

Review Article

Is economic status the main determinant of radiation therapy availability? The Arab world as an example of developing countries



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ABSTRACT

Background and purpose: Arab countries share a common location, history, language and culture with different economic characteristics. In this study, we analyze the availability and factors influencing radiotherapy services and cancer mortality incidence ratio (MIR) in Arabic countries.

Materials and methods: Data were collected from GLOBOCAN report, World Health Organization, World Bank, United Nation and Directory of Radiotherapy Centre databases.

Results: The average number of megavoltage machines (MVM) in Arab countries is 0.84 machine per 1000 cancer patients. The number of MVM per 1000 cancer patients was found to be significantly correlated with gross domestic product (GDP) per capita ($r = 0.583$, $P = 0.006$). In addition, it was found to be significantly more in politically stable countries compared to unstable ones ($P = 0.004$) and more in high and upper-middle income countries (median 0.94 ± 1.0) compared to lower-middle and low income countries (median 0.3 ± 0.51) ($P = 0.013$). MIR was found to be significantly correlated with GDP per capita, physicians per 1000 population, MVM per 1000 cancer patients and absolute MVM deficit ($r = -0.555$, -0.625 , -0.42 , -0.436 and $P = 0.009$, 0.006 , 0.047 , 0.043 , respectively). On multivariate regression analysis, the number of physicians per 1000 population had the strongest prediction of MIR in Arabic countries ($P = 0.01$).

Conclusion: Although the economic status is of paramount importance, it is not the only factor determining the quantity and quality of radiotherapy services in the Arab world. More efforts are urgently needed to improve the status of radiation oncology and fill its gap in the Arab countries.

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Cancer is the second most common cause of death globally as it was responsible for 9.6 million deaths in 2018 [1]. Cancer management necessitates extensive and intimate co-operation between health, economic authorities and the society as well as strong health and education infrastructures. Radiotherapy (RT) is a common essential treatment modality used in the management of many tumours. The Health Economics in Radiation Oncology (HERO) project from the European Society for Radiotherapy and Oncology (ESTRO) reported a gap between evidence-based optimal RT utilization and radiotherapy treatment actually delivered, even in European countries [2]. The access to radiotherapy remains limited globally to the extent that the overall number of additional teletherapy units needed corresponds to about twice the installed capacity in Asia-pacific and even more in Africa [3].

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The correlation between gross national income per capita and the availability of RT services has been demonstrated in different regions. The range of radiotherapy needs currently covered varies from 0% and 34% in low income countries in Latin America and Africa, respectively, up to 59–79% in upper-middle income countries in Europe and Central Asia. The estimated number of new cancer patients requiring radiotherapy is considered a key parameter for planning the resources needed in each country [3]. The Global Task Force on Radiotherapy for Cancer Control (GTRCC) used radiation fractions as the key variable in assessing the needed equipment, staff and facilities to ensure optimal radiotherapy coverage [4]. GlobalRT, a virtual platform created by GTRCC, was established to facilitate education and exchange of information about the essential role of radiotherapy for cancer care in a trial to render radiotherapy a global health priority. The Global Impact of Radiotherapy in Oncology (GIRO) project, launched by ESTRO, is the next phase of GTRCC that provides solutions to overcome the gap in radiotherapy access. Recently, an increasing number of articles have been addressing the impact of different social, economic and political factors on the availability of radiotherapy services.

Arab countries include 22 members in the Middle Eastern and North African regions. They share Arabic as the main speaking language and they are located in either Asia ($n = 12$) or Africa ($n = 10$) [5]. Some Arab countries sustain cultural and scientific relations with the West, while others faced major political instability over the last 2 decades.

Despite the fact that RT is an effective and relatively cheap treatment modality representing around 5% of cancer treatment cost [6], the expenses of designing radiation centers with the necessary infrastructure and equipment together with the need for extensive training of staff remain major barriers. The maintenance of modern megavoltage machines (MVM) with their advanced technology is another challenge for the sustainability of an effective service. In the current review, we shed light on RT availability and analyze the effect of different variables on RT services and cancer outcomes in the Arab world.

Materials and methods

Arab countries were defined according to the portal of League of Arab States (LAS) [5]. Population, gross domestic product (GDP) and GDP per capita (in US\$) in 2017 were obtained from World Health Organization (WHO) [7] and United Nation (UN) Databases [8]. In the World Bank list of economies, Arab countries are divided into income groups according to 2016 gross national income (GNI) per capita. Only Comoros is classified as low income (LIC) ($\text{GNI} \leq 1005\$$), while 11 countries are classified as lower-middle income (LMIC) ($\text{GNI} 1006\text{--}3955\$$): 7 African countries (Egypt, Tunisia, Sudan, Morocco, Mauritania, Somalia, and Djibouti) and 4 Asian countries (Yemen, Palestine (Gaza/West bank), Jordan and Syria). Four countries (Iraq, Libya, Lebanon and Algeria) are classified as upper-middle income (UMIC) ($\text{GNI} 3956\text{--}12,235\$$) and 6 countries (Oman, Saudi Arabia, United Arab Emirates, Bahrain and Kuwait) are classified as high income (HIC) ($\text{GNI} \geq 12,236\$$) countries [9].

The most recently published health indicators in 2015 including current health expenditure (CHE) as percentage of GDP, current health expenditure (CHE) per capita in US\$, current health expenditure, numbers of physicians and hospital beds were extracted from WHO and UN databases [10]. In the absence of online updated cancer registry in most of the Arab countries, GLOBOCAN 2018 and WHO reports [1,11] were used to extract cancer incidence and mortality rates. As of September 2018, Directory of Radiotherapy Centres (DIRAC) database was used to obtain data on the number of MVM, brachytherapy facilities, conventional and CT simulators in each of the countries [12]. For data analysis and comparison purpose, Arab countries were geographically categorized into Asian, African, North African (Morocco, Algeria, Tunisia, Libya and Egypt) and Gulf countries (Oman, UAE, Kuwait, Saudi Arabia, Bahrain and Qatar) subgroups. Another category includes six countries (Egypt, Tunisia, Algeria, Morocco, Jordan and Lebanon) which sustain professional relations with reciprocal cancer centers in Western countries via international meetings and workshops [13–15]. In addition, 7 countries (Syria, Yemen, Libya, Iraq, Palestine, Somalia and Djibouti) were categorized as politically unstable countries. These countries have been going through military wars, civil wars, multiple premature major governmental changes, revolution, military coup, resignation or assassination of executives and therefore were considered politically unstable [16].

In the absence of accurate estimation of radiotherapy courses based on actual data of stage distribution incidence of each malignant disease, the need for radiotherapy was estimated based on a benchmark of 50% need for radiotherapy for new cancer patients as suggested by Rosenblatt et al. [17]. Based on the latest published cancer incidence data [11] and the International Atomic Energy

Agency (IAEA) estimates of maximum of 500 radiotherapy courses per machine per year [18,19], we calculated the expected number of needed radiotherapy machines.

Statistical analysis

Descriptive data are presented as numbers and percentages or mean, median and range. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 22 (SPSS Inc., Chicago, IL) for Windows. Pearson's correlation test and linear regression analysis were used for estimating the correlations between various parameters and Mann-Whitney's U test was used for mean comparisons. Stepwise multivariate regression analysis was performed on factors that showed significant correlations with cancer mortality incidence ratio (MIR) on univariate tests. Significance level was determined at P value ≤ 0.05 .

Results

Around 429,325 new cancer patients were expected to be diagnosed across the 22 Arab countries in 2018. The mean crude rate (CR) and age-standardized rate (ASR) are estimated at 93.8 (range 45.6–283.8) and 123 (range 46.8–242.8) new case per 100,000 population, respectively with an average estimated cumulative risk of 12.73, with variation in incidences among different countries. While lung cancer is the most fatal cancer in 50% of Arabic countries, breast and cervix uteri cancers are considered to be the commonest (Table 1) [11]. Of note, there is a high discrepancy in cancer incidences noted between different countries, where the highest reported incidence is in Lebanon while the lowest incidence is reported in Yemen and Djibouti.

According to DIRAC data, a total of 173 RT centers are established in 22 Arab countries with an average of 7.9 centers per country [12]. Egypt has the largest percentage ($n = 68$, 39%) of RT centers, while four countries (Somalia, Comoros, Djibouti and Palestine) have no RT facilities at all. A total of 338 MVM (282 linear accelerators and 56 Cobalt-60 machines) are reported with an average of 1.74 MVM per center indicating fragmentation of service. Only 15 centers (8.7%) contain four MVM or more offering multiple advanced radiation techniques, six of which are located in Egypt. There are three Gamma Knife machines (two in Egypt and one in Jordan) and three Cyberknife machines (two in Kingdom of Saudi Arabia (KSA) and one in Qatar). In addition, there are two helical tomotherapy machines, one in each of KSA and United Arab Emirates (UAE), and three intra-operative radiotherapy (IORT) units in KSA. Furthermore, two proton therapy units will be soon operating in KSA and Egypt [12]. It is noteworthy that these advanced facilities are recorded in the DIRAC as either radioactive telemachines or linear accelerators and very limited data is available on dates of installment, state of operation or year of manufacture of the registered machines. There exist 206 simulators in 148 centers in Arab countries, the majority of which are located in Egypt ($n = 100$) and 49% of them are CT simulators. Although Kuwait has one RT center with a CT simulator, it is not recorded in the DIRAC. Furthermore, among countries with RT facilities, only Kuwait and Yemen have no records of any treatment planning systems (Table 2). The median number of MVM/1000 patients is 1.25 ± 1.22 , 0.72 ± 0.23 and 0.3 ± 0.51 in HIC, UMIC and LMIC respectively, with an average of one MVM serving 592, 1220 and 1493 patients, respectively.

Fifty-eight brachytherapy units are distributed in 15 Arab countries, where fifty-five centers have both teletherapy and brachytherapy services. Fifty-four remote after-loading brachytherapy units (43 low-dose rate (LDR) and 11 high-dose rate (HDR) units) are available in the Arabic region, while four countries

Table 1
Crude and age-standardized cancer incidence and mortality rates per 100,000 population in each Arabic country.

Country	Incidence				Mortality				MIR
	Number	Crude Rate	ASR	Commonest	Number	Crude Rate	ASR	commonest	
Algeria	53,076	126.3	130.8	Breast 24.85%	29,453	70.1	73.3	Lung 15.01%	55.49%
Bahrain	1048	66.9	105.2	Breast 23.23%	603	38.5	70	Lung 13.72%	57.54%
Comoros	510	61.3	99.8	Cervix uteri 33.81%	367	44.1	77.7	Cervix uteri 33.44%	71.96%
Djibouti	674	69.4	87.9	Breast 30.66%	472	48.6	64.8	Breast 21.43%	70.03%
Egypt	128,892	129.7	156.9	Liver 22.03%	85,432	86	107.1	Liver 32.35%	66.28%
Iraq	25,320	64.4	105.5	Breast 23.69%	14,524	36.9	64.7	Lung 16.50%	57.36%
Jordan	10,898	110	157.8	Breast 21.98%	5813	58.7	89.7	Lung 19.86%	53.34%
Kuwait	3582	85.3	121.8	Breast 24.13%	1658	39.5	68.3	Breast 14.44%	46.29%
Lebanon	17,294	283.8	242.8	Breast 20.69%	8976	147.3	119.8	Lung 18.76%	51.90%
Libya	6308	97.5	120.3	Breast 13.05%	3375	52.2	69.1	Lung 18.53%	53.50%
Mauritania	2733	60.2	98.5	Cervix uteri 20.56%	1933	42.6	73.8	Cervix uteri 20.31%	70.73%
Morocco	52,783	145.8	139.6	Breast 21.04%	32,962	91.1	86.9	Lung 21.87%	62.45%
Oman	3322	68.8	103.3	Breast 15.11%	1681	34.8	60.8	Stomach 12.07%	50.60%
Qatar	1260	46.8	97.3	Breast 16.54%	672	24.9	65.1	Lung 11.33%	53.33%
Saudi Arabia	24,485	73	88.7	Breast 15.95%	10,518	31.3	43.3	Leukemia 9.5%	42.96%
Somalia	9942	65.5	120.8	Breast 21.75%	8198	54	105.1	Breast 17.78%	82.46%
Sudan	25,746	62	95.9	Breast 25.49%	17,160	41.3	67.7	Breast 19.82%	66.65%
Syria	23,170	126.7	169.9	Breast 23.88%	14,042	76.8	105.6	Lung 17.06%	60.60%
Tunisia	15,894	136.3	115.4	Breast 16.02%	10,092	86.6	71.3	Lung 20.42%	63.50%
UAE	4707	49.3	112.5	Breast 23.64%	2079	21.8	61.7	Colon 14.15%	44.17%
Yemen	13,182	45.6	76.1	Breast 20.59%	9085	31.4	57.3	Breast 13.30%	68.92%
Gaza and West Bank	4499	89	158.6	Breast 21.61%	2640	52.2	101.1	Lung 15.35%	58.68%

Table 2
Radiotherapy facilities and density in Arabic countries.

Countries	RT Centers	LINAC	Co60	CT	Simulator	TPS [*]	BT ^{**} units	MVM	MVM/RT center	Pop. in million	MVM/million inhabitants	MVM/1000 patients
Algeria	15	34	4	5	7	23	13	38	2.53	42.01	0.90	0.72
Bahrain	2	4	0	2	0	6	0	4	2	1.567	2.55	3.82
Comoros	0	0	0	0	0	0	0	0	0	0.832	0	0
Djibouti	0	0	0	0	0	0	0	0	0	0.97	0	0
Egypt	68	95	23	49	51	64	11	118	1.74	99.38	1.19	0.92
Iraq	11	17	1	2	4	11	0	18	1.64	39.34	0.46	0.71
Jordan	5	13	1	6	2	18	1	14	2.8	9.9	1.41	1.28
Kuwait	1	3	0	0	0	0	1	3	3	4.2	0.71	0.84
Lebanon	11	16	2	7	5	39	3	18	1.64	6.09	2.96	1.04
Libya	3	2	1	0	3	4	1	3	1	6.47	0.46	0.48
Mauritania	1	1	0	1	0	1	1	1	1	4.54	0.22	0.37
Morocco	20	36	2	14	4	28	7	38	1.90	36.19	1.05	0.72
Oman	1	2	0	1	1	1	1	2	2	4.83	0.41	0.60
Qatar	1	3	0	1	0	8	1	3	3	2.69	1.12	2.38
Saudi Arabia	14	35	0	12	4	28	8	35	2.5	33.55	1.04	1.43
Somalia	0	0	0	0	0	0	0	0	0	15.18	0	0
Sudan	3	2	5	1	4	4	2	7	2.33	41.51	0.17	0.27
Syria	2	2	5	3	2	2	2	7	3.5	18.28	0.38	0.30
Tunisia	11	12	10	7	6	17	5	22	2	11.66	1.89	1.38
UAE	3	5	0	2	0	8	1	5	1.67	9.54	0.52	1.06
Yemen	1	0	2	0	0	0	0	2	2	28.92	0.07	0.15
Palestine (West Bank, Gaza)	0	0	0	0	0	0	0	0	0	5.05	0	0
Total	173	282	56	113	93	262	58	338	1.74	422.72		

RT: Radiotherapy, TPS: Treatment planning System, BT: Brachytherapy, MVM: Megavoltage Machines.

(Egypt, Lebanon, Syria and KSA) still have manual loading LDR units. Patients in seven countries (Iraq, Comoros, Djibouti, Libya, Somalia, Yemen and Palestine) lack access to brachytherapy facilities [12].

The need for RT rises in developing countries as a result of the common presentation of advanced disease necessitating radical, adjuvant, neoadjuvant and/or palliative RT. Upon using a benchmark figure of 50% of new cancer cases requiring radiotherapy in their treatment course, we concluded that 214,662 radiation courses would be needed in all Arabic countries in 2018. This calculation entails at least 430 MVM to cover the demand for radiotherapy in the Arabic region and a total of 92 MVM would be needed to fill the gap of 21% (92/430) in the radiotherapy service. To date, only 7 countries (Bahrain, Jordan, Lebanon, Qatar, Saudi

Arabia, UAE and Tunisia) fulfill this MVM need. On the contrary, 4 countries (Comoros, Djibouti, Somalia and Palestine) have no radiotherapy services at all and another 5 countries (Libya, Mauritania, Sudan, Syria and Yemen) have less than half of the required machines.

Across the Arab World, the average number of MVM for each 1000 cancer patients varies between 0 and 3.82 MVM with an average of 0.84 (Tables 2 and 3). Considering country-specific density of MVM, only 7 countries fulfill the recommended MVM/1000 cancer patients (4 HIC, 1 UMIC and 2 LMIC), while 2 out of the 6 HIC (Oman and Kuwait) did not reach the recommended level. The number of available MVM per 1000 cancer patients was found to be significantly more in politically stable countries (median 1.07 ± 0.94) compared to the unstable countries (median

Table 3

The available and needed megavoltage machines (MVM), its deficit & the ratio of available/needed MVM in each Arabic country in 2018.

Countries	Cancer cases 2018	Expected number of RT courses [*]	Available MVM	Needed MVM ^{**}	MVM deficit	Available/needed MVM
Algeria	53,076	26,538	38	53	15	%72
Bahrain	1048	524	4	1	−3	%382
Comoros	510	255	0	1	1	%0
Djibouti	674	337	0	1	1	%0
Egypt	128,892	64,446	118	129	11	%92
Iraq	25,320	12,660	18	25	7	%71
Jordan	10,898	5449	14	11	−3	%128
Kuwait	3582	1791	3	4	1	%84
Lebanon	17,294	8647	18	17	−1	%104
Libya	6308	3154	3	6	3	%48
Mauritania	2733	1366.5	1	3	2	%37
Morocco	52,783	26391.5	38	53	15	%72
Oman	3322	1661	2	3	1	%67
Qatar	1260	630	3	1	−2	%238
Saudi Arabia	24,485	12242.5	35	24	−11	%143
Somalia	9942	4971	0	10	10	%0
Sudan	25,746	12,873	7	26	19	%27
Syria	23,170	11,585	7	23	16	%30
Tunisia	15,894	7947	22	16	−6	%138
UAE	4707	2353.5	5	5	0	%106
Yemen	13,182	6591	2	13	11	%15
Ghaza and west Bank	4499	2249.5	0	5	5	%0
Total	429,325	214662.5	338	430	92	79%

^{*} Based on the assumption that 50% of new cancer patients will need RT (disregarding re-irradiation).^{**} Based on the assumption that each MVM can accommodate up to 500 RT course per year (rounded).

0.15 ± 0.28) with *P* value of 0.004. Although there was a trend for MVM to be more available in Asian countries (median 0.94 ± 1.1) compared to African countries (median 0.43 ± 0.46), the difference was not statistically significant (*P* = 0.09). Meanwhile, the 6 countries sustaining academic and educational links with reciprocal Western centers have higher MVM per 1000 patients (median 0.98 ± 0.28) compared to other countries (median 0.43 ± 1.03), with no statistically significant difference (*P* = 0.076).

In 2017, the mean expenditure on health in 20 Arab countries was 5.53% of GDP (range 2.2–10.6%) (Somalia and Palestine data were not published) [9]. On average, 1.56 physicians are available for each 1000 inhabitants, while the hospitals have an average of 2.1 beds per 1000 population (table 4). WHO 2015 report [10] estimated an average of 553 USD as current health expenditure (CHE) per capita in 18 Arab countries (lacking data from Libya, Somalia,

Syria and Palestine). In five countries (Qatar, UAE, Bahrain, KSA and Kuwait), the health expenditure per capita exceeded 1000 USD per year, while in four other countries (Comoros, Djibouti, Mauritania and Yemen), it amounted to less than 100 USD per year. In the present study, the percentage of CHE from GDP was not found to be significantly different between Asian (4.58%) and African Arab countries (6.69%) (*P* = 0.102). However, Asian countries have significantly higher absolute CHE per capita (average of 875 USD) than 151.5 USD in African countries (*P* = 0.013).

High-income Arabic countries are well equipped with 135.4% of the needed MVM, whereas UMIC and LMIC have 75.5% and 72.5% of the needed MVM, respectively. The number of available MVM per 1000 cancer patients was found to be statistically correlating with GDP per capita (*r* = 0.583, *P* = 0.006) (Fig. 1). This correlation was still significant (*r* = 0.74, *p* = 0.0002) even after removal of the out-

Table 4

Economical and Health expenditure parameters in 2017.

Countries	GDP [*] in million US\$	GDP/capita (in US\$)	Health expenditure (% of GDP)	Physicians/1000 pop.	Hospital bed/1000 pop.
Algeria	164,779	4154.1	7.2	NA	1.9
Bahrain	31,126	22600.2	5	0.9	2
Comoros	1079	1368.9	6.7	NA	2.2
Djibouti	1737	1956.3	10.6	0.2	1.4
Egypt	315,917	3452.3	5.6	0.8	1.6
Iraq	164,234	4509.0	5.5	0.9	1.4
Jordan	37,517	4940.1	7.5	2.6	1.4
Kuwait	114,054	29303.9	3	1.9	2
Lebanon	50,149	8571.4	6.4	2.4	2.9
Libya	34,457	5488.2	5	2.1	3.7
Mauritania	5023	1235.0	3.8	NA	NA
Morocco	100,359	2919.3	5.9	0.6	1.1
Oman	69,832	15550.8	3.6	1.5	1.6
Qatar	164,641	73653.4	2.2	2	1.2
Saudi Arabia	653,219	20710.6	4.7	2.6	2.7
Somalia	1559	144.5	NA	~0.0	8.7
Sudan	79,546	1977.0	8.4	3.1	0.8
Syria	28,393	1534.5	3.3	1.5	1.5
Tunisia	41,199	3660.9	7	1.6	2.2
UAE	370,296	40438.8	3.6	1.6	1.2
Yemen	29,688	1106.4	5.6	0.3	0.7
Palestine (West Bank, Gaza)	NA	NA	NA	NA	1.26

^{*} GDP: Gross domestic product.

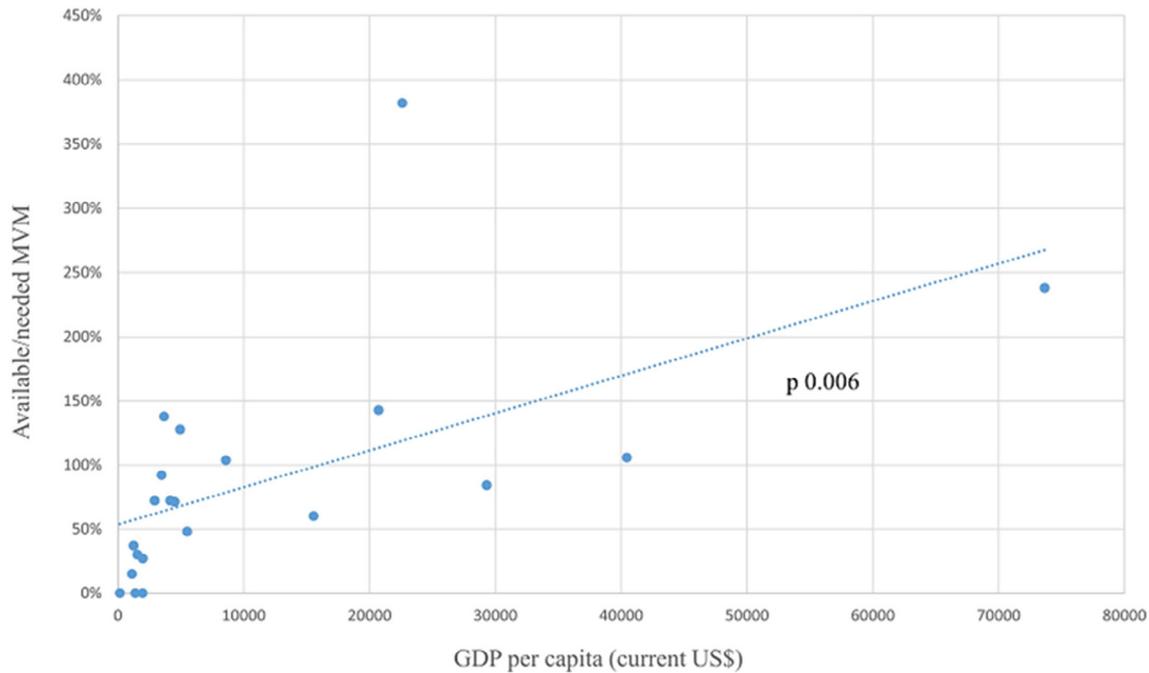


Fig. 1. Correlation between number of available MVM per 1000 cancer patients and GDP per capita.

liers in the curve. This correlation was not significant with percentage of health expenditure from GDP, hospital bed density or physicians per 1000 inhabitants ($r = -0.338$, -0.137 and 0.182 and $P = 0.157$, 0.552 and 0.469 , respectively). Moreover, MVM per 1000 cancer patients was found to be significantly more in HIC and UMIC (median 0.94 ± 1.04) compared to LMIC and LIC (median 0.3 ± 0.51) with ($P = 0.013$). Similarly, MVM is more available for patients in Gulf countries, which are considered to be HIC, compared to the rest of Arabic countries (median 1.2 ± 1.2 versus median 0.48 ± 0.46 , respectively) ($P = 0.01$).

Based on GLOBOCAN report in 2018, the average MIR in Arab countries is 59.5%. The least MIR is reported in Saudi Arabia (43%), UAE (44.2%) and Kuwait (46.3%); however, MIR exceeded 50% in the remaining 19 countries and surpassed 70% in four African countries as shown in Table 1. It is noteworthy that the mean MIR in Arab Asian countries is significantly lower than African ones (53.4% versus 62.7%, respectively, $P = 0.016$). Moreover, MIR is significantly less in Gulf countries than in the rest of Arab countries (49.2 versus 60.9%, respectively, $P = 0.005$). On the other hand, our analysis showed that MIR was not significantly different in North African countries compared to the rest of Arabic countries (60.24% versus 59.27%, $P = 0.092$), or in politically stable versus unstable countries ($P = 0.34$). Unsurprisingly, HIC and UMIC have statistically significant lower MIR compared to LMIC and LIC (51.3% versus 66.3%, $P = 0.001$). Table 5 demonstrates correlation between MIR and different factors. It was found to be significantly

correlated only with GDP per capita, physicians per 1000 population, MVM per 1000 cancer patients and absolute MVM deficit (Fig. 2a–d).

Using multivariate linear regression test, a significant regression equation was found with $F = 6.689$, $P = 0.004$ and an R^2 of 0.673. MIR was found to be significantly influenced by the number of physicians per 1000 population with standardized and non-standardized coefficients of -0.508 and $-5.3 (\pm 1.8)$ and P values of 0.01. Available/needed MVM, absolute MVM deficit and GDP per capita were not significant predictors for MIR with P values of 0.746, 0.115 and 0.151, respectively.

Discussion

Breast, liver, colorectal and lung cancers are the commonest cancers in Arabic countries, where RT is a cornerstone in their management [11]. GTRFCC used CCORE research and other contributions from the Global Task Force to assess radiotherapy cost-benefit ratio. It concluded that investing 94 billion US\$ in radiotherapy services in low- and middle-income countries would yield a benefit of 280 billion US\$ in 20 years [4].

While 338 MVM serve a total population of 422.7 million in Arabic countries (1.25 million per MVM), RT facilities are not evenly distributed across the region. The high discrepancy in cancer incidences noted between different countries may be partially attributed to the inaccuracy of cancer reporting and verification rather than real variation in incidence rate. Considering the benchmark figure of 50% of cancer patients requiring RT at one point along their disease history and considering that each MVM offer an average of 500 courses per year, the Arabic region possess only 79% ($n = 338/430$) of its MVM needs. Such MVM availability seems higher than that of Africa and Asia-pacific (34% and 61%, respectively), but lower than Latin America and Europe (88% and 92%, respectively). Of note, North America is over equipped with 195% of its needed MVM [3]. High income Arabic countries are well equipped with 135.4% of the needed MVM, which is statistically higher than that in UMIC (75.5%) and LMIC (72.5%). It is notewor-

Table 5
Correlation between mortality incidence ratio (MIR) and different factors.

Factor	Correlation coefficient (r)	P value
GDP per capita	-0.555	0.009
Physicians per 1000 population	-0.625	0.006
MVM per 1000 cancer patients	-0.42	0.047
Absolute MVM deficit	-0.436	0.043
Bed density per 1000 inhabitants	0.370	0.099
Number of RT centers	0.028	0.9
Absolute number of MVM	-0.014	0.95
Availability of brachytherapy units	-0.151	0.502

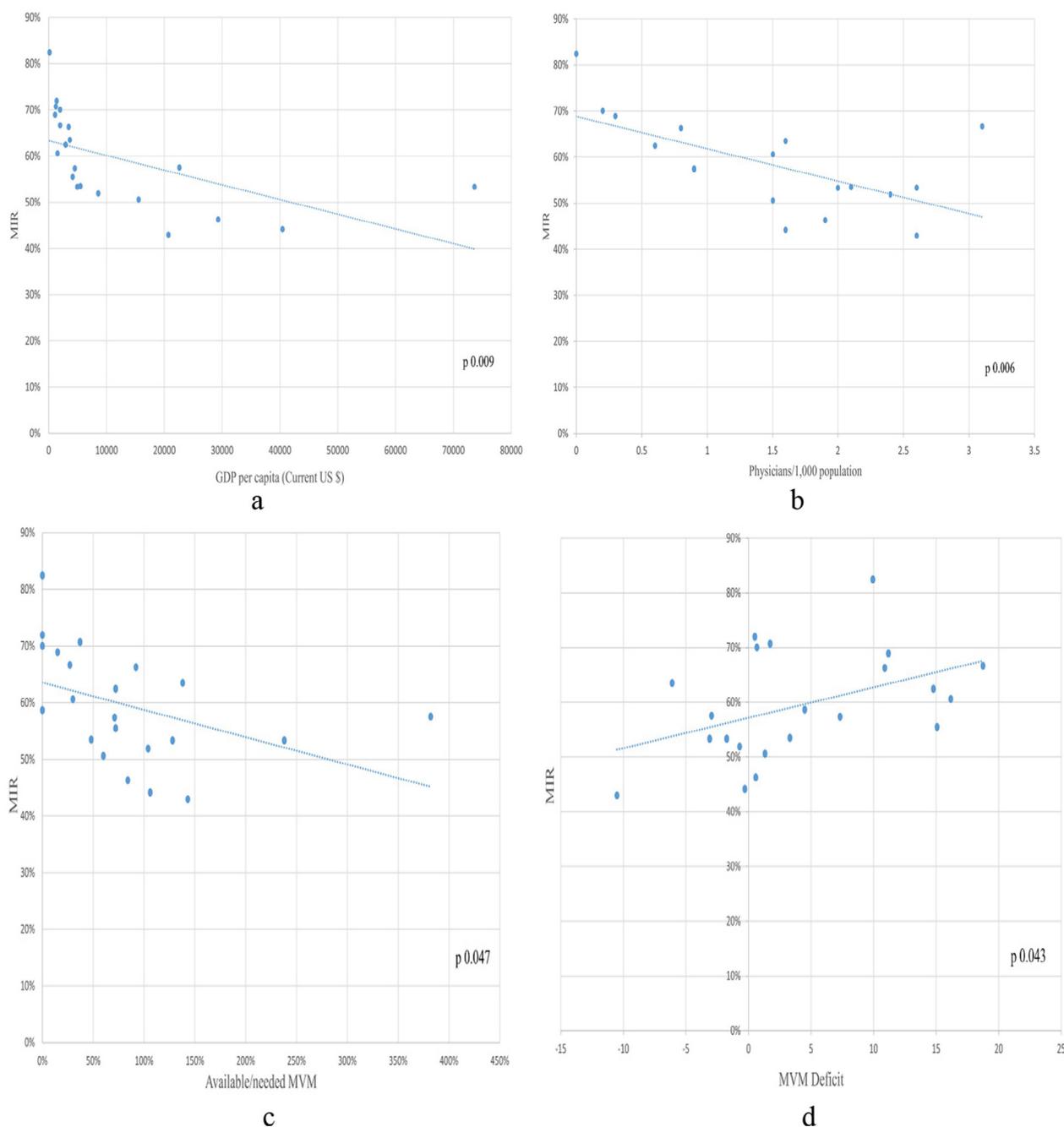


Fig. 2. Factors influencing MIR: a) GDP per capita (Current US\$). b) Physicians per 1000 population. c) Available/needed MVM. e) MVM deficit.

thy that the MVM deficit could be underestimated as the need for re-irradiation was not considered in this study.

Our results show that the availability of RT service was significantly influenced by economic status and correlated positively with GDP per capita ($r = 0.583$, $P = 0.006$). Although Gulf countries (HIC) are well equipped with a median of 1.25 ± 1.22 MVM for each 1000 cancer patient, not all HIC in the region enjoy the same high average MVM per 1000 cancer patients, as Kuwait and Oman have an average of 0.98 MVM per 1000 cancer patients compared to an average of 1.49 in the remaining 4 HIC. On the other hand, Asian Arabic countries are better equipped with RT resources than Asia-Pacific region (available/needed MVM 83.6% versus 61%, respectively) [3]. Similarly, African Arabic countries have more RT resources compared to Africa as a whole (available/needed MVM 76.5% versus 34%, respectively). Another finding in the pre-

sent study is the lower MIR in Gulf countries compared to the rest of Arab world. This could be explained by the higher RT availability in Gulf countries and also by the policy of overseas treatment for their citizens. For instance, 415 Saudi cancer patients were treated overseas in one year, sponsored by the Saudi government [20]. Another plausible explanation could be that most of Gulf countries provide new-generation high-technology services, including Cyberknife, tomotherapy and volumetric modulated arc therapy. Such high-quality RT, besides Western training of most radiation oncologists in the Gulf, could potentially contribute in increasing tumor control and reducing radiation-induced toxicities. In addition, the availability of novel expensive systemic therapies might also contribute in improving MIR.

Arabic countries with academic links to Western oncology associations or centers are fairly equipped with a country-specific

mean of 1.01 ± 0.28 MVM for each 1000 cancer patients, while the overall RT availability in the region is 0.89 MVM per 1000 patients. Jordan represents one particular example of an Arab country exhibiting recent advancement in its radiotherapy facilities. This was first triggered in 1993, when King Hussein of Jordan was diagnosed by cancer and treated in the United States. This raised cancer awareness in Jordan and attracted governmental attention to support the establishment of modern, well-equipped cancer centers. As a result, King Hussein Cancer Centre (KHCC) was founded in 1997 and over the past two decades, Jordan has gradually shifted from a state of deficient cancer care to one of excellence, benefiting from training and technical support provided by multiple Western centers [15]. After Princess Dina Mired had successfully led KHCC to be one of the distinguished centers in LMIC as a director general for 15 years, she extended her efforts globally to be elected as the president for Union for the International Cancer Control (UICC) in 2018, to become the first Arabic to serve in this highly regarded position. She continued, through her new position, to cooperate with Arabic oncology centers and personnel to improve the educational and research status [21].

Arabic LMIC and UMIC have 72.5% and 75.5% of their needed MVM, respectively, which is higher than the global coverage of 31% and 46% in the same economical categories, respectively [22]. However, this partially satisfactory coverage in MVM service was not extended to brachytherapy services. Unfortunately, 1953 new cervical cancer patients were expected to be diagnosed in 2018 in the seven brachytherapy-deficient countries with expected inferior cure rates compared to matching cases in countries possessing brachytherapy facilities [23]. Of 22 Arabic countries, five have had political uprisings since January 2011, what is called "Arab spring". Unfortunately, three (Yemen, Libya and Syria) are still suffering from political turmoil. In addition, four more countries, Palestine, Djibouti, Iraq and Somalia, went through wars at some point during the last two decades. Political instability in these seven countries has drained national resources, created competing priorities that slowed down medical sector expansion and caused health expenditure to be placed at the bottom of national priorities [24]. Though 2 of these 7 countries (Iraq and Libya) are UMIC, still MVM is not adequately available in them. Only 36% of the required MVM are currently available which is significantly less compared to other politically stable Arab countries. Unsurprisingly, three of these politically unstable countries have no radiation facilities.

Formal education and training programs are provided for radiation oncologists (ROs) in less than half of Arab countries, while education for medical physicists (MP) is usually delivered in faculties of science with minimal, if any, clinical training during the academic years. In most countries, the training opportunities are usually offered as on-job training in hospitals or oncology centers. As a result of lacking local radiation oncology training programs [25], radiation oncologists in some Gulf countries travel abroad for postgraduate training programs in North America, Western Europe or Australia. The situation is even worse for radiation therapy technologists (RTTs), as less academic and training programs are currently being offered. The lack of well-structured training programs and shortage of well-trained professionals are among the difficulties hindering radiotherapy availability and development in most Arab countries. Unfortunately, in most low- and middle-income countries, low national budgets are allocated for education and healthcare [26,27]. Thus, healthcare providers rely on individual connections to facilitate training in European or North American centers.

Recently, many Arab countries have been taking the initiative of establishing national training programs to fulfill clinical needs.

Numerous universities started to implement certified programs, in conjunction with cancer hospitals and centers, to graduate MPs, dosimetrists and RTTs in an attempt to enhance staff knowledge and skills and lower the dependence on foreign labor [13,28]. Realizing the supreme importance of adequate RTTs training, some Egyptian universities, both governmental and private, established Bachelor and Master's degrees in radiation oncology technology. Egypt also offers diverse training programs for ROs including academic Master's and Doctorate degrees in clinical oncology or radiation oncology as well as clinically oriented training programs such as the Egyptian radiation oncology fellowship [13]. Moreover, the radiation oncology Arab, Jordanian, Egyptian and Kurdistan boards are successful examples of training boards that share the cardinal aim of improving cancer services, both scientifically and technically, in the Arab world. RO residency training program in Saudi Arabia is scheduled to start in October 2019.

On an international level, the IAEA has worked together with the member states to initiate several working agreements through which the latter can establish academic and clinical training pathways graduating high-caliber MPs and RTTs. ARASIA (Arab States in Asia) is one such agreement that was initiated in 2002 and defined as a "co-operative agreement for Arab States in Asia for research, development and training related to nuclear science and technology". Under the ARASIA umbrella, several projects were carried out to upgrade the medical physics services through post-graduate education, clinical residency programs and supporting calibration laboratories [28]. As a result, the status of training of MPs in Egypt, Jordan, KSA and some North African Arab countries are nearly comparable with attempts to establish multinational joint academic-clinical certified degrees and fellowships [28]. Further efforts were taken in collaboration with several international organizations, for example the IAEA, Global Task Force on Radiotherapy for Cancer Care (GTFRCC) of the UICC and the international NGO foundation Radiating Hope, to raise the standard of staff training in low- and middle-income countries including the Arab countries [29]. In addition, Children's Cancer Hospital in Egypt offers a unique joint fellowship with Dana Farber Cancer Institute and Mass General Hospital in USA on pediatric radiation oncology [13]. Decreased cancer-related mortalities reflect the success of national strategies against cancer. In addition to different health expenditure parameters, the availability of well-trained oncology surgeons, radiation oncologists, well-equipped cancer centers, systemic and radiation therapies are other factors that directly influence treatment outcome and mortality. The GTFRCC findings showed the potential to save one million lives per year by 2035 through optimum access to radiation therapy, with a clear economic benefit of 365 billion US\$ over a period of twenty years [30].

In this study, MIR was found to be correlated with the absolute deficit of MVM and inversely correlated with MVM per 1000 population. Similarly, Medenwald et al. found evidence for an inverse association of MVM density in the population and MIR for some cancer types [31]. Although the number of RT centers and MVM/million inhabitants was not significantly different between high income Gulf countries and the rest of Arab countries, MVM/1000 cancer patients and MIR were significantly different in the former than in the latter, which is in accordance with Batouli et al.'s report [32]. Among the factors correlating with MIR, stepwise multivariate regression analysis ascertained that MIR is significantly correlated with the number of physicians per 1000 population. This correlation might emphasize the role of variable subspecialties in comprehensive cancer management and the influence of other factors, such as chemotherapy, immunotherapy and specialized oncological surgery on MIR, all of which are not included in our analysis.

Study limitations

The data presented in this study has relatively variable reference dates. Economic parameters were published in 2017 and radiotherapy data were gathered from DIRAC records in September 2018. Many Arabic countries do not have nationwide population-based cancer registries; thus, the data on cancer incidence were derived from GLOBOCAN 2018 report (1) which is an estimate and not real-life data. Considering the evolving political issues in some countries, some cancer records are under-estimated. Additionally, economic data were not readily available in some countries. In addition, the DIRAC data depend on self-reporting, without auditing, which is subjected to under-estimation, low data quality or deficient information [33]. DIRAC does not also report on the complexity of available machines or the techniques used.

To the best of our knowledge, this is the first analysis of the availability of radiotherapy services in Arab countries, which largely represents the situation in third world countries. High income countries are well equipped with RT services with significantly lower MIR compared to the remaining Arabic countries. Politics is another influential factor in RT availability, where politically unstable countries have significantly less available services compared to stable countries. Arabic countries sustaining professional relations with Western centers are fairly equipped with RT services; however, this was not translated into real improvement of MIR compared to other countries. This report shows the gap in radiotherapy coverage that needs to be filled and demonstrates the substantial discrepancy in radiotherapy services across the Arab World. We urge governments, the Arab league and international organizations to share the responsibility of improving radiotherapy infrastructure and encouraging investments in radiotherapy services in the Arab region.

References

- Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin* 2018;68:394–424. <https://doi.org/10.3322/caac.21492>.
- Borras JM, Lievens Y, Dunscombe P, Coffey M, Malicki J, Corral J, et al. The optimal utilization proportion of external beam radiotherapy in European countries: an ESTRO-HERO analysis. *Radiation Oncol* 2015;116:38–44. <https://doi.org/10.1016/j.radonc.2015.04.018>.
- Zubizarreta E, Van Dyk J, Lievens Y. Analysis of global radiotherapy needs and costs by geographic region and income level. *Clin Oncol* 2017;29:84–92. <https://doi.org/10.1016/j.clon.2016.11.011>.
- Atun R, Jaffray DA, Barton MB, Bray F, Baumann M, Vikram B, et al. Expanding global access to radiotherapy. *Lancet Oncol* 2015;16:1153–86. [https://doi.org/10.1016/S1470-2045\(15\)00222-3](https://doi.org/10.1016/S1470-2045(15)00222-3).
- <http://www.lasportal.org/en/aboutlas/Pages/CountryData.aspx/> [accessed 02 August 2018].
- Baskar R, Itahana K. Radiation therapy and cancer control in developing countries: can we save more lives? *Int J Med Sci* 2017;14:13–7. <https://doi.org/10.7150/ijms.17288>.
- <http://gco.iarc.fr/today/fact-sheets-populations/> [accessed 15 Sept. 2018].
- <http://data.un.org/Default.aspx/> [accessed 05 Sept. 2018].
- <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups/> [accessed 05 Sept. 2018].
- <http://apps.who.int/nha/database/ViewData/Indicators/en/> [accessed 15 Sept. 2018].
- http://gco.iarc.fr/today/online-analysis-table?v=2018&mode=cancer&mode_population=continents&population=900&populations=900&key=asr&sex=0&cancer=39&type=0&statistic=5&prevalence=0&population_group=0&ages_group%5B%5D=0&ages_group%5B%5D=17&nb_items=5&group_cancer=1&include_nmssc=1&include_nmssc_other=1/ [accessed 15 Sept. 2018].
- <https://dirac.iaea.org/Query/Countries/> [accessed 05 Sept. 2018].
- Zaghloul MS, Bishr MK. Radiation oncology in Egypt: a model for Africa. *Int J Radiat Oncol Biol Phys* 2018;100:539–44. <https://doi.org/10.1016/j.ijrobp.2017.10.047>.
- Important ESTRO dates. *Radiation Oncol* 2011;100(3):1.
- Bhadelia A, Treish I, Bitar Z, Anastas R, Sarhan M. Jordan: creating a regional center of excellence for cancer care as a focus for a national program on CCC. In: Knaul FMJR, Gralow R, Atun A, editors. *Bhadelia Closing the cancer divide: an equity imperative*. Cambridge, MA: Harvard Global Equity Initiative/Harvard University Press; 2012. p. 129–32.
- Jong-A-Pin R. *Essays on political instability: measurement, causes and consequences*. Enschede, the Netherlands: Print Partners Ipskamp BV; 2008. p. 4–5.
- Rosenblatt E, Fidarova E, Zubizarreta EH, Barton MB, Jones GW, Mackillop WJ, et al. Radiotherapy utilization in developing countries: an IAEA study. *Radiation Oncol* 2018;128:400–5. <https://doi.org/10.1016/j.radonc.2018.05.014>.
- Yap ML, Zubizarreta E, Bray F, Ferlay J, Barton M. Global access to radiotherapy services: have we made progress during the past decade? *J Glob Oncol* 2016;2:207–15. <https://doi.org/10.1200/JGO.2015.001545>.
- International Atomic Energy Agency Planning national radiotherapy services: A practical tool. 2010. IAEA human health series no. 14.
- [https://www.moh.gov.sa/Ministry/Statistics/book/Documents/2017-08-24-01000 Page 232](https://www.moh.gov.sa/Ministry/Statistics/book/Documents/2017-08-24-01000%20Page%20232).
- https://www.uicc.org/sites/main/files/atoms/files/HRHPPrincess-Dina-Mired_Bio_Oct2017.pdf.
- Zubizarreta EH, Fidarova E, Healy B, Rosenblatt E. Need for radiotherapy in low and middle income countries – the silent crisis continues. *Clin Oncol (R Coll Radiol)* 2015;27:107–14. <https://doi.org/10.1016/j.clon.2014.10.006>.
- Nag S, Chao C, Erickson B, Fowler J, Gupta N, Martinez A, et al. The American brachytherapy society recommendations for LDR brachytherapy of the cervix. *Int J Radiat Oncol Biol Phys* 2002;52:33–48.
- Levin V, Tatsuzaki H. Radiotherapy services in countries in transition: gross national income per capita as a significant factor. *Radiation Oncol* 2002;63:147–50.
- <https://www.scfhs.org.sa/en/MESPS/TrainingProgs/TrainingProgsStatement/Pages/default.aspx>. [accessed 15 August 2018].
- Abdel-Wahab M, Bourque JM, Pynda Y, Iżewska J, Van der Merwe D, Zubizarreta E, et al. Status of radiotherapy resources in Africa: an International Atomic Energy Agency analysis. *Lancet Oncol* 2013;14:e168–75. [https://doi.org/10.1016/S1470-2045\(12\)70532-6](https://doi.org/10.1016/S1470-2045(12)70532-6).
- Grover S, Xu MJ, Yeager A, Rosman L, Groen RS, Chackungal S, et al. A systematic review of radiotherapy capacity in low-and-middle-income countries. *Front Oncol* 2015;4:380. <https://doi.org/10.3389/fonc.2014.00380>.
- Wadi-Ramahi S, Moftah B, Khader J, Alhaddad Z, Mula-Hussain L, Hassan Z. Challenges and solutions of establishing advanced radiation oncology services in low and middle income (LMI) countries. In: International conference on advances in radiation oncology (ICARO2) Vienna, Austria 20–23 June. p. 157–8.
- Bishr MK, Zaghloul MS. Radiation therapy availability in Africa and Latin America: two models of low and middle income countries. *Int J Radiat Oncol Biol Phys* 2018;102:490–8. <https://doi.org/10.1016/j.ijrobp.2018.06.046>.
- Rodin D, Abdel-Wahab M, Lievens Y. Global radiotherapy challenge: turning data into action. *Lancet* 2018;6:S15–6. [https://doi.org/10.1016/S2214-109X\(18\)30089-5](https://doi.org/10.1016/S2214-109X(18)30089-5).
- Medenwald D, Vordermark D, Dietzel C. Number of radiotherapy treatment machines in the population and cancer mortality: an ecological study. *Clin Epidemiol* 2018;10:1249–73. <https://doi.org/10.2147/cep.s156764>.
- Batouli A, Jahanshahi P, Gross CP, Makarov DV, Yu JB. The global cancer divide: relationships between national healthcare resources and cancer outcomes in high-income vs. middle- and low-income countries. *J Epidemiol Glob Health* 2014;4:115–24. <https://doi.org/10.1016/j.jegh.2013.10.004>.
- International Atomic Energy Agency. DIRAC (Directory of Radiotherapy Centers). <http://www-naweb.iaea.org/nahu/dirac/default.asp> [accessed 15 Sept. 2018].