

Lessons learnt from errors in radiotherapy centers

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ABSTRACT

Background: The purpose of this work is to discover and analyze errors and incidents in some radiotherapy centers, and to introduce methods that could reduce their occurrences, especially those which had happened due to the use of improper and inadequate equipment. This work is a first step toward clarifying the role of education in a risk-conscious culture, and changing the attitude of radiotherapy staff when they are working under encouraging conditions that remove barriers for reporting errors. **Materials and Methods:** For the present study clinical investigation, the data of 6000 patients were checked. They were treated at a few radiotherapy centers during one year. Patients were treated by linear accelerator or cobalt machine, photon or electron beams. A purposely designed check list was used for error data collection. Incidents were discovered by manual check at different steps of treatment. By highlighting frequency of occurrence, further investigation for preventing error repetition can be possible. Eighty five incidents were reported by Technologists, fifty four were reported by Physicists, and twenty six events were pointed out by Radiation Oncologists. **Results:** About fifty percent of total 165 detected events were classified as treatment field errors. Geometrical misses in treatment field have the highest probability for both photon and electron beams. **Conclusion:** Incident prevention considering likelihood of individual event can be possible when using facilities like record-and-verification (R&V) system and electronic-portal-image-device (EPID), taking seriously QA, defining and implementing layers of defense in depth, and making an organized system for reporting and analyzing errors.

Keywords: Quality control, radiotherapy errors, clinical audit, lack of technology.

► Technical note

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INTRODUCTION

Radiotherapy has been an imperative part of cancer treatments for many years ⁽¹⁾. Radiotherapy is a complicated process, which requires a working group that consists of Radiation Oncologists (RO), Radiotherapy Technologists (RT), Medical Physicists (MP), Medical Dosimetrist (MD), and Radiation Safety Officer (RSO). Each treatment procedure consists of several steps such as assessment of patient, decision to treat, prescription of treatment dose, imaging

and target delineation, treatment planning, quality assurance (QA) and verification of the plan, patient set up, treatment delivery and verification. It should be noted that these processes include the periodic QA process, which are being performed on radiation delivery system, imaging device, and treatment planning system in order to verify their functionality, accuracy of radiation delivery and dose calculation algorithm and clinical data used in the planning systems ^(2, 3). Such complexity leads to many opportunities for errors happening while consequences can be extremely critical ⁽⁴⁾.

Despite the sophisticated manual and electronic equipment's developed in this field, various errors occur in this field. In general, the error can be subdivided into operator error, or system error. For instance, using a linear accelerator system equipped with Multileaf Collimator System for Intensity Modulated Radiation Therapy (IMRT) treatment of a patient, therapist had noticed that the leaves of the collimator do not move during the treatment. In another event, a treatment system for stereotactic treatment was calibrated with an ionization chamber that was larger than the recommended system.

Different international organizations, like the World Health Organization (WHO) in 1988, American Association of Physicists in Medicine (AAPM) in 1998, European Society for Therapeutic Radiation Oncology (ESTRO) in 1995 and Clinical Oncology Information Network (COIN) in 1999, have issued recommendations for standards to reduce occurrence of errors in radiotherapy (2, 4-7).

International standard quality assurance (QA) protocols and some newly designed computer controlled patient treatment setup and treatment parameters such as record-and-verification (R&V) system and electronic-portal-image-device (EPID) represent tools to reduce some of these errors in data transfer and management of treatment delivery(7). Local quality control needs to be developed, based on each radiotherapy center's evaluations, requirements and available facilities.

There are lots of error reports from different countries and centers each year which are issued to prevent patient accidental radiation and treatment errors (8). Williams in 2007 at the Royal College of Radiologists in UK worked on patient safety in radiotherapy by learning from near misses, incidents and errors with improving reporting toward "no blame" culture (9). Ishikura from National Cancer Center in Japan has a review article about QA improvement which focuses on advance program for patient safety (10). Gerard *et al.* (11) [2009] from France investigated IMRT quality assurance methods to reduce statistical hazards by statistical process control (SPC) tools. Some studies considered type of errors: random and systematic errors. Random errors mostly relate to the operators'

work and it is difficult to detect because of possible inadequate facilities or lack of operators' knowledge. Systematic errors refer to errors related to systems such as incorrect dosimetry or wrong planning data entry that may cause a series of incidents, so have to be detected and corrected as soon as possible. Gluhchev from Portugal in 2002 evaluated error detection in radiotherapy procedure according to random and systematic mistakes. He suggested an optimal value for the systematic errors to have smaller deviation after correction (12).

Baiotto *et al.* (13) [2009] studied patients underwent radiotherapy treatment during 6 years in an Italian center to compare delivered treatment planning and R&V system information with emphasis on manual check as necessary tool in routine QA. There are some case report studies in external photon or electron beam radiotherapy, for example Klein *et al.* (14) [2005] worked on potential errors which continue to happen in their radiation oncology department in the U.S.A.

This study is about discovery, investigation and evaluation of errors; data was collected for one year at four radiotherapy centers, considering their limitations and problems.

This investigation emphasis on the need to have more serious attention to QA program in radiotherapy centers with deficiency of recent technologies such as EPID and R&V systems and to take a critical look at the system for multi-layered prevention of accidental exposures in radiotherapy treatment.

MATERIALS AND METHODS

For these clinical investigations, data of 6000 patients, in the time period of one year were evaluated. They were treated at four radiotherapy centers during one year. Overall 15% of radiation oncologists, 75% of physicists and 50% of technologists at each center contributed in this project. None of the selected radiotherapy departments have R&V system or EPID tools, and all the setup parameters were entered manually. Patients were treated by linear accelerator (Varian Clinac 2100C, Siemens

PRIMUS, Elekta Synergy) or cobalt machine (Theratron 780E), photon or electron beams. Intensity Modulated Radiation Therapy (IMRT) and stereotactic radiosurgery (SRS) were not included in this particular study. Incidents were discovered by manual check at different steps of treatment. If the error was found before starting the radiation therapy, it is referred to near misses.

Error collection method

A special check list form was designed for reporting errors during this project. This form became available for Radiation Oncologists, Medical Physicists and Technologists. Potential failures were identified at different treatment steps: simulation, target contouring, dose prescription, planning, and dose delivery.

Incidences recorded in this form are classified into two major subgroups: (a) accidents related to basic errors, treatment field's errors, and angular errors, (b) beam modification errors.

Major incidents were named after the basic errors in that group, which have more effective consequences such as: treatment of wrong

patient, bad patient fixation, mistake in dose prescription, carelessness about target contouring and wrong source - surface distance or source-axis distance (SSD/SAD). Errors related to dosimetry data entry in treatment planning software and dose calculations are considered in this subgroup too.

Field errors include fields overlapping, uncertainty at matching lateral and opposed fields, displacement of isocenter or wrong field size. For angle errors gantry, collimator and table angle were considered. In our data sheet, subgroup (b) includes beam modification errors. Mistake related to wedge, bolus and shielding errors such as wrong dimensions, wrong shielding perspex coefficient data entry and improper shielding are classified as beam modification errors. Figure 1 briefly describes errors classification of this study.

Errors analysis

Using the custom designed form, the process of analysis of failures at each step of radiotherapy was completed. By highlighting frequency of occurrence, further investigation for prevention of error repetition can be possible. Errors were

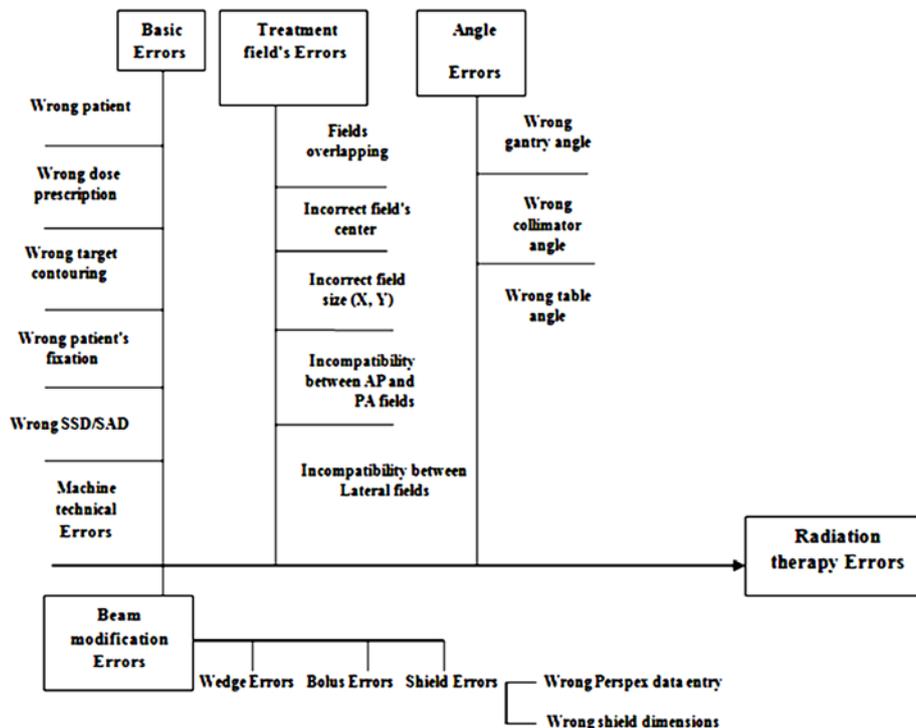


Figure 1. Errors classification chart of this study.

reported based on their numbers of happening during accomplishing this vast project.

RESULTS

The check lists that were introduced during this project provided an excellent tool to investigate individual error specifications and contributing factors of occurrence. A total of 165 events were detected at this audit for the time period of February 2012 to April 2013 for a total of 6000 patient treatment. Figure 2 briefly describes the distribution of these errors as a function of the type of the error. Approximately 85 incidents were reported by the Technologists, 54 were reported by the Physicists and 9 events were discovered by the Radiation Oncologists. About 50% of the errors are classified as treatment field errors. Errors in dose prescription and wrong contouring, contributed approximately 14.5% and 0.6% of the total errors, respectively.

Overall, geometrical misses of field shaping have the highest probability for both photon and electron beams. These errors often occur due to patient shift during treatment set-up or delivery of treatment. Approximately, 28% of total errors

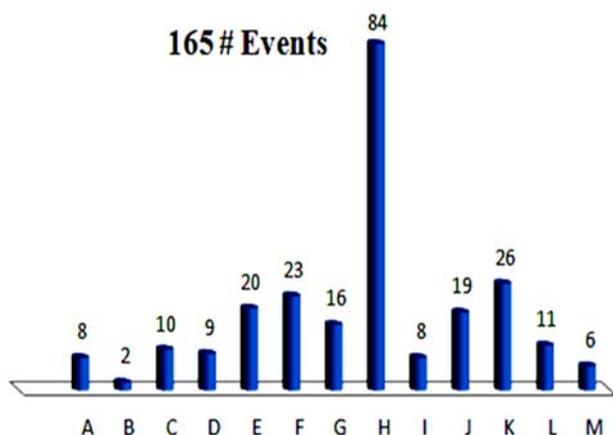


Figure 2. Different Errors and their numbers : **A)** inappropriate wedge **B)** inappropriate bolus **C)** bad fixation **D)** wrong angle of Collimator/Gantry **E)** incorrect shielding **F)** wrong depth of tumor **G)** incorrect SSD/SAD **H)** wrong treatment field **I)** inappropriate target contouring **J)** incorrect treatment duration **K)** wrong dose **L)** wrong energy **M)** incorrect machine.

are related to wrong data registration. In addition, 31% and 14% of errors refer to wrong calculation and wrong set up, respectively. The discovered errors in these investigations includes: treatment of wrong person (1.1%), treatment of wrong organ (1.2%), machine technical problems (3%), mistake at calculated activity for cobalt machine (5.3%), wrong radiotherapist dose prescription by radiation oncologist (6.8%), poor planning (3.7%), etc.

Results of these investigations were analyzed by the quality control committee of this project to find contributing factors for each event. Analyses of the most common events are presented in figure 2.

Incorrect field shaping

The major incidences related to the uncertainties of Anteroposterior (AP)/ Posteroanterior (PA) or AP/Lateral fields, were carefully analyzed in this project. In these evaluations it was found that there were 14 errors related to matching between AP and PA fields and 11 errors were regarding the matching between AP and Lateral fields in irradiation the same target. Other fields' errors with its numbers of occurrence have been shown in figure 3.

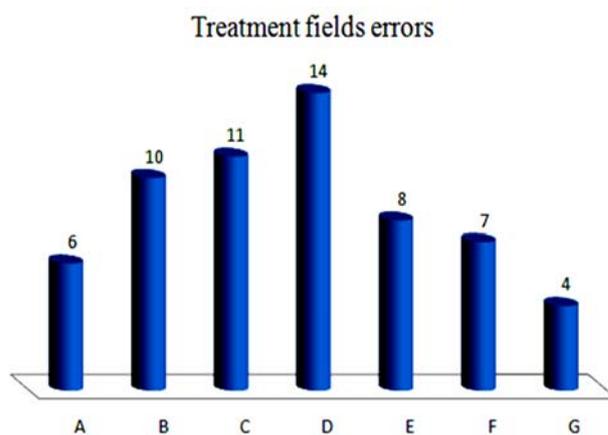


Figure 3. Treatment fields Errors: **A)** wrong field's overlapping **B)** incompatibility between Left and Right, Lateral fields **C)** incompatibility between AP and Lateral fields **D)** incompatibility between AP and PA fields **E)** dislocation of isocenter **F)** field's X and Y interchanging **G)** wrong field dimensions.

Dose

Dose error is recommended to be maintained less than 5% of the prescribed dose (15). In additions, because of the radiobiology risks and patient safety it is very crucial to consider proper documentation of the total optimal dose, dose per fraction, and number of fractions. Figure 4 shows the number of incidences related to dose, which were discovered in this project.

Shielding, Wedge and Bolus

Beam modification devises (group b) such as shielding blocks, wedge, and bolus have the potential for major errors. In this investigation, two bolus errors and eight wedge errors were registered. Wedge errors included wrong wedge angles or wrong wedge orientations.

Shielding blocks errors can affect the field shaping, which may cause missing target or overdose of the organ at-risk and normal tissue. Considering shielding Perspex coefficient, dimension or location of shielding, unnecessary shielding, and incorrect usage of shielding for a critical organ were among the parameters which were considered in the study. Results of these investigations are presented in figure 5.

Location of treatment

To access a precise protocol for our radiotherapy center, investigations were concentrated toward determination of probability of errors as a function of treatment organs. Having 47 detected errors in the head and neck tumors emphasize on need for more accurate immobilization. Eighty six of errors were reported in organs with inter or intra-fractions motion. In this sec-

tion errors were discovered by daily check of laser and markers position. In addition, differences between the planning SSD and measured SSD during treatment were determined. Table 1 shows the results obtained during these investigations.

Results were analyzed by local quality control committee of this project to find the main source of each event. Lack of full concentration of staff was found to be the most outstanding reason of errors occurrence. Other sources of events were attributed to poor communication and transfer of information between the staff.

Table 2 indicates the most cause of events with their number of occurrences. These errors consists of inappropriate management of staff training, shortage of proper equipment, untoward relationship between different clinical groups, absence of oncologist or physicist at first session of treatment, elimination of patient's isocenter or laser markers, overloading work or stressful condition and finally using old systems with poor maintenance support.

Table 1. Errors are represented based on location of treatment.

Treatment Location	Number Of Reports	% Of Total
Head and Neck	47	34%
Breast	38	28%
Thorax	5	3%
Abdomen	13	10%
Pelvis	30	23%
Other organs	3	2%
Total	136	100%

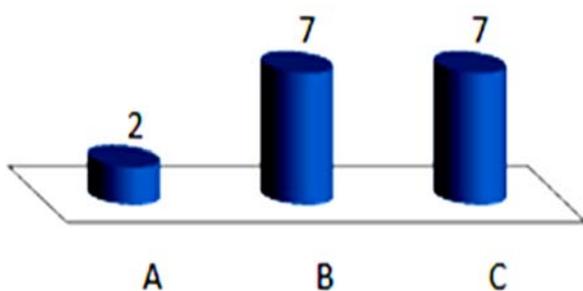


Figure 4. Detected Dose Errors: A) Wrong dose per fraction B) Wrong number of fractions. C) Wrong total dose.

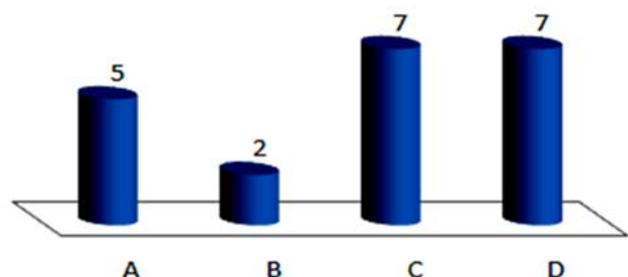


Figure 5. Shielding Errors: A) Wrong Perspex coefficient B) unnecessary shielding C) Incorrect Organ-At-Risk D) Error in dimension or location of shield.

Table 2. Cause of events with their number of occurrence.

Cause of Events	Number Of Occurrence	% Of Total
Lack of staff knowledge	22	13.3 %
Inappropriate management	24	14.5 %
Deficiency of suitable equipment	19	11.5 %
Bad communication between clinical groups	21	12.7 %
Absence of Physicist or Oncologist at first day of treatment	15	9 %
Wrong way of patient's setup	9	5.4 %
Removing patient's markers	7	4.2 %
Stress and work overloading	42	25.4 %
Other reasons	6	3.6 %
Total	165	100%

DISCUSSION

This study shows just 18% of incidents were discovered before happening and registered as near misses, 76 % of errors were found after some treatment fractions were delivered, and about 6 % of events were detected after treatments were finished. Baiotto *et al.* ⁽¹¹⁾ [2009] suggested a manual verification of the data that was inserted in the R&V system by a medical physicist as a valid tool to improve awareness on radiation treatment status. In this study, manual confirmation has been utilized to find errors that may happen at centers without R&V or EPID controlling systems.

It was interesting to note that the most outstanding reason for error occurrence was related to oversight by staff. In addition, other event-paths originated from the lack knowledge or training, inappropriate management, shortage of proper equipment, poor communication between different clinical staff, work overload or stressful working environment and finally, using old systems with poor maintenance. Presence of the Radiation Oncologists or Physicists at the first session of treatment could reduce the chance of error.

Using equipments such as R&V and EPID systems, periodic QA procedure, defining and implementing layers of defense in depth and making organized system for reporting and analyzing errors lead to prevention of accidental exposures.

Although with a designed check list and having response plan and clear list of actions, we can be alert and be prepared for different situations, some accidental exposures may still occur. International atomic energy agency (IAEA) suggests multilayer prevention against accidental exposures to achieve the best result ⁽¹⁶⁾. Several layers of safety provisions, such as physical components and procedures used to defend against events. These layers need to be independent of each other and can be defined for events individually ⁽¹⁶⁾. For example layers to prevent wrong MU calculations include: first, calibration and measurement of machine output by standard protocols such as TG-51 preferably by more than one physicist to get sure about precision of measurements; second, compare calibration data with source certificate; third, experimental postal dosimetry audit, and finally *in-vivo* dosimetry ⁽¹⁷⁾. An implemented QA program with a particular protocol based such as IAEA or AAPM TG-51 on each center needs under supervision of trained people can provide these layers.

CONCLUSION

In summary, the lessons learnt from accidental exposures leads to stress on performing periodic QA procedures and establishing a program for national reporting of radiation incidents. As a successful example we can

mention the Canadian Partnership for Quality Radiotherapy which is an alliance among the national professional organizations involved in the delivery of radiation treatment in Canada (CPQR) (18). A national reporting system could improve the rate of near miss errors detection in radiotherapy centers and it is possible to reduce the number of incidents.

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REFERENCES

1. Delaney G, Jacob S, Featherstone C, Barton M (2005) The role of radiotherapy in cancer treatment, estimating optimal utilization from a review of evidence-based clinical guidelines, American Cancer Society. *Cancer*, **104**: 1129-37.
2. World Health Organization (2008) Radiotherapy Risk Profile-Technical Manual.
3. Moller TR, Ceberg J, Einhorn N, Lindholm C, Nyhle'n U, Svensson S, for the SBU Survey Group (2003) Radiotherapy techniques in current use in Sweden. *Acta Oncol*, **42**: 376-86.
4. Fraass B, Doppke K, Hunt M, Kutcher G, Starkschall G, Stern R, Van Dyke J. (1998) American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53: Quality assurance for clinical radiotherapy treatment planning. *Med Phys*, **25**: 1773-1829.
5. Thwaites D, Scalliet P, Leer JW, Overgaard J (1995) Quality assurance in radiotherapy. European Society for Therapeutic Radiology and Oncology Advisory Report to the Commission of the European Union for the 'Europe Against Cancer Program. *Radiother Oncol*, **35(1)**:61-73.
6. Karp SJ (1999) The Clinical Oncology Information Network (COIN) Project: background, purpose and products. *J Eval Clin Pract*, **5(2)**:179-87.
7. Ortiz P, Cosset J M, Dunscombe P, Holmberg O, Rosenwald JC, Ashton L, Vilaragut Llanes J, Vatnitsky S. (2009) Preventing Accidental Exposures from New External Beam Radiation Therapy Technologies. ICRP Publication 112, *Annals of the ICRP*, **39 (4)**:63-74.
8. Pennsylvania Patient Safety Advisory (2009) *Errors in Radiation Therapy*, **6(3)**:87-92.
9. Williams MV (2007) Improving patient safety in radiotherapy by learning from near misses incidents and errors. *BJR*, **80**: 297-301.
10. Ishikura S (2008) Quality Assurance of Radiotherapy in Cancer Treatment: Toward Improvement of Patient Safety and Quality of Care. *Jpn J Clin Oncol*, **38**: 723-729.
11. Gerard K, Grandhaye J, Marchesi V, Aletti P, Husson F, Noel A, Kafrouni H (2009) Feasibility study of using statistical process control to optimize quality assurance in Radiotherapy Quality assurance in radiotherapy. *Journal of Quality in Maintenance Engineering*, **15**: 331-43.
12. Gluhchev G and Shalev S (1996) The systematic error detection as a classification problem. *Pattern Recognition Letters archive*, **17**: 1233-1238.
13. Baiotto B, Bracco C, Bresciani S, Mastantuoni A, Gabriele P, and Stasi M (2009) Quality assurance of a record-and-verify system. *Tumori*, **95**: 467- 472.
14. Klein E, Drzymala R, Purdy J, Michalski J (2005) Errors in radiation oncology: A study in pathways and dosimetric impact. *Journal of Applied clinical medical physics*, **6**: 81-94.
15. International commission on radiation units and measurements (1976) Determination of Absorbed Dose in a Patient Irradiated by Beams of X or Gamma Rays in Radiotherapy Procedures. ICRU Report 24.
16. International Atomic Energy Agency (2000) Lessons learned from accidents in radiotherapy. Vienna: IAEA Safety Reports Series No.
17. IAEA training course. Prevention of accidental exposure in radiotherapy. Available from: http://rpop.iaea.org/RPOP/RPOP/Content/Documents/TrainingAccidentPrevention/Lectures/AccPr_5.01_Preventive_measures_WEB.ppt.
18. Lefresne S, Olivotto IA, Joe H, Blood PA, Olson RA (2013) Impact of quality assurance rounds in a Canadian radiation therapy department. *Int J Radiat Oncol Biol Phys*, **85**: e117-21.

