a total of 87,754 people died due to cancer (41,590 men and 44,164 women). Prostate, lung, and gastric cancer for men, and breast, cervical, and liver cancer for women as the three most common causes of death.[6]

2. Mexican health system

The health system in Mexico is divided into a public and a private sector. Modern public sector originated with the creation of the Mexican Institute of Social Security (IMSS) and the Ministry of Health (SSA) in 1943. While many existing social security schemes were subsumed by IMSS, some social security funds and services remained independent or were subsequently created for specific groups, such as the Institute of Security and Social Services for State Workers (ISSSTE) in 1960, Secretariat of National Defence (SEDENA), Secretary of Navy (SEMAR), among others, all of which provide health services to government or private employees. In 2003, the health and social protection system formerly named "*Seguro Popular*" was created to provide health services to the unemployed population, which was recently replaced by Welfare Health Institute (INSABI) in early 2020. The goal of this new institute is to provide universal health care; as for today, Mexican health access is still being provided through independent systems which have recently been joining the INSABI. The private sector includes private health insurance companies, diverse healthcare service providers and those with financial capability.[7]

According to the Organisation for Economic Co-operation and Development (OECD), the density of radiotherapy (RT) machines per million habitants in Mexico is approximately 1.7–1.8. OECD included orthovoltage x-ray and brachytherapy units, in addition to radionuclide, clinical and linear accelerators (as defined by IAEA). Therefore, it overestimates data from DIRAC IAEA report (1.15 per million population).[8] National organizations such as "*Centro Nacional de Excelencia Tecnológica en Salud*" (CENETEC) collect data indirectly[9] and other previous surveys had an accrual rate as low as 32.5%.[10] These surveys have reported 134 linear accelerators, 30 cobalt-60 units, and 40 high dose rate brachytherapy in 2017. Therefore, accurate and updated information is required. The Mexican Radiation Therapy Certification Board (CMRO) performed a national survey of radiation therapy centers. The aim was to make a situational diagnosis of radiotherapy availability in Mexico, in order to offer accurate information to the radiation oncology community and promote an adequate development and investment for the country.

3. Material and methods

The Mexican Radiation Oncology Certification Board (CMRO for its acronym in Spanish) conducted a nationwide census from January through November 2019 to determine the current infrastructure and capabilities of radiotherapy in the country. Gathered information was combined with CMRO database for sociodemographic information and human resources.

3.1. Participants

The target group included all the radiation oncology facilities and machines currently in operation. The study excluded non-operational facilities and RT machines that are either currently non-functional or being installed or pending commissioning.

3.2. Survey distribution

Only members of the CMRO performed the national survey; this survey was done by either phone, email or personal interview. All the members of the CMRO carried out the census only with radiation oncologists or physicists who currently or previously had worked in the interviewed hospital over the preceding 12 months. Information from hospitals that refused to participate or were unavailable was acquired through DIRAC webpage from IAEA.

3.3. Data analysis

It included a descriptive analysis of qualitative variables: RT centers; RT machines [radionuclide therapy units (cobalt-60 teletherapy and radionuclide stereotactic machines such as GammaKnife), linear accelerators, clinical accelerators (helical TomoTherapy, robotic radiotherapy, and mobile accelerators for intraoperative radiotherapy)]; kilovoltage x-ray generators; and brachytherapy equipment (classified as manual or automated afterload; low or high dose rate). A description of overall frequency, distribution by location, and density of equipment per million inhabitants was included. Density per million population was calculated for clinical and linear accelerators. Private and public facilities were combined for statistical analysis.

4. Results

4.1. Radiotherapy centers in Mexico

The study included 103 RT centers with available information [95.1% answered the survey], with a median of 2 centers by state (ranging from 0 in Tlaxcala to 20 in Mexico City) and with a report of only 1 center in 11 states (34.4%). Fifty-six (54.3%) of the centers are public and 47 (45.7%) are private institutions. Fourteen centers (13.6%) have residency-training programs: 12 radiation oncology residency and 2 radiation oncology fellowship (1 of neurological radiosurgery and 1 of paediatric radiation oncology). Most of the centers offer adult and childcare (71 centers, 68.9%), with healthcare attention exclusive for adults in 18 centers (17.5%) and exclusive for children in only 3 centers (2.9%).

Table 1
Certified number of radiation oncologists by CMRO per year. Reflects the increase of human resources in the last decade.

Year	Female	Male	Total
2011	3	11	14
2012	2	5	7
2013	6	7	13
2014	5	13	18
2015	9	7	16
2016	9	12	21
2017	7	17	24
2018	12	15	27
2019	7	15	22

4.2. Human resources

At this point, there are no medical schools with radiation oncology in their curriculum, therefore, undergraduate medical students lack adequate exposure to this field. Mexico's radiation oncology residency program entails one to two years of internal medicine (according to the specific university program) followed by 3 years of radiation oncology training. Participating in research, although encouraged, is scarce due to the residents' workload.

Since the foundation of the Mexican CMRO in 1988, 368 radiation oncologists have been certified (99 women and 269 men), only 346 of them remain as an active part of Mexico's workforce. This means there is roughly one radiation oncologist for every 345,000 habitants. Although radiation oncologist training remains lower than it should be, Mexico has had a steady increase of its radiation oncology workforce (Table 1 shows the number of physicians trained in the last nine years). In 2019, twenty-two radiation oncologists were certified, and in 2020, thirty-seven new radiation oncologists will sit the certification examinations, the largest number ever.

In 1981, the "*Sociedad Mexicana de Radioterapeutas* (SOMERA)" was founded and remains to be the main society of radiation oncologists in the country. SOMERA currently holds a biennial national meeting, and for the last two years (2018–2019) an annual conference with the European Society of Therapeutic Radiation Oncology (ESTRO) and increasing webinars for continuous medical education.

Meanwhile, physicists study 4.5 years to get their physics' degree and 2 additional years to obtain a medical physicist master degree. The master's program for medical physicist started at Universidad Nacional Autónoma de México (UNAM) in 1997,[11] and it's currently offered only by two universities. From the starting date of the master's degree program until now, it is estimated that there are above 250 medical physicists in the country, and there is still no certifying board or independent organism that regulates them.

Currently, there is not a formal course for dosimetrists, and their training is conducted either abroad or informally under a supervision of a senior dosimetrist and/or physicist.

4.3. Overall radiotherapy machines

The total number of RT machines is 162 (141 clinical and linear accelerators, and 21 radionuclide units), with a median of 3 machines by state (0 in Tlaxcala to 46 in Mexico City) and with ≤3 machines in 18 states (56.25%). The overall calculated density of RT machines per million habitants (according to INEGI last population register in 2015) is 1.32, varying from 0 in Tlaxcala to 5.16 in Mexico City. The density of RT machines per million inhabitants is 0 in 1 state (3.1%), 0.1–0.49 in 4 states (12.5%), 0.5–0.99 in 8 states (25%), 1–1.49 in 9 states (28.1%), 1.5–1.99 in 5 states (15.6%) and ≥2 in 5 states (15.6%).

Table 2
Availability of radionuclide cobalt units by state (radionuclide radiosurgery units in brackets).

State	Cobalt-60 teletherapy units
Aguascalientes	1
Baja California	2
Chiapas	1
Chihuahua	1
Coahuila	1
Guanajuato	1
Guerrero	1
Jalisco	0 (1 GammaKnife)
Mexico City	2 (1 GammaKnife)
Michoacan	1
Oaxaca	1
Sinaloa	2
Tamaulipas	1
Veracruz	3
Yucatan	1

a **Cobalt-60 radionuclide units**

Out of the 162 RT machines, 21 are radionuclide therapy units (13.0%), including 19 cobalt-60 teletherapy units (90.5%) and 2 radionuclide stereotactic units (9.5%, both GammaKnife). Table 2 shows radionuclide therapy units by location.

b **Linear and clinical accelerators**

One-hundred forty-one linear and clinical accelerators were identified throughout Mexico, representing 87% of the total of RT machines. The density of linear and clinical accelerators per million population in each of the 32 states of Mexico is shown in Table 3 and Fig. 1, with an overall density in Mexico of 1.19 (ranging from 0 in Chiapas and Tlaxcala to 4.82 in Mexico City). This ratio is 0 in 2 states (6.25%), 0.1–0.49 and 0.5–0.99 in 7 states (21.9%) each, 1–1.49 in 9 states (28.1%), 1.5–1.99 in 3 states (9.4%) and ≥2 in 4 states (12.5%). The 4 states (12.5%) with the total of 77 accelerators (54.2%) are Mexico City, Nuevo León, Jalisco and Guanajuato. Number of accelerators and cobalt-60 radionuclide units is shown by city in Fig. 1.

Although still scarce, the number of high precision accelerators has increased according to previous data.[9–11] Of the 141 accelerators:

- 128 are linear accelerators (90.8%) including 25 Synergy® (19.5%), 8 VitalBeam™ (6.3%), 6 TrueBeam™ (4.7%) and 2 Versa HD™ (1.6%).
- 13 are clinical accelerators (9.2%), including 8 helical TomoTherapy® (61.5%), 3 robotic radiotherapy (23.1%, all CyberKnife®) and 2 mobile photon accelerators for intraoperative radiotherapy (15.4%).
- Additionally, but not counted, there are 12 kilovoltage x-ray generators.
- There are no circular or particle accelerators identified.

4.4. Brachytherapy units

The records of brachytherapy infrastructure are also shown in Table 3 and Fig. 2. Only 59 of the 103 centers have a brachytherapy unit (57.3%). The total number of brachytherapy units is 66, with a median of 1 center with brachytherapy unit per state, 5 states with 0 centers (15.6%), 11 states with 1 brachytherapy unit per state (34.4%-), 8 with 2 (25%), 5 with 3 (15.6%) and 1 with 4, 5 and 15 brachytherapy units per state (3.1%), respectively. Thirty-seven brachytherapy units (56.1%) have automated afterload high-dose rate and in 29 centers manual afterload low-dose rate brachyther-

Table 3
Availability of centers, clinical and linear accelerators, centers with brachytherapy and brachytherapy units per state in Mexico.

State	Million population	Centers with RT machines	Clinical and linear accelerators	Clinical and linear accelerators per million population	Centers with brachytherapy	BT units	BT units per million population
Aguascalientes	1,312,544	3	2	1.52	1	1	0.76
Baja California	3,315,766	5	3	0.90	2	2	0.60
Baja California Sur	712,029	1	1	1.40	1	1	1.40
Campeche	899,931	1	1	1.11	1	1	1.11
Chiapas	5,217,908	1	0	0	1	1	0.19
Chihuahua	3,556,574	4	4	1.12	2	2	0.56
Coahuila	2,954,915	2	2	0.67	2	2	0.68
Colima	711,235	1	1	1.41	0	0	0.00
Durango	1,754,754	2	3	1.71	1	1	0.57
Guanajuato	5,853,677	8	9	1.53	3	3	0.51
Guerrero	3,533,251	1	1	0.28	1	1	0.28
Hidalgo	2,858,359	1	1	0.35	0	0	0.00
Jalisco	**7,844,830**	**6**	**11**	**1.40**	**4**	**5**	**0.64**
Mexico City	**8,918,653**	**20**	**43**	**4.82**	**11**	**15**	**1.68**
Mexico State	**16,187,608**	**3**	**4**	**0.25**	**2**	**2**	**0.12**
Michoacán	4,584,471	2	2	0.43	1	1	0.22
Morelos	1,903,811	2	2	1.05	1	1	0.53
Nayarit	1,181,050	1	1	0.85	1	1	0.85
Nuevo León	**5,119,504**	**6**	**14**	**2.73**	**3**	**3**	**0.59**
Oaxaca	3,967,889	1	1	0.25	1	1	0.25
Puebla	6,168,883	4	6	0.97	2	2	0.32
Querétaro	2,038,372	4	5	2.45	2	2	0.98
Quintana Roo	1,501,562	1	1	0.67	0	0	0.00
San Luis Potosí	2,717,820	2	3	1.10	1	1	0.37
Sinaloa	2,966,321	3	3	1.40	2	3	1.01
Sonora	2,850,330	3	4	1.40	3	3	1.05
Tabasco	2,395,272	1	1	0.42	1	2	0.83
Tamaulipas	3,441,698	4	3	0.87	2	2	0.58
Tlaxcala	1,272,847	0	0	0.00	0	0	0.00
Veracruz	8,112,505	5	3	0.36	4	4	0.49
Yucatán	2,097,175	4	5	2.38	3	3	1.43
Zacatecas	1,579,209	1	1	0.63	0	0	0.00
Total	**119,530,753**	**103**	**141**	**1.18**	**58**	**66**	**0.55**

BT: brachytherapy; RT: radiation therapy.
RT machines includes linear accelerators, clinical accelerators (helical TomoTherapy, robotic radiotherapy and mobile accelerators for intraoperative radiotherapy) and radionuclide units (cobalt-60 teletherapy units and radionuclide stereotactic units).

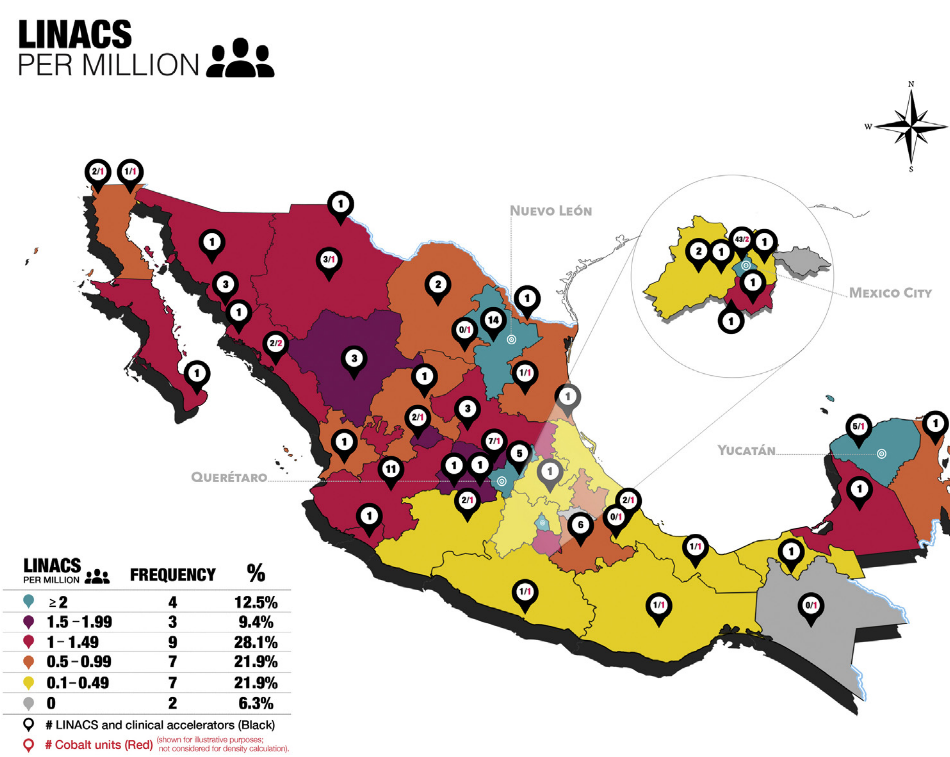

Fig. 1. Accelerators per million habitants across Mexico. Density of linear and clinical accelerators was divided in 0, 0.1-0.49, 0.5-0.99, 1-1.49, 1.5–1.99 and, ≥1.99 per million population and it is represented with different color. Numbers in black represent the quantity of accelerators per city whereas numbers in red represent the quantity of cobalt-60 units per city for illustrative purposes only. Cobalt-60 units were not accounted for the density of LINACS per million population.

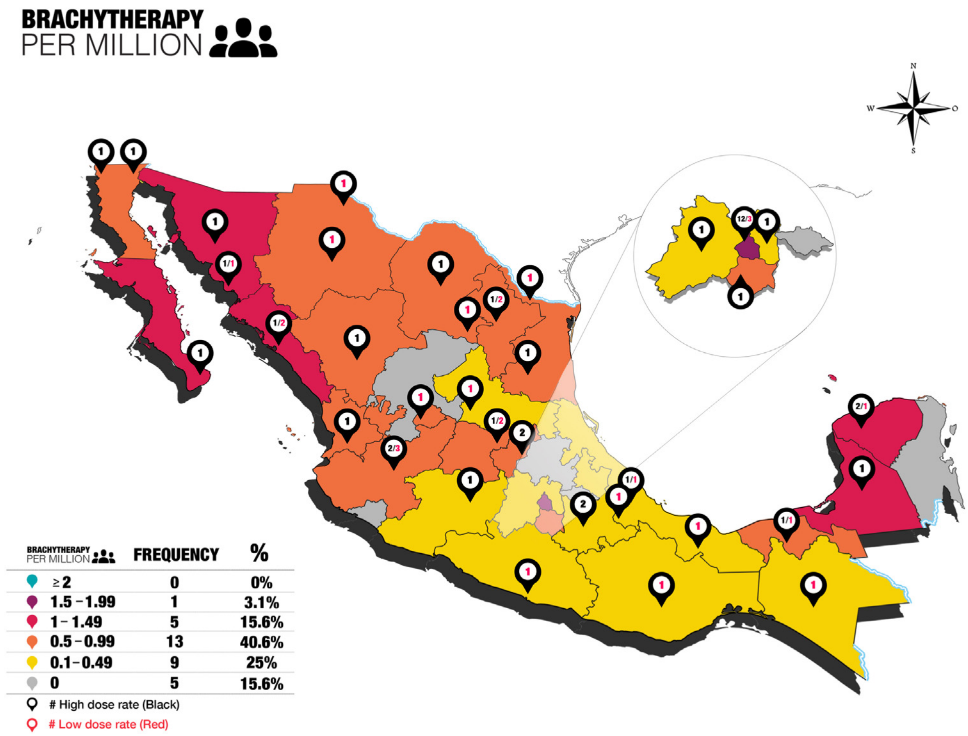

Fig. 2. Brachytherapy per million habitants across Mexico. Numbers show the quantity of high dose rate (HDR, in black) or low-dose rate (LDR, in red) equipment per city. Density of brachytherapy units (accounting both, HDR and LDR per million population) was divided in 0, 0.1–0.49, 0.5–0.99, 1–1.49, 1.5–1.99 and, ≥1.99 per million population and, it is represented with different color.

apy (43.9%) is still used. The overall rate of brachytherapy units per million inhabitants is 0.55 (Fig. 2), varying from 0 in 5 states (15.6%), 0.1–0.49 in 8 states (25%), 0.5–0.99 in 13 states (40.6%), 1–1.49 in 5 states (15.6%) and 1.5–1.99 in Mexico City (3.1%). No states in the country have >2 units per million inhabitants.

5. Discussion

This study shows the results of the last national census conducted by the CMRO. The data presented is unique and provides a useful insight about the radiation oncology capabilities of the country. The results, although different from previous publications, are the most accurate since all interviews were performed only by members of the CMRO with working radiation oncologists or physicists across the country. The limitation of the survey is that 4.9% of the clinics with radiotherapy refused to participate or were unreachable. Lastly, the information collected relied on verbal information provided by the interviewed physicists and/or radiation oncologists, and although there is no reason to distrust it, inaccuracies are possible.

From the 32 states, only Mexico City accomplished the ideal ratio of 4 RT machines per million people as defined by the IAEA[12] and the minimum density of 4 RT machines per million inhabitants but not the desirable density of 5.9 RT machines per million inhabitants as defined by European QUARTS project (QUAntification Of Radiation Therapy Infrastructure And Staffing Needs).[13–15] The recommended average of 2 and 3.5 LINACS per million in low- and middle-income countries were met in 4 states and only in Mexico City, respectively. However, the recommended 5.5 LINACS per million for high resource countries was not accomplished in any state.[16] Among the OECD members, Mexico's density of machines per million inhabitants is the lowest (OECD estimates 1.5 per million) among other OECD members such as the USA, Canada and Poland with densities of 11.5, 3.0, and 4.5, respectively.[17]

As expected, LINACS and brachytherapy density is strongly associated to socioeconomic difference across the country, where more developed areas like the north and center have a higher density of equipment compared to the south and southwest. This information urges a medical evidence-based investment and implementation of new technology across the nation. Particularly, in states where LINAC and brachytherapy density remains under one equipment per million habitants.

Even though Mexico is limited by its technological facilities, human resources, and quantity of equipment, the lack of access to radiotherapy is compensated with an enthusiastic community of radiation oncologists with an increasing overall technical capability. In the survey, radiation oncologists and physicists where asked about the number of patients treated every shift by linear accelerator, averaging 25 patients per shift per machine. Requested information also included types of treatments available across the country and the average time from the patient first interview with the radiation oncologist to the treatment simulation and the actual treatment start. Every Mexican hospital claims that any radiotherapy emergency such as oncological bleeding, cord compression, pain, is solved within 24 h or less. Surprisingly, the nationwide mean time for a 3D conformal treatment plan was 10 days (range 0–90), with only 3 hospitals in Mexico with waiting times above 60 days which it is only plausible due to the enormous compromise towards its patients from the radiation oncology community. Average waiting time across the country for brachytherapy was 7 days which is also adequate considering the patient workload, lack of staff and facilities.

6. Conclusions

The CMRO publishes the latest survey of radiation capabilities of Mexico. Prior data could have been over- and/or underestimated for previously stated reasons. This is the first time the CMRO conducts a one by one national census for a radiotherapy diagnosis in Mexico. Our country currently holds an alarmingly low density of clinical and linear accelerators, currently reported of 1.19 per million habitants. Meanwhile, national brachytherapy density was 0.55 devices (high dose and low dose rate combined), and barely 57% of radiotherapy centers have brachytherapy units, which could be considered critical, especially when cervical cancer remains one of the 3 leading causes of death among women. Even so, Mexico's radiation oncology facilities are overall increasing, more radiotherapy centers are available with more precision equipment than ever. Radionuclide therapy equipment, such as cobalt-60, is decreasing and it is being replaced by LINACS across the country, 56% of brachytherapy is already automated afterload high-dose rate and, in parallel, human resources have been growing in the last 10 years. Even though we remain below international recommendations, in 2020 the largest generation of radiation oncologists will take their certification exams with the CMRO.

Financial disclosure

None declared.

Conflict of interest

None declared.

Acknowledgments

The CMRO would like to acknowledge the 103 hospitals and clinics on which radiation oncologists and physicists took their time to answer the census. Without their selfless participation the overall response rate of 95.1% wouldn't have been achieved. Special thanks to those who got involved in current and future projects and helped reach fellows and colleagues from other centers for census elaboration.

References

1. Jiménez Sierra CL, Sosa Ramírez J. [México país megadiverso y la relevancia de las áreas naturales protegidas]. Mexico a megadiverse country and the importance of natural protected areas. *Investigación y Ciencia de la Universidad de Aguascalientes*. 2014;60(1):6–22.
2. INALI (March 13th, 2003). «Ley General de Derechos Lingüísticos de los Pueblos Indígenas». Nueva Ley DOF 13-03-2003 Webpage: https://www.inali.gob.mx/pdf/ley-GDLPI.pdf Accessed: January 5th, 2020.
3. UNWTO Tourism Highlights: 2018 Edition World Tourism Organization. Webpage: https://www.e-unwto.org/doi/pdf/10.18111/9789284419876. Accessed: January 5th, 2020.
4. World Bank Country and Lending Groups. Web page: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Accessed: January 5th, 2020.
5. INEGI. Epidemiological data. Webpage: https://www.gob.mx/cms/uploads/attachment/file/520501/LSDM2019_OK_23DIC19.pdf. Accesed: January 5th, 2020.
6. INEGI Mortality. Interactive tabulator. Webpage: https://www.inegi.org.mx/programas/mortalidad/ Last update: September 30th, 2019. Accessed: January 5th, 2020.
7. Gallegos D, Poitevin Chacón MA, Wright JL. Radiation oncology in Mexico: Toward a unified model. *Int J Radiat Oncol Biol Phys*. 2018;102(1):5–10, http://dx.doi.org/10.1016/j.ijrobp.2018.05.035.
8. Number of Radiotherapy Machines Per Million People. Webpage: https://dirac.iaea.org/Query/Map2?mapId=0. Accessed: January 5th, 2020.
9. Centro Nacional de Excelencia Tecnologica. Inventario Nacional EMAT. Available at: http://www.cenetec.salud.gob.mx/contenidos/biomedica/mapa.html. Accessed: March 20, 2019.
10. Poitevin-Chacón A, Hinojosa-Gómez J. Patterns of care of radiotherapy in México. *Rep Pract Oncol Radiother*. 2013;18(2):57–60, http://dx.doi.org/10.1016/j.rpor.2012.09.001.
11. Brandan ME. The medical physics M.SC. Program at the national university of Mexico: Results and lessons learned after 100+ graduates. World congress on medical physics and biomedical engineering. *SpringerLink*. 2015;51:1604–1607, http://dx.doi.org/10.1007/978-3-319-19387-8_390.
12. Rosenblatt E, Acuña O, Abdel-Wahab M. The challenge of global radiation therapy: An IAEA perspective. *Int J Radiat Oncol Biol Phys*. 2015;91(4):687–689, http://dx.doi.org/10.1016/j.ijrobp.2014.12.008.
13. Slotman BJ, Cottier B, Bentzen SM, et al. Overview of national guidelines for infrastructure and staffing of radiotherapy. ESTRO-QUARTS: Work package 1. *Radiother Oncol*. 2005;75:349–354, http://dx.doi.org/10.1016/j.radonc.2004.12.005.
14. Rosenblatt E, Izewska J, Anacak Y, et al. Radiotherapy capacity in European countries: an analysis of the Directory of Radiotherapy Centers (DIRAC) database. *Lancet Oncol*. 2013;14:e79–86, http://dx.doi.org/10.1016/S1470-2045(12)70556-9.
15. Dunscombe P, Grau C, Defourny N, on behalf of the HERO consortium. Guidelines for equipment and staffing of radiotherapy facilities in the European countries: final results of the ESTRO-HERO survey. *Radiother Oncol*. 2014;112:165–177, http://dx.doi.org/10.1016/j.radonc.2014.08.032.
16. Grau C, Defournyb N, Malicki J, et al. Radiotherapy equipment and departments in the European countries: final results from the ESTRO-HERO survey. *Radiother Oncol*. 2014;112(2):155–164, http://dx.doi.org/10.1016/j.radonc.2014.08.029.
17. https://data.oecd.org/healtheqt/radiotherapy-equipment.htm OECD (2020), Radiotherapy equipment (indicator). doi: 10.1787/47a5492f-en (Accessed on 28 April 2020).