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Original research article

Assessment of performance indicators of a radiotherapy department using an electronic medical record system

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ABSTRACT

Aim: To retrospectively assess the performance indicators of our radiotherapy department and their temporal trends, using a commercially available electronic-medical-record (EMR) system.

Background: A recent trend in healthcare quality is to define and evaluate performance indicators of the service provided.

Materials and methods: Patient and external-beam-radiotherapy-treatments data were retrieved using the Mosaiq EMR system from 1-January-2012 till 31-December-2015.

Annual performance indicators were evaluated as: productivity (number of new cases/year and diagnosis distribution); complexity (ratio of Volumetric-Modulated-Arc-Therapy (VMAT) courses, average number of imaging procedures/patient); and quality (average, median and 90th percentile waiting times from admission to first treatment).

The temporal trends of all performance indicators were assessed by linear regression.

Results: Productivity: the number of new cases/year increased with an average rate of 4%. Diagnosis distribution showed that breast is the main pathology treated, followed by gastro-intestinal and head-and-neck.

Complexity: the ratio of VMAT courses increased from 13% to 35%, with an average rate of 7% per year. The average number of imaging procedures/patient increased from 8 to 11.

Quality: the waiting times from admission to treatment remained stable over time ($R^2 \leq 0.1$), with average, median and 90th percentile values around 20, 15, and 31 days, respectively.

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Conclusions: An EMR system can be used to: monitor the performance indicators of a radiotherapy department, identify workflow processes needing attention and improvement, estimate future demands of resources.
Temporal analysis of our data showed an increasing trend in productivity and complexity paired with constant waiting times.
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1. Background

As an attempt to improve the healthcare quality, a recent and increasing trend is to define and evaluate performance indicators of the service provided. Performance indicators are specific to each medical specialty and designed to assess operational conditions and trends of practice over time, as well as plans of action for a continuous quality improvement.[1–4]

Practical tools to generate data for performance assessment are the electronic medical record (EMR) systems which allow departments not only to collect and access comprehensive patient information, but furthermore to report and monitor data on their performance.[5,6]

The performance evaluation by indicators is still not largely used in radiotherapy and only a few experiences have as yet been reported.[7–9] Due to the increase in cancer incidence and developments in technology and knowledge, the radiotherapy practice is constantly evolving, therefore measuring and responding to temporal changes is useful in ensuring that a department runs efficiently.

The purpose of the current study is to retrospectively assess the performance indicators of our radiotherapy department and their trends during the last 4 years, using a commercially available EMR system.

2. Materials and methods

Patient and treatment data were retrieved using reports generated by the Mosaiq EMR system (Elekta AB, Stockholm, Sweden) version 2.6, from 1 January 2012 till 31 December 2015. Retrospective data analysis included external beam radiotherapy treatments (EBRT) delivered on 3 linear accelerators (linacs), all equipped with on-board imaging systems and used in clinical routine since June 2007, June 2010 and February 2012, respectively. One of the linacs was decommissioned from clinical use in February 2013.

Mosaiq EMR system is specifically designed for oncology departments, offering tools of recording patient information such as: clinical assessment, prescribed medication, diagnostic images, laboratory results, and external documentation. In addition to the management of a clinical cancer database, it provides the function of a record-and-verify system for radiotherapy through the ability to distribute and access radiotherapy planning, treatment, and patient management information. The system stores all radiotherapy-related information (e.g. beam data, patient's reference images and associated structures, treatment set-up data) and transfers them to the treatment units. Treatment is allowed only after verification and appropriate approvals, and once delivered the system records the delivery parameters.

All patients receiving EBRT were registered in the EMR system at the time of admission. Data were exported to an Excel worksheet version 2010 (Microsoft Corporation, Washington, USA). All radiotherapy courses were image-guided.

A multi-disciplinary team including all radiotherapy department stakeholders (radiation oncologists, physicists, radiation therapists, nurses, administrative assistants) defined and evaluated the performance indicators on annual basis, as follows:

1. Productivity, measured by the number of new cases per year, and diagnosis distribution.
2. Complexity, measured by the ratio of Intensity-Modulated-Radiation-Therapy (IMRT) and Volumetric-Modulated-Arc-Therapy (VMAT) courses, average number of fractions per patient, and average number of images per patient.
3. Quality, measured by the average, median and 90th percentile waiting times from admission to first treatment session, and number of patients exceeding 31 days waiting time.

The trends of all performance indicators during the analyzed time interval were assessed by linear regression, using IBM SPSS Statistics software version 20 (IBM Corporation, NY, USA).

3. Results

3.1. *Productivity*

The number of new cases per year increased from 696 to 833, with an average rate of 4% per year; consequently, the number of radiotherapy fractions rose over time from about 12400 to 14750. The trend lines in Fig. 1a and b show a continuous shift from three-Dimensional-Conformal-Radiation-Therapy (3D-CRT) toward VMAT treatments.

Diagnosis distribution showed that breast is the main pathology treated in our department, followed by gastro-intestinal (GI) and head-and-neck (H&N). Breast cases ratio constantly increased, from 38% to 46%, with an annual average rate of 6%. GI and head-and-neck cases ratio slightly fluctuated over time around the average value of 12% each.

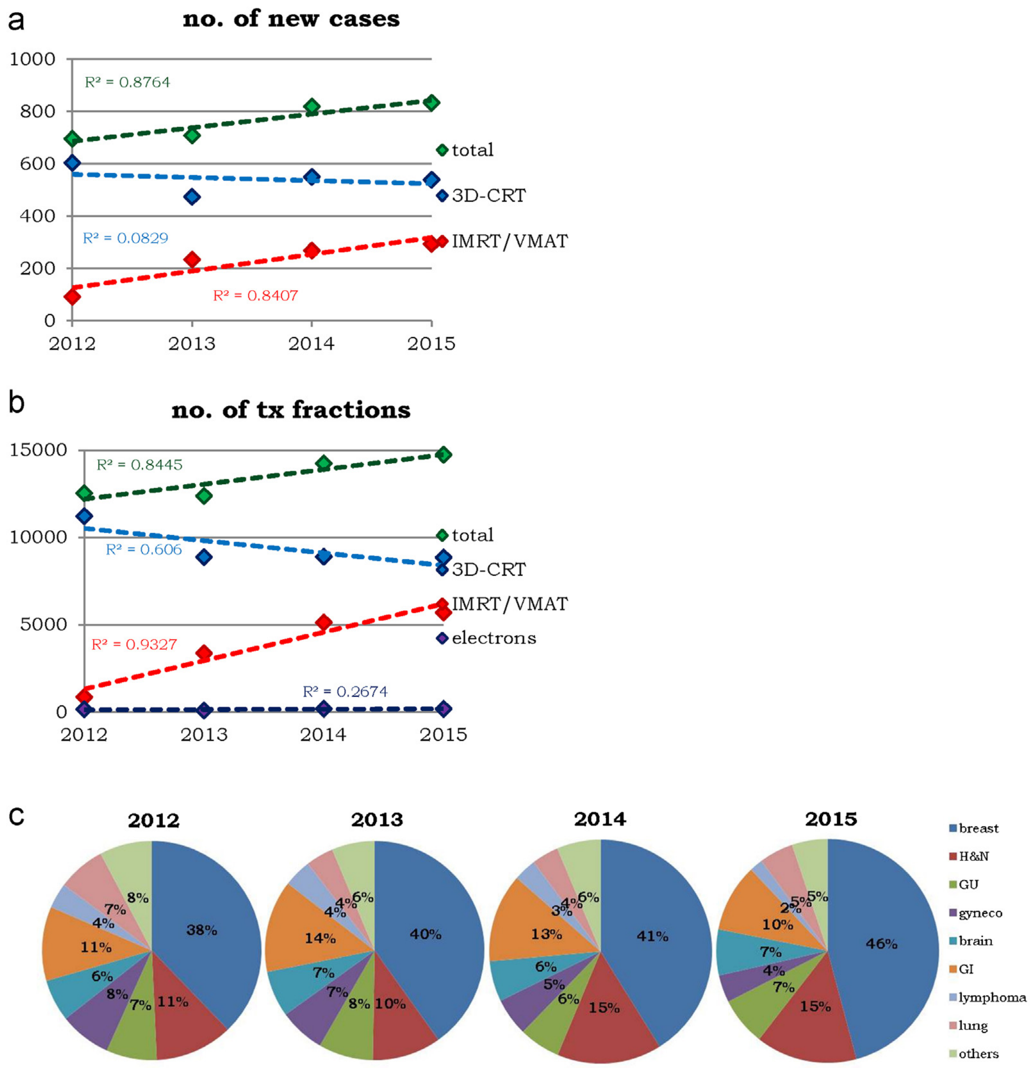

Fig. 1 – Number of new cases (a) and number of treatment fractions per year (b). (c) Diagnosis distribution per year.

3.2. *Complexity*

The ratio of VMAT courses increased from 13% to 35%, with an average rate of 7% per year. The temporal trend is shown in Fig. 1a and b.

The average number of fractions per patient slightly varied around the value of 18 (Fig. 2a).

The average number of images per patient increased from 8 to 11. The ratio of Cone-Beam-Computed-Tomography (CBCT) imaging was also growing over time, from 14% to 50%, with an average rate of 10% per year. This trend is presented in Fig. 2b.

3.3. *Quality*

The waiting times from admission to treatment remained stable over time ($R^2 \leq 0.1$), with average, median and 90th percentile values around 20, 15, and 31 days, respectively, as shown in Fig. 3a. An increase of the waiting times was noticed in 2013, amended during the following years.

Although extended up to 13% in 2013, the number of patients exceeding 31 days waiting time slightly decreased to 10% during the following years, presenting an overall stable trend ($R^2 \leq 0.1$), as shown in Fig. 3b. The clinical cases with current long waiting times appeared to be head-and-neck, genito-urinary (GU), gynecological and brain cancer (Fig. 3c).

4. Discussion

Assessing and monitoring the performance in healthcare became increasingly important, as it leads to improvement, by allowing medical professionals to make decisions based on objective quality measures. Performance indicators are quantifiable and specific elements, based on standards established from evidence-based information or consensus of experts when evidence is lacking.[10,11] They can be used to: document the quality of care, compare and benchmarking institutions, set managerial priorities, sustain accountability, regulation and accreditation. Performance indicators also indicate areas that require further attention and development and help to identify and monitor healthcare trends in the process of quality improvement.[10–14]

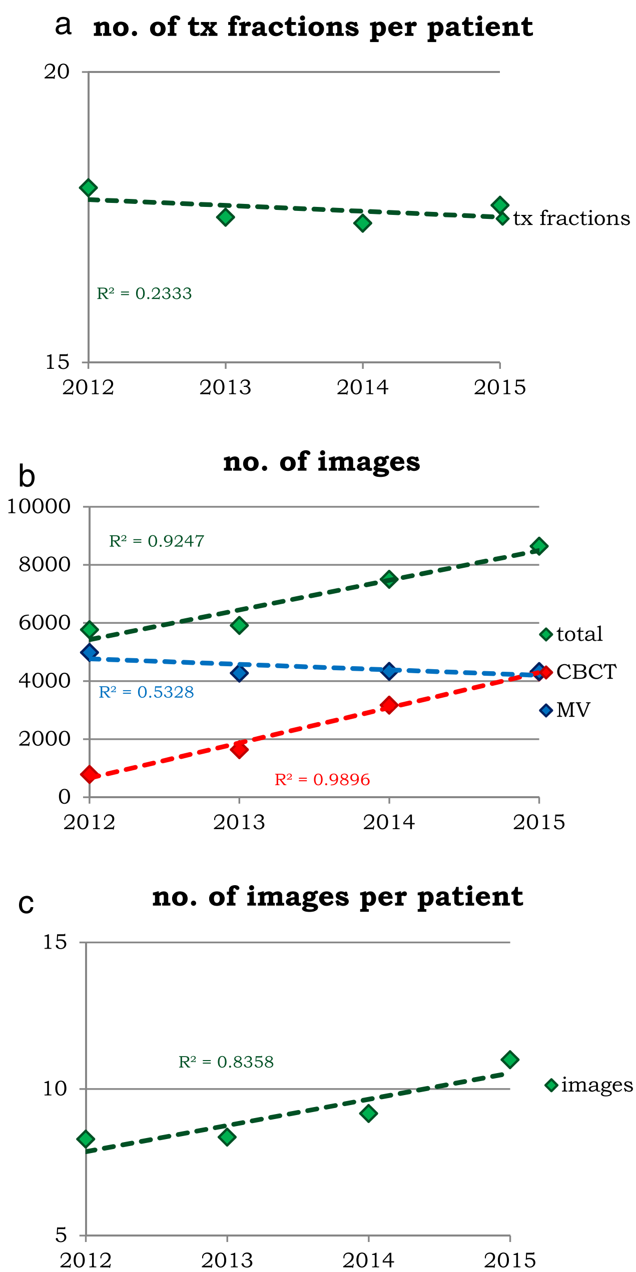

Fig. 2 – (a) The average number of treatment fractions per patient per year. (b) Number of images per year. (c) Number of images per patient per year.

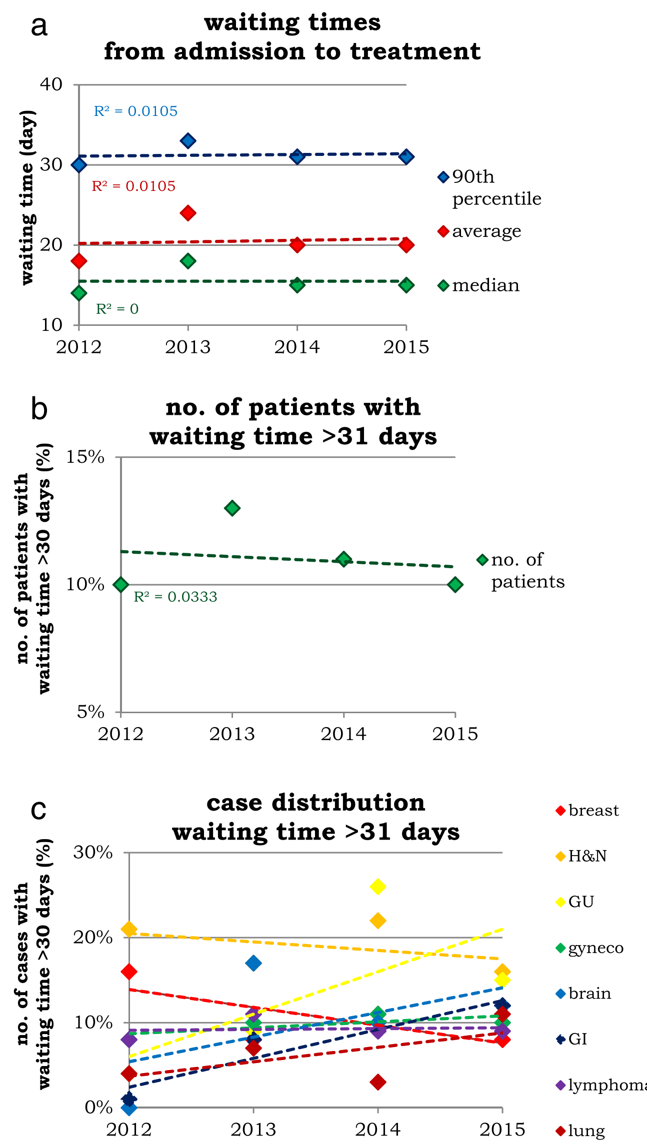

Fig. 3 – (a) Average, median and 90th percentile waiting times from admission to treatment per year. (b) Number of patients exceeding 31 days waiting time per year. (c) Diagnosis distribution of patients exceeding 31 days waiting time per year.

In the particular case of radiation oncology, evidence-based quality indicators have been defined, aiming to provide benchmarking data and to help in establishing strategies of optimizing the institutional performance.[1–5] However, recent research on the reported performance indicators of radiation oncology centers showed that literature on this subject is scarce and that the selection of relevant indicators is challenging.[16,17] Cionini et al. proposed a set of indicators able to monitor the performance and quality status of a typical radiotherapy department.[2] They were related to general features of the service, technical complexity of treatment, and specific medical physics activities. Van Lent et al. tested possible performance indicators in four European radiotherapy centers and concluded that the workload, percentage of patients treated with new technologies and waiting times appear to be the most relevant indicators.[16] These were the indicators we selected to report in this study, by a self-assessment of productivity (as a general indicator of radiotherapy service efficiency), complexity, and waiting times (as a quality characteristic of the service).

4.1. *Productivity*

The rationale of this indicator is to evaluate the efficiency in the utilization of specific radiotherapy equipment. The optimal radiotherapy services are provided if they are integrated into well-designed healthcare systems and national cancer programs that comprise screening and early detection, as well as adequate resources for treatment. Among all cancer patients, radiotherapy has proven to be beneficial to about 48–62% of them, according to the profile and stage of disease at presentation, which are population-specific.[18–20] Therefore, in order to estimate the radiotherapy demand over a definite period of time, it is necessary to know the number of patients requiring radiotherapy, the distribution of diagnosis and stages, along with their related temporal trends.

The European Society for Therapeutic Radiology and Radiation Oncology (ESTRO) developed in 2005 the QUARTS (Quantification of Radiation Therapy Infrastructure and Staffing Needs) project, which estimated an annual workload of 450 radiotherapy courses per linac in Europe.[21] This standard is debated nowadays given that the radiotherapy practice has significantly evolved by the development of advanced technologies and fractionation schedules. Nevertheless, another international standard adapted to the current practice has not been yet established. Recent national Dutch and British reports indicate annual workloads of 500 and 800 radiotherapy courses per linac, respectively.[8,22] Our data revealed a continuously increasing workload, from 230 radiotherapy courses per linac in 2012 to 420 in 2015, with an average rate of 4% per year. The workload increasing rate is relevant because, paired with data on cancer incidence growth rate, it provides a basis for estimation of future radiotherapy demand. The latest report of Saudi Cancer Registry also confirms this trend.[23]

Analysis of diagnosis distribution of patients receiving radiotherapy showed that the breast cancer is the main pathology treated in our department, followed by GI and head-and-neck. The number of breast cases constantly increased over time, reaching about 46% of the total number of cancer patients, while GI and head-and-neck cases slightly fluctuated around the average value of 12% each. The Saudi Cancer Registry revealed a different pattern of diagnosis distribution, with ratios of 15%, 18% and 7% for breast, GI, and head-and-neck, respectively, due to the fact that their reported data include all new cancer cases, not only the ones receiving radiotherapy.[23]

4.2. *Complexity*

A more comprehensive method to determine the radiotherapy demand is to take into account the full spectrum of diseases and their stages at national level, together with the ratio of patients that will require advanced treatment techniques (such as IMRT/VMAT) in comparison to 3D-CRT. This approach was suggested by a report of the International Atomic Energy Agency (IAEA), which recommended annual workloads ranging from 200 to 500 patients per linac, based on a standard of minimum 7 h per day of linac use.[24] Our data fall within this workload range. During the last 4 years the number of EBRT courses increased by about 4% per year, with a continuous shift from 3D-CRT to IMRT/VMAT treatments, which reached 35% of all EBRT courses. Similar published data are heterogeneous. A Dutch study described that the number of EBRT courses raised by 4% per year, 40% of them being IMRT, while a British one revealed 2.3% increase per year and 33% of all EBRT treatments delivered by IMRT.[8,22]

Number of treatment fractions per linac has been used for radiotherapy services evaluation and planning and recognized as a meaningful indicator.[25–28] The British National Radiotherapy Advisory Group reported an annual average of 7500 treatment fractions per linac, assuming 258 working days per year, 10 working hours per day, 4 fractions per hour, activity at 87% capacity, 3% downtime and 10% for testing, research and staff training.[8] Data of our department revealed an average of 6100 treatment fractions per linac over the last 4 years. Considering that our working day is 8 h, this indicator appears in agreement with radiotherapy practice in UK. However, substantial variations in radiotherapy fractionation practices between radiotherapy departments or radiation oncologists have been recognized, and currently there is no evidence-based benchmark for an optimal value.[27,29–31]

The crude value of average number of fractions per patient appears to be more appropriate, as it is related to the treatment complexity. The underlying assumption is that an increase of the average number of fractions per patient indicates a growing number of radical and/or dose escalation treatments. Obviously, the ratio of palliative to radical treatments may affect the value of the indicator. Recent data from Australia estimates that a curative course of radiotherapy requires an average of 22 fractions and a palliative one, 3 fractions, thus the total average would be 18 fractions per course, for a ratio of 4:1 curative to palliative treatments.[7] Our study confirms this estimation: the average number of fractions per patient constantly increased over time around the value of 18. This occurred despite a large and increasing number of breast cases treated by hypofractionated dose regimen, and is probably the net effect of a rising number of radical and/or dose escalation treatments.

Radiotherapy is an evolving healthcare discipline that rapidly implements advanced technologies; therefore, indicators describing this progress are of outstanding relevance. Image-guidance, using CBCT or EPID (electronic portal imaging detection), is commonly used to evaluate the stability and reproducibility of patient set-up and accuracy of treatment delivery. The usage of image-guidance correlates with the complexity of treatment, as more advanced and highly conformal treatments such VMAT require increased precision of patient positioning. With an increasing ratio of VMAT treatments, the number of imaging procedures was expected to rise, too, and be confirmed by practice. Our analysis indicates that the average number of images per patient increased from 8 to 11 due to a growing use of advanced techniques and a slightly rising number of fractions per patient. Noticeably, the ratio of CBCT imaging also increased over time, from 14% to 50%, with an average rate of 10% per year. The result is not surprising: as the dose distribution is planned and evaluated in 3D, it would be logical for the accuracy of patient positioning to be also verified in 3D.

4.3. *Quality, assessed by waiting times*

Waiting times depend on the capacity of the healthcare system to meet the demand for radiotherapy services and are noticeable indicators of performance. Delay in receiving radiotherapy is critical, as it increases the risk of local recurrence, detrimentally affects survival, and decreases the quality of life.[25,32] The shortage of radiotherapy resources (staff and equipment) is the main cause of the existence of waiting lists, and outstanding waiting times imply the need for additional resources.

As evidence showed, waiting times for radiotherapy should be as short as reasonably achievable, according to the clinical condition of the patient and treatment objective.[32–35] They were reported to range from 10 days for palliative/symptomatic treatments, to 60 days for adjuvant post-operative radiotherapy.[8,9,22,24]

The present study indicates that in our practice the average waiting times decreased from 24 days in 2013 to 20 days in the following years, while median and 90th percentile values remained stable, around 15 and 31 days, respectively. Also, the number of patients exceeding 31 days waiting time marginally decreased from 13% to 10%. The British national standard requires waiting times of 62 days from referral to first treatment, and, for radical radiotherapy, maximum 31 days between decision to treat by radiotherapy and first treatment, for 90% of patients.[8] Canadian reports specify the waiting time as the number of days from when the patient is ready for treatment to the start of treatment, and set a national target of 14 days median waiting time and 28 days waiting time for 90th percentile of patients.[9] Given the heterogeneity in defining waiting times, the scarcity of published data and in the absence of a Saudi national benchmark, a head-to-head comparison of our findings to similar studies is difficult, although they appear to meet the requirements of the British and Canadian national standards. We are reporting waiting times from patient admission till the first treatment; this period includes clinical and laboratory examinations, CT-simulation, treatment planning and verification, and sometimes even adjuvant treatments.

The need for adequate waiting times is based on indirect data. While it is impossible to conduct randomized trials testing the effect of treatment delays in cancer care, there is published evidence indicating that eventual treatment delay has a worsening impact on local control and survival of many cancers.[32] In our department, the clinical cases with long waiting times appeared to be head-and-neck, GU, gynecological and brain cancers.

In the particular case of squamous cell carcinoma of the head-and-neck, by studying the time gap from staging CT to planning CT, the net influence of waiting times on disease control was demonstrated: within 4 weeks of waiting time, the patients presented tumor progression; 20% of them developed new lymph node metastases and 16% progressed in their T-stage.[36]

Among GU cancers, prostate carcinoma is the most common and known to be a slowly growing tumor, therefore, not too sensitive to eventual delays of radiotherapy. Research showed that treatment delays of 2.5, 4 and 5 months can result in a 5-year estimates of PSA failure-free survival of 55%, increased use of salvage hormonal therapy, and increased prostate cancer-specific mortality, respectively.[37,38] The waiting times reported to adversely affect the outcome in prostate radiotherapy are outstanding and unlikely to be reached in our practice.

Brain cancers cover a wide range of pathologies; though, the current literature lacks data on the possible effects of radiotherapy delay. Irwin et al. analyzed 172 patients with grade 3 or 4 astrocytoma and reported that time to radiation therapy from surgery independently correlated with survival. They found that every additional week of delay of radiotherapy increased the risk of death by 8.9%, and a 6-week delay decreased median survival by 11 weeks for a typical patient.[39]

As head-and-neck cancers appear to be most detrimentally affected by long waiting times, we prioritized them for radiotherapy start and kept a close follow-up on their work-up and treatment planning workflow; the linear regression curve in Fig. 3c shows the effect of this policy over time. Next diagnosis group of concern regarding waiting times would be the cervix cancer, since the trend analysis revealed an increase of the number of patients with waiting times exceeding 30 days (Fig. 3c). Research determined the adverse effect of outcomes in cervical cancer due to radiotherapy delay.[40,41] Song et al. indicated that, even in the era of concurrent chemo-radiotherapy, a treatment time longer than 56 days is detrimental to pelvic control, although not associated with an increase in distant failure or disease specific mortality.[41]

Performance monitoring is becoming an important process in the organizational management of health structures, in order to promote a continuous improvement of services. The analysis of temporal trends of the performance indicators enabled us not only to identify workflow processes needing attention and improvement, but to estimate future demands of equipment and resources, too. Some of the indicators presented in this study, such as workload and waiting times, can be adapted to other health specialties, while technical complexity can be used to monitor advances of radiotherapy specific treatments.

The introduction of EMRs into clinical practice has changed the way healthcare is being managed, and it was perceived as a significant advance, especially in disciplines with high volumes of information to be collected, archived, and retrieved.[5,6] EMRs provide an enhanced capability to access and analyze radiotherapy treatment and patient information with a high level of safety and convenience. We assessed the performance indicators of our radiotherapy department and their trends during the last 4 years using a commercially available EMR system, able to generate reports based on specific data entry. A challenge in performing this study was that EMR-generated reports do not allow for extensive manipulation and trend analysis, and do not include benchmarks we appreciate as useful. To perform the analysis, we have exported data from the EMR into a separate software. Furthermore, not all desired reporting requirements can be met with our EMR because of the specificity of measures; for instance, we could not assess the ratio of palliative to curative treatments. Overall, we found our current EMR easy to handle for the purpose of reporting basic meaningful-use standards.

5. Conclusions

Radiotherapy is a complex environment and measuring productivity along with complexity of workload and quality of service is important in understanding the setting of this specialty. Monitoring and responding to temporal changes of performance is useful in ensuring an efficient run of the department, along with a continuous quality improvement.

A commercially available EMR system can be easily used for monitoring the performance indicators of a radiotherapy department. Analysis of our department data over the last four years showed an increasing trend in productivity and complexity, paired with constant waiting times.

The type of study we have performed, extended at a larger scale, can be also useful for estimating and predicting the radiotherapy needs at the national level.

Conflict of interest

None declared.

Financial disclosure

None declared.

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