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Original Article

Quality control and error detection in the radiotherapy treatment process

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Abstract

Purpose: In 1995, a post of quality control (QC) officer was established in the Radiotherapy Department of the University Hospital Gent (R-UZG). We report here the evolution of error detection in the domain of information transfer during the different steps of the treatment chain, in our department, since the creation of this job.

Material and Methods: From January 1995 to December 1997 (1995 n = 831; 1996: n = 1095; 1997: n = 1091), data on errors were recorded. At the start, an inventory was made of the existing situation and a Quality Assurance (QA) program was outlined for process control. According to the site of origin of errors in the treatment preparation chain, errors were separated into five levels: medical treatment prescription, simulation, treatment planning, treatment data transfer and daily set-up.

Results: The total number of errors found was 459 in 1995; 809 in 1996 and 1046 in 1997. During 1995 and 1996 the medical prescription protocols were adapted to the increasing need of the radiation technologists for more information. This explains an increased number of errors (from 80/459 to 276/809) in 1996. After a period of adaptation, the number of errors decreased in 1997 (257/1046). The second level, where many errors were found, is at the transfer phase (1995: 181/459 1996: 210/809; 1997: 336/1046). Most of these errors were made during the transfer of data from the prescription chart to the computer. These errors were due to lack of attention, human mistakes and calculation errors. The number of errors during simulation increased due to rotation of personnel in 1996. The increase persisted in 1997 for the same reason. Transfer errors due to the automatic transfer of leaf settings decreased (1995:18/29; 1996:15/17; 1997:7/31) Thanks to the start of QC management, errors were detected and corrected in the entire treatment process at R-UZG. Once changes were accepted, new challenges were initiated. After each evaluation, initiatives were taken to try to decrease specific errors. Changing attitudes was a difficult and slow process, but progress was made. The most important change in attitude certainly was the acceptation of the concept of QC.

Keywords:

Quality control; radiotherapy.

INTRODUCTION

In 1995, a post of QC officer was established at the Radiotherapy division of the University Hospital Gent (R-UZG). A radiation technologist (M-Th. Bate) was assigned to this post.

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The primary objective within this QC-officer's job description was process control.[1] Therefore, an inventory of the existing situation was made and a quality assurance (QA) program was outlined for process control.

In order to provide a radiation treatment of good quality, a high degree of precision throughout the treatment process is required at two different levels: i) technical level and ii) clinical level. Efforts have been made by specialised organisations to

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recommend comprehensive quality assurance programs[1,4,5,6] at the technical level.

Using these programs, systematic errors related to equipment or basic dosimetry data are reduced. At R-UZG, radiation physicists and engineers, in close collaboration, execute these duties with the QC officer.

This manuscript reports the changes made at the clinical level, once the post of a QC officer was introduced. It is an attempt to describe the progress in quality of the complete external beam radiation process, starting from the treatment prescription and ending at the last radiation session. An overview of the procedures of the radiotherapy treatment with location of the QC checks is given in Appendix 1.

MATERIAL AND METHODS

The Radiotherapy Division of the University Hospital Gent (R-UZG)

The day-care unit of R-UZG has two Philips linear accelerators (SL-75 and SL-25, Philips Medical System M.E.L., now Elektra Oncology Systems, Crawley, UK) and one Philips SLS simulator. For radiotherapy planning, we use the CT scanner of the radiology department. Since 1995, an automatic verification system (Vericord™) was available on the SL-75. An identical verification system was installed on the SL-25 in August 1996. In July 1995, a Philips Multileaf Collimator (MLC) was installed on the SL-25.

In 1995, the QC officer checked 831 patients who started a new radiation treatment; this number increased to 1095 for 1996; and stabilised at 1091 in 1997. Starting in January 1995, transfer errors only were recorded. Since radiation treatments include a chain of procedures, QC was extended from September 1995 to include treatment prescription, treatment preparation and execution. All the different procedures of the treatment process, involved in the QC check-up are shown in Appendix 1.

The staffing of R-UZG is presented in Table 1. Several other researchers in our department, mainly engineers, were occupied with developments in the field of beam intensity modulation (IMRT) and provided occasional support.

Table 1 Staff of the R-UZG

Category		Number
Medical staff	Senior Radiation oncologist	5
	Radiation oncologists in training	5
Technologists		15
Physics department	Physicists	3
	Accelerator technician	1
	Mould technicians	1

External beam radiation at R-UZG

Most patients were treated with an isocentric technique, symmetric and asymmetric collimation and mainly according to two modalities: i) treatments with single or opposed fields, cerrobend block (shaped or not) and ii) treatments with multiple fields. In the first case, treatment planning was done on a Philips Oncology Support System (Philips Medical System)(2D planning). For treatments with multiple fields, a 2D- or (more frequently) 3D-planning system was used (Sherouse or PLUNC). The complete treatment preparation chain is listed in detail in Table 2 together with the team members involved at each procedure.

Data transfer check

Data checks were performed at i) the start of the treatment; ii) weekly during the whole treatment and iii) after every treatment modification. A list with the type of evaluated data is shown in Appendix 1.

Recording and analysis

From January 1995 to December 1997 all errors discovered by the QC officer were categorised and stored in an MS Excel 5.0 database. All new patient treatments performed on both linear accelerators were included. Data from 1995 was for the first time analysed and discussed early in 1996. The 'Pivot Table' concept in MS Excel was used to count the occurences of categorized errors according to the categories defined in Appendix 1. Proper action was taken to improve quality. A second analysis was carried out beginning in 1997. At the beginning of 1998 the data of 1997 was reported. As the total number of patients in 1996 and 1997 was almost the same, the analysis of data was focused on those two years.

RESULTS

The errors are divided according to their place of origin in the treatment preparation chain [1,4,5,6] and

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the results are shown in Figure 1 as percentage of the total number of deviations and in Figure 2 as absolute value.[3]

Treatment prescription

The intent to treat a patient with external beam RT was a medical decision and the responsibility of the senior radiation oncologist. It contained among other parameters the total dose and fractionation. At R-UZG, a treatment indication was formulated once a patient was accepted as a candidate for receiving radiation treatment. The treatment

Table 2 Procedures in radiotherapy in routine practice in Gent with the responsibilities within the team

Procedures	Type of person in charge	Checked by
Treatment indication	Radiation oncologist	Senior radiation oncologist
Initial prescription	Radiation oncologist	Senior radiation oncologist
Simulation	Radiation technologist	Radiation oncologist
Planning 2D	Radiation technologist	Radiation oncologist
Planning 3D	Radiation oncologist	Physicist
Preparation of treatment chart	Radiation oncologist+technologist	Radiation technologist
Entry of data in the check-and-confirm system	Radiation technologist	Radiation technologist
Treatment execution	Radiation technologist	Radiation technologist
Portal films	Radiation oncologist	Senior radiation oncologist

Off line all procedures (except treatment indication and portal films) are checked by the QC officer

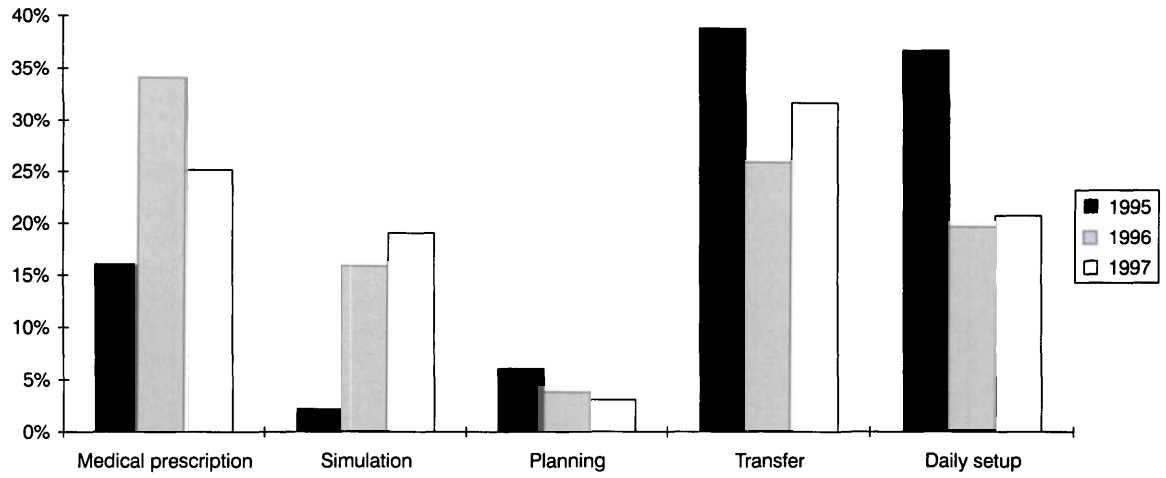

Figure 1. Deviations distributed to their place of origin and given as a percentage of the detected deviations.

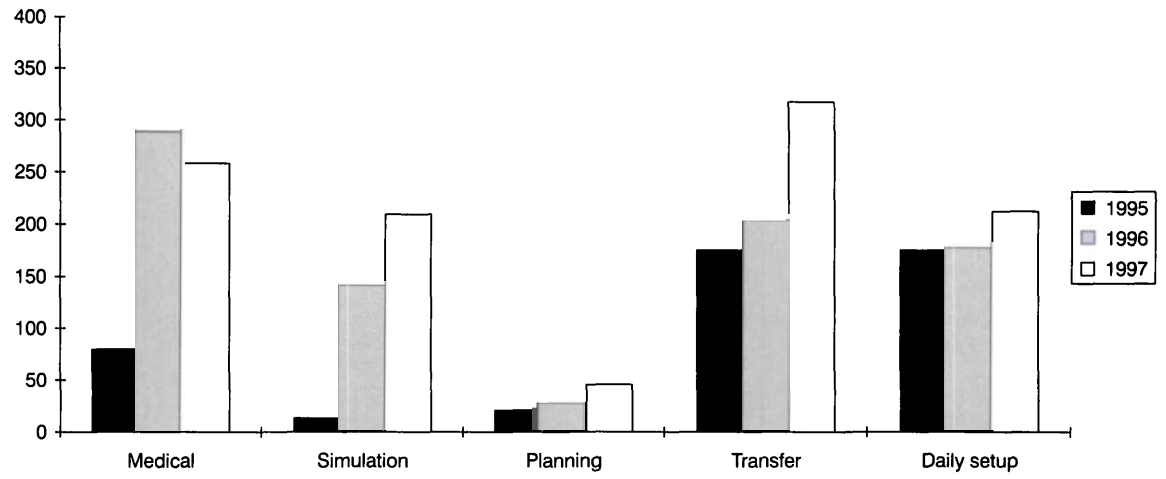

Figure 2. Deviations divided according to their place of origin and given as the total number of detected deviations.

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protocol was based on clinical criteria without considering any of the technical modalities. After treatment simulation and planning, an initial prescription was formulated. This prescription contained the dose, fractionation, beams and geometry for the initial part of the treatment, and a plan for modifications during the treatment. The initial prescription must be approved by all radiation oncologists at the daily staff meeting. After approval the prescription became final and the prescription schedule was filled in (Fig. 3). Radiation prescriptions were based on protocols that were approved by a committee of staff radiation oncologists. A limited inventory of treatment protocols were derived from the analysis of the protocols used in the years 1995–1996. The realisation of this inventory was a major step forward in the quality control process.

Deviations from these protocols were avoided as much as possible or had to be fully explained on the final prescription form. For each patient, the treatment indication and final prescription and the protocols were compared by the QC Officer, accompanied by the radiation oncologist in charge of the particular patient. If these were not identical, the radiation oncologist was questioned about the discrepancy.

During the period covered by this study, several improvements regarding the treatment prescription procedure were introduced (see Table 3). In 1995, prescriptions and any modification of the treatment plan were done via verbal communication. This led to misunderstanding and thus incorrect treatments. In those cases it was virtually impossible to track the source of the error. Getting the complete treatment schedule of every patient in advance, written down, was necessary to allow an optimal organisation of the workload. An example was the case of a head-and-neck patient. As the accelerator where the patient received the first part of his treatment was not equipped to deliver electron beams and the patient was supposed to be transferred from one accelerator to another. Before the improvements were introduced, the technologists often were not informed when or if electron beams were necessary for a particular patient. Therefore, the appointment at the other accelerator was made too late. This led to disorganisation of the work (see example on Table 3).

The different types of errors observed are listed in Table 4. A higher number of errors (80 in 1995 to 283 in 1996) was observed during the adaptation period of the first set of changes. These first changes went

PRESCRIPTION SCHEDULE

PROTOCOL CODE:

Total dose: Gy	Fractionation: x Gy	Sessions/day
Recieved dose Gy	number of fields/session	Sessions/week

Dose Gy	Ant/Post	Lateral	Lower Neck	3 D/IMRT	electrons
0		X	X		
44		V	V		X
56			S		
66		S			S

X= start V= field size changes B= blocks have to change S= stop	name senoir radiation oncologist	name radiation oncologist in training

Example: treatment scheme for patient with a head and neck tumor

The treatment starts at

0 Gy with two lateral photon fields and one anterior lower neck photon field.
44 Gy field reduction
56 Gy stop lower neck fields
66 Gy stop lateral reduced (boost) fields
44 – 66 Gy electrons are given to the dorsal part of the neck nodes

Figure 3. Final prescription scheme

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Table 3 Overview of improvements introduced during the study period

1995		1996
Inventory of medical protocols	→	Comparison of protocols with prescription
	→	Uniform prescription policy
Verbal prescription during the treatment	→	Comprehensive, detailed prescription of the treatment from the start
	→	new treatment prescription charts
Modifications by phone or verbal	→	Clear descriptions of modifications

Example: a patient needs 46 Gy + 10 Gy boost
In 1995 patients started treatment with a provisional total dose of 46 Gy. During the treatment the patient was seen every week by the radiation oncologist. At this occasion the given dose of 46 Gy was communicated by phone to the radiation therapist.
When the dose 46 Gy was given the prescription of the boost dose (10 Gy) was given to the technologists in the same way.
Modifications in the initial prescription followed the same route.

against the established way of working from the radiation oncologist. A certain time was needed to adapt. The new rules were introduced at the end of 1995, and became active during 1996. In addition, in 1996, two new physicians started their radiotherapy training, resulting in an increased number of errors.

Comparing the type of errors between 1996 and 1997 (Table 4), we observed a significant decrease concerning the final prescription (60/257). Final prescription of the treatment was frequently erroneous or incomplete in those patients where treatment was started as an 'urgent' procedure. In cases where the intended treatment schedule had to change, for whatever reason, the final prescription was not always modified (28/257). Filling in the prescription became a routine in 1997. However, an increase of incorrect or incomplete radiation prescriptions was observed. One of the reasons for this increase was the strict adherence to the inventory of treatment protocols.

Simulation

As mentioned before, more attention was paid towards the correct and early completion of the treatment prescription chart.

At the beginning of 1996, new radiation technologists worked at the simulation unit because of personnel rotation. Simultaneously an increased number of errors (Table 5) was observed. However, the increase continued in 1997. We think that the reason for this was too swift a rotation of personnel. As the policy of the department was that every technologist needs to have practical experience and training in every aspect of the treatment chain, including simulation, a rotation schedule was introduced. It

Table 5 Distribution of different types of simulation errors, divided over the different years (N.R. = not registered).

Type of Simulation error	1995	1996	1997
Gantry:	1 (9%)	2 (1.5%)	5 (2.5%)
Diaphragm:	3 (27%)	9 (7%)	7 (3.5%)
Field size:	3 (27%)	21 (16%)	26 (13%)
Offset:	3 (27%)	56 (42%)	51 (25.5%)
Technique:	1 (9%)	2 (1.5%)	16 (8%)
Incorrect parameters on simulation film:	N.R.	23 (17%)	52 (26%)
Incorrect simulation:	N.R.	N.R.	2 (1%)
Incomplete parameters:	N.R.	20 (15%)	32 (16%)
Laser marking incorrect:	N.R	N.R.	2 (1%)
TOTAL	11	132	200

Table 4 Distribution of different types of treatment prescription errors, divided over the different years (N.R. = not registered).

Type of Treatment Prescription error	1995	1996	1997
No final prescription at first treatment session	N.R.	158 (56%)	60 (23%)
Incomplete/incorrect prescription	N.R.	21 (7%)	106 (41%)
Final prescription not conform with protocol	N.R.	39 (14%)	40 (16%)
Treatment changes not registered	73 (91%)	26 (9%)	28 (11%)
Manual doses calculation incorrect	7 (9%)	39 (14%)	23 (9%)
TOTAL	80	283	257

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resulted in a schedule where one technologist stayed at the simulation for a full year, one for 4 months and the third for 3 months. The radiation technologist who had been responsible for the simulations for three years was transferred to another station and this gave rise to a sudden increase in the number of errors. The rotation schedule was adapted accordingly. Now there are technologists that remain at the station when their expertise is considered an important factor for quality.

A major source of errors remained the calculation of the offset of independent collimators in asymmetric fields. Each collimator can be moved separately. The method to specify the collimator position is with the offset of the middle of the field compared to the central ray of the beam. The offset is calculated for our treatment planning system according to these formulae as: Offset X = (X1-X2)/2 or Offset Y = (Y1-Y2)/2. Miscalculation led to treatment plans that were incorrect. Therefore specific training sessions were given to the radiation technologists by another radiation technologist that became responsible for a program of continuous education. Training was given at regular intervals and specific sessions repeated if necessary. A second source of errors was incorrect transfer of parameters to the prescription chart or simulation films. Human mistakes contributed to all other types of errors. One hundred and thirteen of the 200 errors could have led, if not detected, to systematic errors and so to incorrect treatment of the patient.

Planning

Errors made at this level were thought to be due to inattention or to human mistakes and personnel turnover (Table 6). The main source of errors was the tray-factor calculation. In our department shielding was done, at the SL–75, with individually moulded blocks that were fixed on a template and located in a 'shadow' tray, which in his turn was mounted on the treatment-machine head. At the SL–25, a multileaf collimator (MLC) was used. As the leaves were mounted directly inside the treatment head, there was no dosimetric effect compared to cerrobend blocks. After installation of the MLC, the planning computer no longer took into account the output factor for compensating blocks. When extra blocks were used, the necessary calculation had to be done manually. This was often forgotten.

Table 6 Distribution of different types of planning errors, divided over the different years (N.R. = not registered).

Type of Planning error	1995	1996	1997
Energy	3 (16%)	2 (8%)	1 (3%)
Fractionation:	7 (37.0%)	0 (0.0%)	2 (5.5%)
Tray:	3 (16.0%)	13 (54.0%)	17 (47%)
Collimator:	0 (0.0%)	1 (4.0%)	1 (3%)
Technique:	6 (31.5%)	6 (25.0%)	2 (5.5%)
Field size:	0 (0.0%)	2 (8.0%)	10 (28%)
Others	N.R.	N.R.	3 (8%)
TOTAL	19	24	36

Data transfer

Data transfer is a common procedure in a radiotherapy unit. If not done automatically, it is a source of many errors. An overview of manual data transfer procedures is given in Table 7 and data to be checked in Appendix 1.

Table 7 Manual data transfer procedures

From planning to treatment chart
From treatment chart to the operating console of the linear accelerator
From treatment chart to the computer system, controlling the MLC

Of the total number of 336 transfer errors, 282 were made on the SL–25 and 54 on the SL–75. The discrepancy was due to the fact that on the SL–75 simpler and better-established protocols were used: breast radiation, treatment of head and neck, palliative radiotherapy. This led to a certain routine. The more sophisticated treatments were given on the SL–25. Most (1995=75%; 1996=75%; 1997=86%) errors involved the data transfer from treatment chart to the operating console of the Vericord.

One hundred and fifty-five of the 336 of the errors would, if undetected, have lead to systematic errors, and thus to incorrect treatment.

Transfer from planning to treatment chart (Table 8)

At this step, data from the printouts - generated by the 2D- or 3D-planning system - needed to be transferred manually to the final treatment chart. This was done by the radiation oncologist responsible for the particular patient. The observed errors mainly involved the level of

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Table 8 Distribution of different types of Data Transfer errors (from Planning to Treatment Chart), divided over the different years (N.R. = not registered).

Type of Data Transfer error	1995	1996	1997
Total dose:	N.R.	N.R.	3 (19%)
Technique:	0 (0.0%)	1 (2.8%)	3 (19%)
MU:	12 (75.0%)	15 (43.0%)	6 (37%)
Energy:	2 (12.5%)	0 (0.0%)	4 (25%)
Parameters:	1 (6.25%)	19 (24.0%)	0 (0.0%)
Fractionation:	1 (6.25%)	0 (0.0%)	0 (0.0%)
TOTAL	16	35	16

incorrect transfer of data from planning printouts to treatment chart. Incorrect transfer of data was due to human inattention. As these errors are rare it is difficult to avoid them. Detection was done by data control.

Transfer from treatment chart to the operating console of the linear accelerator (Table 9)

Due to the implementation of conformal radiotherapy in 1996, two error types were added to the list: dose/fraction and accumulated dose.

Table 9 Distribution of different types of Data Transfer errors (from Treatment Chart to Computer system), divided over the different years (N.R. = not registered).

Type of Data Transfer error	1995	1996	1997
Total Dose:	15 (11.0%)	20 (13.0%)	56 (19%)
Dose/fraction:	N.R.	7 (4.4%)	4 (1%)
Accumulated Dose:	N.R.	18 (11.0%)	22 (8%)
Technique:	1 (0.7%)	1 (0.6%)	6 (2%)
MU:	30 (22.0%)	8 (5.0%)	8 (3%)
Parameters:	79 (58.0%)	96 (61.0%)	40 (14%)
Energy:	11 (8.0%)	8 (5.0%)	7 (2%)
incomplete:	N.R.	N.R.	146 (50%)
TOTAL	136	158	289

The majority of errors were due to forgotten parameters on the treatment chart, printed out by the Vericord system. If blocks were used, the technologist had to fill in a number that identified the tray. The number corresponded to the hardware tray identificator. As blocks were replaced by leaves the item for the block number was always zero. Leaves had to be specified separately; otherwise it looked as if the patient was treated without the necessary shielding. These were the majority of the errors coded as 'incomplete' (70/146). As the number of parameters checked also increased in 1997, we can conclude that this item in the process chain was our weak spot.

In 1998, a third accelerator was installed and at the same time, a data transfer network. This should decrease the number of manual transfers. It is expected that errors will decrease accordingly.

Transfer from the treatment chart to the MLC (Table 10)

The installation of the MLC on our SL-25 happened in three distinct phases. Initially, the MLC-computer operated independently from the operating console of the SL-25. Moreover, all data-input had to be done manually and separately on each computer. Later, the MLC-settings obtained from the 3D-planning data were transferred automatically from the planning-computer to the MLC-computer through a TCP/IP Ethernet network. Finally, the MLC-computer was fully integrated in the master computer of the operating console and MLC-data from both 2D- and 3D-planning systems were transferred automatically through the network. This last step was finished mid 1997. A gradual decrease of transfer errors resulted except for no data for leaf setting which was newly identified.

Table 10 Distribution of different types of Data transfer errors (from Treatment Chart to Multileaf Collimator), divided over the different years (N.R. = not registered).

Type of Data Transfer error	1995	1996	1997
Beam:	1 (3.4%)	0 (0.0%)	0 (0.0%)
Incorrect leaves:	18 (62.0%)	15 (88.0%)	7 (23%)
Energy:	2 (7.0%)	0 (0.0%)	0 (0.0%)
Field size:	5 (17.0%)	2 (12.0 %)	1 (3%)
Offset:	3 (10.0%)	0 (0.0%)	0 (0.0%)
Leaves not ready:	N.R.	N.R.	4 (13%)
No data of leaf-setting:	N.R.	N.R.	19 (61%)
TOTAL	29	17	31

Daily set-up (Table 11)

At the outset, only one accelerator (SL-75) was equipped with an automatic verification system (Vericord™ system). The absence of an automatic verification system at the SL-25 was considered a major quality problem. In August 1996, a similar Vericord™ system was installed on the SL-25, resulting in a significant decrease of wrongly charted sessions or doses.[2]

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74/217 errors have led to incorrect irradiation: (i) wrong couch rotation (21/74) due to erroneous table rotation readings, (ii) one field of the treatment not given (26/74) are the major problems. Other errors were treatment with the data of another patient and bolus material forgotten. Checking if bolus material was not forgotten can not be done systematically; it was only counted if the radiation technologist reported it.

Incorrect administration also included errors that were not corrected within the day following by the detection of the errors. As the goal was control of all data within two days after the first treatment, we considered it an error if the data were not available in this period.

In one case a technologist changed the medical prescription without consulting the radiation oncologist first. The prescription was different from the protocol, but this was intentional. The event was recorded as an error because the patient received one session too much.

Table 11 Distribution of different types of Daily Set-up errors, divided over the different years (N.R. = not registered).

Type of Daily Set-up error	1995	1996	1997
Wrongly charted sessions/dose:	95 (56.0%)	94 (56.0%)	0 (0.0%)
Portal film not taken:	48 (28.0%)	19 (11.0%)	37 (17%)
Incorrect irradiation:	N.R.	35 (21.0%)	74 (34%)
Incorrect administration:	25 (15.0%)	20 (12.0%)	34 (16%)
No data:	N.R.	N.R.	72 (33%)
TOTAL	168	168	217

DISCUSSION

The first analysis (data for 1995) identified problems at the level of:

1. Treatment prescription
   - no final prescription
   - no clearly written protocols
   - 91% of treatment changes were not registered.
2. Data transfer
   - manual transfer of leaf settings
   - manual charted sessions/dose

The cause was attributed to a lack of communication between radiation oncologists and technologists. Therefore as a first step priority was given to improvements concerning the information flow:

1. Inventory of all used protocols.
2. New treatment prescription chart, with space for clearly written changes, if they were necessary during the treatment.
3. Final prescription at the start of the treatment.
4. Start of a monthly department meeting of the technologist to discuss new initiatives and evaluate the improvements.

After the introduction of the first improvements and an adaptation time, there was marked progress in the filling in of the final prescription and of the changes in the treatment schedule.

For the data transfer errors we felt the need for a Record and Verify system on the accelerator that did not have one. After installation in September 1996 no 'sessions' or 'doses given' were charted wrongly.

The software system for automatic electronic transfer of leaf settings reduced errors correlated to this item from 88% in 1996 to 23% in 1997.

New items on the prescription chart were introduced to force everyone to take responsibility for the data that they introduced into the chain at every major step.

We asked the radiation oncologists to fill in an item, after the morning staff meeting, to confirm the acceptance by all staff members of the proposed treatment (simulation) or to fill in the corrections that had to be made.

The radiation technologist was asked to fill in and sign an item at the time data were transferred to the computer console and at the start of the treatment. He or she thereby confirmed that the data were correct and complete. The aim of this item was (i) a second check if the treatment was approved by the staff, (ii) to give technologists and radiation oncologists more responsibilities in the quality control process.

At the second (data 1996) and the third evaluation(data 1997) a gradual decrease of errors at simulation was seen. We believed the rotation schedule was the cause. A new rotation schedule was introduced in 1998. One technologist remains

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now for 5 years at the simulator. Two others rotate every year. The reason behind is to have always at least two technologists that know the pitfalls, at the simulation, resulting in fewer errors and a better use of simulation time.

Quality is the effort of a whole team, so it is important that the concept of QC is accepted. The QC officer also had to collaborate with the radiation oncologists, the radiation technologist, the physicist and engineers. To improve this communication we started a quality taskgroup.

Participants were:

1. The QC officer.
2. One radiation oncologist.
3. One engineer.
4. One technologist from each workstation.

This taskgroup replaced a monthly department meeting with all radiation technologists and radiation oncologists, that appeared inefficient because of the size of the group.

The objectives of the taskgroup are (i) working out new initiatives to decrease the error rate, (ii) motivate the colleagues to work on quality.

CONCLUSION

The job of QC officer was in the first place created for process control. Due to QC, a great number of errors were found and corrected throughout the entire process. The job of QC officer not only exists to find errors and prevent accidents, it is his/her task to enforce attention to decreasing error rates and thus to make fewer mistakes. Examination of the data shows that in two years (1996–1997) the errors didn't decrease, except for the errors made by the radiation oncologists.The reason for this could be the progressively more rigorous control of all parameters, but a second reason was that the concept of quality as the effort of a whole team was not fully accepted . Radiation technologists accepted that errors are found by the QC officer but sometimes it appeared that they relied on her error detection skills instead of trying to avoid the errors. Introducing this new concept was very difficult. Changes were made very slowly.

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Appendix 1 Procedures of the radiotherapy treatment with situation of the QC checks at the R-UZG.

Procedure	documents	Checks*		Error categories
Treatment indication (T.I.)	Patient file			
Initial prescription (I.P.)	T.I. Protocols	QC check 1 ☐	not ok ☐	ask on staff meeting
Final prescription (F.P.)	I.P. Treatment schedule RX	QC check 2 ☐	not ok ☐	Medical prescription error
Simulation (Sim)	F.P. RX Sim. data Sim. film	QC check 3 ☐	not ok ☐	Simulation error
Planning	Sim data Sim films Treatment chart with the radiation prescription	QC check 4 ☐	not ok ☐	Planning error
Transfer data in the check- and confirm system	Treatment chart Radiation sheet	QC check 5 ☐	not ok ☐	Transfer error
Transfer Leaf-setting	Automatic	QC check 6 ☐	not ok ☐	Transfer error
Daily treatment set-up	Treatment chart Radiation sheet Treatment schedule	QC check 7 ☐	not ok ☐	Daily set-up error

*** Checks**

QC check 1 Prescription conform with protocol. If not ask reason on the staff meeting

QC check 2 Prescription conform with protocol. conform with staff decision Is treatment schedule filled in Is the radiation prescription identical to the schedule Items of the radiation prescription:
- Correct entry dose/beam
- Correct technique
- Correct fractionation
- Correct energy
- Correct transfer of the monitor units/beam

If no planning is made: correct manual calculation

QC check 3 Patient identity correct and identical on treatment chart and simulation film Are data on treatment chart and simulation films identical ?
Are the blocks drawn on the simulation films?
X_1+X_2 ok?
Y_1+Y_2 ok?
Offset ok?
Position of the patient correct?
Are all necessary data for a correct patient set-up filled in?

QC check 4 Technique ok?
Correct fractionation?
Correct energy?
Dose level = 100%
Data identical to simulation data?
If there are blocks: is the tray-factor calculated?
Normalisation is done?
Is planning checked by a senior radiation oncologist

QC check 5 Correct transfer of the data in the check-and-confirm system
Complete transfer of the data?

QC check 6 Correct transfer of leaves-setting?
Transfer was done in time.

QC check 7 Check of the radiation sheet once a week: all beams given?
MU ok?
Patient set-up ok?
Were the verification films taken?
TLD's where necessary
Appointment for simulation of boost done in time.

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