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A Framework for Comprehensive Electronic QA in Radiation Therapy

J. Kildea
Medical Physics Department,
McGill University Health Centre
1650 avenue Cedar
Montreal, Quebec
H3G 1A4, Canada
jkildea@medphys.mcgill.ca

M. Evans
Medical Physics Department,
McGill University Health Centre
1650 avenue Cedar
Montreal, Quebec
H3G 1A4, Canada
mevans@medphys.mcgill.ca

W. Parker
Medical Physics Department,
McGill University Health Centre
1650 avenue Cedar
Montreal, Quebec
H3G 1A4, Canada
wparker@medphys.mcgill.ca

***Abstract*—We describe a framework for comprehensive electronic QA currently under development in the department of Radiation Oncology at the Montreal General Hospital. When complete, the system will incorporate all data generated within the department. It will allow for easy access to all aspects of a patient's treatment and to the state of all relevant equipment at the time of treatment. Quality control will be achieved through automated Shewhart-type control charting with appropriate statistical analysis. Machine learning methods will be used to examine the data in order to search for errors, inconsistencies and unnecessary treatment delays. The system will entail a web interface internal to the clinic and written in PERL.**

***Keywords*-Comprehensive electronic QA; Shewhart; control charts, treatment delays in radiation oncology, machine learning in radiation oncology QA;**

I. Introduction

Radiation therapy is the use of ionizing radiation in the treatment of disease, typically cancer, with the goal delivering a prescribed dose of radiation to kill a target lesion with minimal irradiation of surrounding healthy tissue. Modern radiation therapy achieves its goal through the use of sophisticated radiation-generating devices and complex treatment planning algorithms.

While the technical capability of delivering radiation doses as prescribed has recently advanced (for example, the developments of intensity modulated radiation therapy and image guided radiation therapy), the practical delivery has become more dependent on properly functioning equipment and correct patient setup. Indeed, the potential benefits of modern techniques may be compromised by the necessity of patients waiting longer for treatment while sophisticated treatment planning and quality assurance procedures are performed. All considered, a comprehensive and semi-automated quality control system for radiation therapy treatments presents itself as an important tool in the modern radiation therapy clinic.

At the McGill University Health Centre (MUHC), Montreal, Canada, we are developing a comprehensive web-based system for electronic archiving and analysis of quality assurance (QA) data. All aspects of each patient's treatment, from initial consult until final treatment, will be incorporated. Interfaces to examine individual patient treatment histories, together with statistical data and process behaviour charts pertaining to all patients and to the resources of the clinic, are under development. We present here the rationale and the framework for development of our system.

II. Rationale for Comprehensive Electronic QA

A. Statistical Process Control

Statistical process control (SPC) has been used in manufacturing industry since its invention by Walter A. Shewhart at Bell Laboratories in 1924 [1]. Shewhart's technique involves continuously monitoring a process in order to compare its current and historical performances. A process is considered in control if variations in its performance can be attributed to common statistical (ie random) causes. Any variation beyond expected statistical limits indicates a process that is out of control due to a specific non-statistical cause, which must be investigated and fixed in order to bring the process back into control.

Shewhart introduced the concept of the control chart (also known as the process behaviour chart). A control chart presents the behaviour of a process as a function of time and shows lines depicting the mean and upper and lower statistical control limits. The limits are set at a multiple of the standard deviation. Three times the standard deviation is typically used.

Shewhart control charts have recently gained acceptance as a means to control and monitor clinical quality in health care. Applications have been reported in the literature in medical fields as diverse as clinical chemistry [2], DXA QA [3], MRI QA [4], clinical governance [5] and radiation therapy QA [6].

B. Treatment Delays in Radiation Therapy

Over the last 20 years, while radiation therapy techniques have advanced, the demand for radiation therapy has also increased. The increase in demand is attributed to an ageing population, increasing incidence of cancer [7] and new clinical indications for radiation therapy. As demand increases,

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the result is often an increase in waiting lists with associated prolonged delays for radiation therapy [8]. Reducing waiting lists and treatment delays through the elimination of unnecessary treatment steps and identification of treatment bottlenecks is thus important in radiation therapy planning.

C. Electronic Data in Radiation Therapy

Electronic charting is becoming the standard of care in the radiation oncology community. In general, radiation therapy lends itself well to the development of electronic data records, owing to the electronic nature of the treatment planning and treatment delivery processes. Indeed, electronic medical record (EMR) and electronic record-and-verify systems are now common components of the overall treatment process.

Whereas digitization of data in radiation oncology has progressed steadily, digitization in the medical physics domain has been slower to materialize. The lack of progress may be attributed to the diversity of manufacturers and dosimetric equipment available. Many manufacturers have produced electronic archival systems for data produced with their own equipment but few clinics operate with all medical physics equipment provided by a sole manufacturer.

III. Radiation Therapy at the MUHC

The radiation oncology department at the McGill University Health Centre is equipped with six linear accelerators, a cobalt teletherapy unit for total body irradiation and a brachytherapy suite. Five of the accelerators were manufactured by Varian Medical Systems, Palo Alto, California. The sixth accelerator, a tomotherapy unit, was manufactured by Tomotherapy Inc., Madison, Wisconsin. The brachytherapy suite features a high-dose-rate remote afterloader manufactured by Nucletron, Veenendaal, The Netherlands. All of the Varian machines and the brachytherapy suite are connected to the clinic's record-and-verify database; *ARIA*. ARIA is a Varian Medical Systems product and at the MUHC it is both a record-and-verify database for the Varian linear accelerators and a comprehensive EMR system for the patients seen at the clinic.

The clinic operates under a policy of paperless and electronic charting. Only electronic patient records are maintained and all treatment related parameters are recorded and verified using the ARIA system. Patient and physician appointments are scheduled using Varian's *Time Planner* application and the steps involved in each patient's treatment planning are kept in order using a tasking system, whereby each step is considered a task that must be completed by an assigned individual before the following task, assigned to another individual, may begin.

Figure 1 presents an overview of the tasking system used for treatment planning at the MUHC. The columns represent the individuals responsible for each task, while the rows,

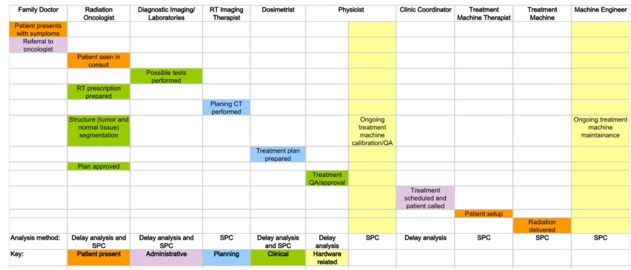

Figure 1. Overview of the electronic tasking system for treatment planning in operation at the MUHC. The columns list the individuals responsible for each task, while the rows, descending sequentially, represent the tasks/steps involved. The second to last row lists the quality control analyzes appropriate for the tasks in each column.

descending sequentially, represent the tasks/steps involved. The delay in carrying out each task can be determined from the ARIA database by calculating the time between its creation and completion.

Medical physics QA at the MUHC encompasses a large number of the AAPM TG-40 recommended procedures [9] and includes bi-weekly, monthly, quarterly and annual QA checks. All medical physics data are presently recorded on paper and physically archived at the end of each calendar year.

IV. Framework for a Comprehensive Electronic QA System at the MUHC

Development of a comprehensive and semi-automatic system for archiving, linking and analyzing all of the data pertaining to each patient's treatment and to general operation of the radiation oncology department is presently underway at the MUHC. Our plan is to provide an internal web-interface that will seamlessly link the existing Varian ARIA database for treatment data with a custom *MySQL* database for Medical Physics and other clinical information, including event reports, machine maintenance/engineering logs and in-house clinical trial data. The system will replace all remaining paper forms with electronic forms. This will include all medical physics paper records and the clinic's existing paper system for adverse event reporting. Figure 2 presents a simple overview of the web-based database system.

Important benefits of the centrally-linked electronic system will include ease of access to all of a patient's treatment data and related departmental data from a single place, and automatic generation of statistical summaries pertaining to clinical performance. A system to automatically generate Shewhart-type control charts for clinical and medical physics data is in development. The goal is to improve efficiency in the treatment planning system through identification of bottlenecks and backlogs (time delay analysis) and to maintain the quality of the treatment machines using SPC methods. The last row in figure 1 shows the method of analysis (either

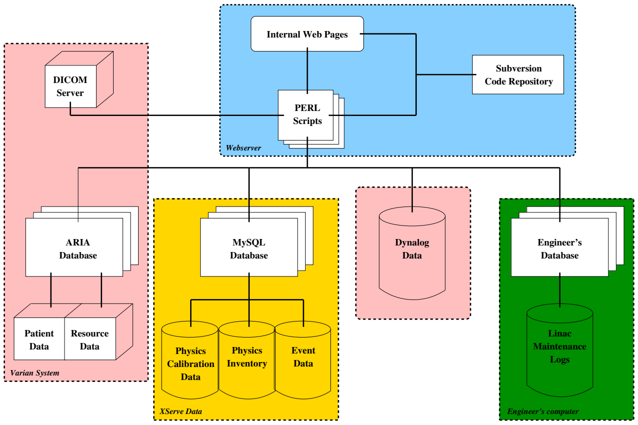

Figure 2. Overview of the electronic QA system under development at the MUHC. The various databases in operation at the clinic will be linked through a central webserver and will allow access to all data produced in clinic.

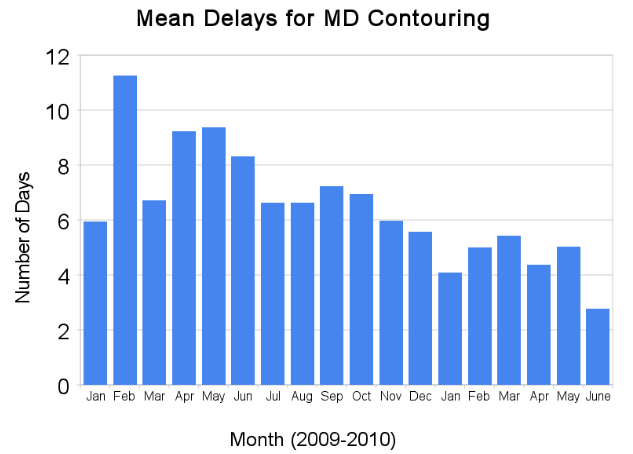

Figure 3. Plot of the mean delay for physician segmentation of CT slices for radiation therapy treatment planning during 2009 and 2010.

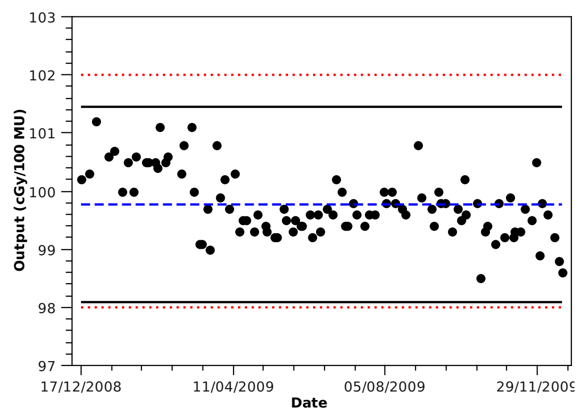

Figure 4. Shewhart control chart showing the output of the 6 MV beam of a Clinac 23-EX linear accelerator at the MUHC.

delay analysis or SPC) to be used for each step of the treatment planning process. Records pertaining to patient safety event reports and to research related data will also be summarizable and automatically updated.

To demonstrate the potential of the system we present two examples of the automated analysis that will be possible: (1) an example showing the potential for treatment time delay analysis using the clinic's electronic tasking system, and (2) an example of a Shewhart-type control chart for SPC analysis using the output data for a single linear accelerator over the last 1.5 years.

A. Treatment Time Delay Analysis

As shown in figure 1, one of the first steps in the treatment planning process is segmentation (contouring) of the patient's tumor volume on his/her CT slice images. This task is carried out by the treating radiation oncologist and may involve co-registration of CT slice images with MRI images or PET scan data. It is a critical and often slow step in the treatment planning sequence. Over recent months, several inefficiencies in the procedure were identified and improved upon. To illustrate both the improvement in efficiency and to demonstrate the potential for automated delay analysis, figure 3 presents a plot of the mean segmentation time for all physicians at the MUHC over the past year.

B. Statistical Process Control with Shewhart Control Charts

Pawlicki et al [6], demonstrated the usefulness of SPC in medical physics QA using control charts for linear accelerator output and beam flatness and symmetry. Likewise, we show here a Shewhart control chart for the 6 MV output of one of our linear accelerators, a Varian Clinac 23-EX machine, over the course of 1.5 years. Figure 4 presents the result. The upper and lower control limits, as shown by the solid black lines, were set at three standard deviations from the mean. The clinical action levels of 2.0% are shown by the dotted red lines. It is clear that, for this linear accelerator, use of the Shewhart upper and lower control limits would maintain the machine within acceptable clinical operation.

Work is ongoing to study the best use of Shewhart-type charting at the MUHC, with the objective being identification of a suitable parameter to represent each process of interest in the clinic. With a single parameter to represent each process, it should be possible to automatically chart and monitor the performance of all processes as a function of time. Charting will incorporate both administrative (eg delay times), and physical (dosimetric) data and charts will be presented via the web and generated dynamically using a web-database interface written in PERL.

We are also investigating the potential of applying machine learning methods to the data, similar in philosophy to the work of [10], with the goal of seeking out errors, inconsistencies and unnecessary treatment delays.

V. Conclusion

Development of a comprehensive electronic QA system to incorporate all data generated within the department of radiation oncology at the MUHC is underway. When complete, the system will allow for examination of each patient's electronic record and for statistical analysis of all processes related to treatment planning and medical physics measurements. We expect to have an early version of our system in operation by December 2010.

Acknowledgement

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