Original Article

Use of a Checklist Approach on a Telecobalt in an Attempt to Reduce Human Errors in Radiotherapy Delivery and Improve Therapeutic Ratio

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Abstract

Background: The process of radiotherapy treatment planning and delivery involves multiple steps and professionals causing it to be prone to errors. Radiotherapy centers equipped with old telecobalt machines have certain peculiar challenges to workflow. We designed and tested a checklist for radiotherapy technicians (RTTs) to reduce chances of error during treatment delivery on a telecobalt machine. **Materials and Methods:** A physical checklist was designed for RTTs to use in the pretreatment pause using a template advocated by the American Association of Physicists in Medicine. It was tested on 4 RTTs over 1000 radiotherapy delivery sittings. **Results:** The checklist helped to rectify 41 documentary lapses and 28 errors in radiotherapy treatment parameters while also identifying 12 instances where treatment plan modifications were due and 30 where the patient was due for review by the radiation oncologist. The average time to go through the checklist was between 2.5 and 3 min. **Conclusions:** The development and use of the checklist has helped in reducing errors and also improving workflow in our department. It is recommended to utilize such physical checklists in all radiotherapy centers with telecobalt machines. The success of the checklist depends upon leadership, teamwork, acceptance of a need to inculcate a "safety culture," with voluntary error-reporting and a willingness to learn from such errors.

Keywords: Checklist, error, radiotherapy, telecobalt

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Introduction

Cancer is a leading cause of death and disability in the world today. Radiation Oncology is the field of medicine which utilizes ionizing radiation safely and effectively in the treatment, palliation, and cure of malignant diseases. Ionizing radiation is generated by highly sophisticated, complex, and expensive medical machines of essentially two types: linear accelerators (LINACs) and cobalt teletherapy units or telecobalts.

Radiotherapy treatment process has multiple steps carried out by a team of varied professionals with specific skills and responsibilities working together toward a common goal. The Radiotherapy Technician/Radiation Therapist (RTT) is the team member who executes the treatment plan on a day-to-day basis [Figure 1].

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A radiotherapy "*error*" can be described as a nonconformance where there is an unintended divergence between a radiotherapy process followed and that defined as correct by local protocol.[1] An error may or may not lead to a radiotherapy *"incident,"* which is any unintended event that has consequences that are not negligible from the point of view of protection or safety of the patient.[2]

The multidisciplinary and multistep nature of radiotherapy makes it prone to errors at every step. Complex technologies, computer applications, multiple interphases, and the stressful

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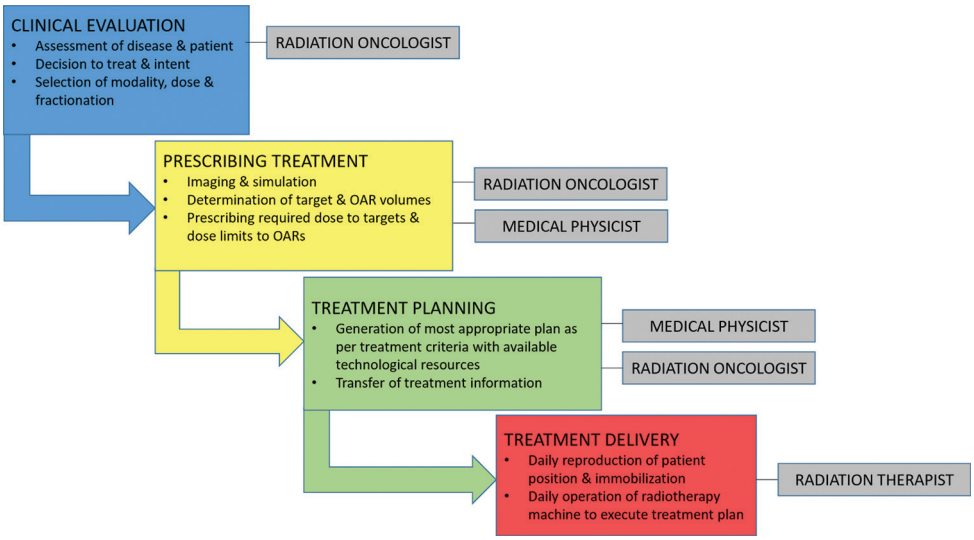


Figure 1: Different steps in a radiotherapy treatment workflow. The figure also depicts the team members primarily responsible for each respective step

and time-constrained milieu of modern medicine are some of the factors that may abet these errors. At the same time, the multistep nature of the radiotherapy (RT) process also endows multiple opportunities for detecting and correcting the errors in a modular and less confounding manner.

Errors in radiotherapy have been detected at every stage from documentation, simulation, treatment planning, treatment delivery, and also during transfer of information and instructions between various stages. While some can be blamed on machine failures and faulty software, the majority (60% or more) can be traced to human inattention and mistakes. Human errors can be caused by failures of communication, nonadherence to standard protocols, poor documentation, and oversight.

Checklists have been successfully used to prevent errors and improve performance in complex environments such as aviation, aeronautical and space engineering, architecture, and product manufacturing.[3,4] They have been used in the field of medicine for the last 30 years and have repeatedly proven to be effective in reducing complications in high intensity fields such as critical care and surgery.[4-7] Even in radiation oncology, they have been widely introduced in simulation, treatment planning, treatment delivery, and in audits of radiotherapy processes.[8-12] With the widespread use of computers in radiotherapy, most departments have multiple electronic checklists integrated into the radiotherapy information system/software.

Radiotherapy centers in developing countries like India face some peculiar challenges. Most departments in government sector hospitals treat a high volume of patients while the RTTs at many of these centers are understaffed and overworked. Furthermore, India still has 180 functioning Telecobalts which up one-thirds of all teletherapy machines in India.[13,14] The majority of these are a decade old and are not compatible with electronic checklists.

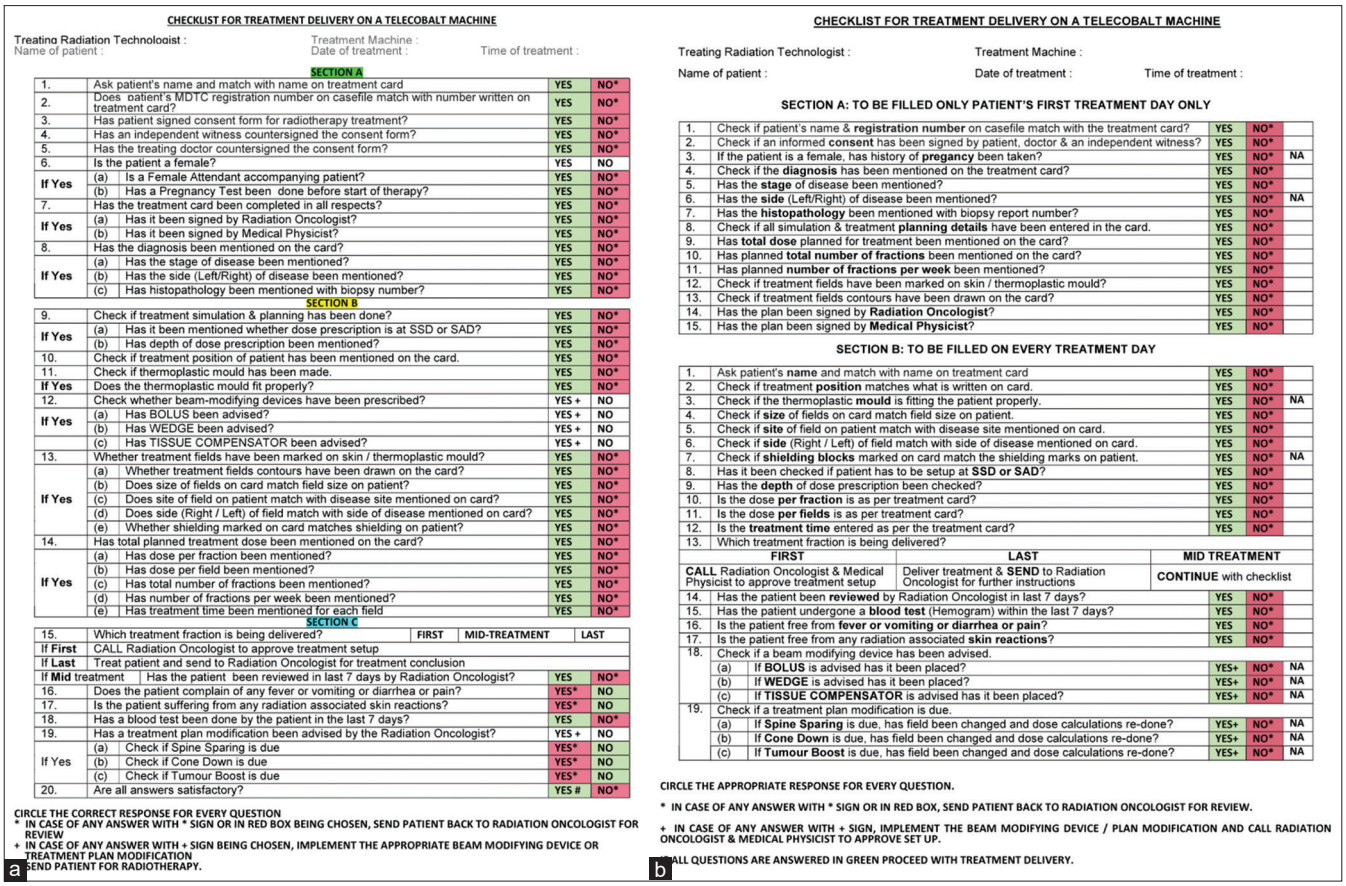
Under these demanding and error-prone circumstances, we felt that there was an unmet need for a physical checklist for treatment delivery on the aging telecobalt. Physical checklists have been used successfully for radiotherapy audits and treatment simulation,[9,12] though we could not find one in literature designed for treatment delivery on a telecobalt.

We have designed and tested a checklist for the last but very critical step of the RT process: treatment execution on a telecobalt unit by the RTTs. The RTTs were assigned the responsibility of conducting the checklist before treatment of every patient. We present the results of our exercise.

Materials and Methods

The American Association of Physicists in Medicine guidelines for developing safety checklists in radiotherapy[3] were used as a template to design the checklist. The step at which the checklist would be gone through was just before treatment delivery by the RTT. The development team included radiation oncologists, medical physicists, and RTTs. The first checklist that was developed consisted of three sections [Figure 2a]. The first section was used to check the recording of patient's details and consent on the treatment card to avoid regulatory lapses. As treatment delivery is the final step of the entire radiotherapy process, the second section was designed as a final check of all parameters of treatment planning and delivery as entered in the treatment card. The language was kept simple, direct, and unambiguous. Questions with only yes or no type responses were used and color coding was utilized for easy marking and auditing of detected faults. The third section was developed to help the RTT in detecting if the treatment plan was due for a modification or if the patient needed to be reviewed by the physician.

The checklist would be run by two RTTs posted on the telecobalt unit with one completing all tasks while the



CHECKLIST FOR TREATMENT DELIVERY ON A TELECOBALT MACHINE

Treating Radiation Technoloogist : Treatment Machine :
Name of patient : Date of treatment : Time of treatment :

SECTION A

1.	Ask patient's name and match with name on treatment card		YES	NO*
2.	Does patient's MDTC registration number on casefile match with number written on treatment card?		YES	NO*
3.	Has patient signed consent form for radiotherapy treatment?		YES	NO*
4.	Has an independent witness countersigned the consent form?		YES	NO*
5.	Has the treating doctor countersigned the consent form?		YES	NO*
6.	Is the patient a female?		YES	NO
If Yes	(a)	Is a Female Attendant accompanying patient?	YES	NO*
	(b)	Has a Pregnancy Test been done before start of therapy?	YES	NO*
7.	Has the treatment card been completed in all respects?		YES	NO*
If Yes	(a)	Has it been signed by Radiation Oncologist?	YES	NO*
	(b)	Has it been signed by Medical Physicist?	YES	NO*
8.	Has the diagnosis been mentioned on the card?		YES	NO*
If Yes	(a)	Has the stage of disease been mentioned?	YES	NO*
	(b)	Has the side (Left/Right) of disease been mentioned?	YES	NO*
	(c)	Has histopathology been mentioned with biopsy number?	YES	NO*

SECTION B

9.	Check if treatment simulation & planning has been done?		YES	NO*
If Yes	(a)	Has it been mentioned whether dose prescription is at SSD or SAD?	YES	NO*
	(b)	Has depth of dose prescription been mentioned?	YES	NO*
10.	Check if treatment position of patient has been mentioned on the card.		YES	NO*
11.	Check if thermoplastic mould has been made.		YES	NO*
If Yes	Does the thermoplastic mould fit properly?		YES	NO*
12.	Check whether beam-modifying devices have been prescribed?		YES +	NO
If Yes	(a)	Has BOLUS been advised?	YES +	NO
	(b)	Has WEDGE been advised?	YES +	NO
	(c)	Has TISSUE COMPENSATOR been advised?	YES +	NO
13.	Whether treatment fields have been marked on skin / thermoplastic mould?		YES	NO*
If Yes	(a)	Whether treatment fields contours have been drawn on the card?	YES	NO*
	(b)	Does size of fields on card match field size on patient?	YES	NO*
	(c)	Does site of field on patient match with disease site mentioned on card?	YES	NO*
	(d)	Does side (Right / Left) of field match with side of disease mentioned on card?	YES	NO*
	(e)	Whether shielding marked on card matches shielding on patient?	YES	NO*
14.	Has total planned treatment dose been mentioned on the card?		YES	NO*
If Yes	(a)	Has dose per fraction been mentioned?	YES	NO*
	(b)	Has dose per field been mentioned?	YES	NO*
	(c)	Has total number of fractions been mentioned?	YES	NO*
	(d)	Has number of fractions per week been mentioned?	YES	NO*
	(e)	Has treatment time been mentioned for each field	YES	NO*

SECTION C

15.	Which treatment fraction is being delivered?	FIRST / MID-TREATMENT / LAST		
If First	CALL Radiation Oncologist to approve treatment setup			
If Last	Treat patient and send to Radiation Oncologist for treatment conclusion			
If Mid treatment	Has the patient been reviewed in last 7 days by Radiation Oncologist?		YES	NO*
16.	Does the patient complain of any fever or vomiting or diarrhea or pain?		YES*	NO
17.	Is the patient suffering from any radiation associated skin reactions?		YES*	NO
18.	Has a blood test been done by the patient in the last 7 days?		YES	NO*
19.	Has a treatment plan modification been advised by the Radiation Oncologist?		YES +	NO
If Yes	(a)	Check if Spine Sparing is due	YES*	NO
	(b)	Check if Cone Down is due	YES*	NO
	(c)	Check if Tumour Boost is due	YES*	NO
20.	Are all answers satisfactory?		YES #	NO*

CIRCLE THE CORRECT RESPONSE FOR EVERY QUESTION
* IN CASE OF ANY ANSWER WITH * SIGN OR IN RED BOX BEING CHOSEN, SEND PATIENT BACK TO RADIATION ONCOLOGIST FOR REVIEW
+ IN CASE OF ANY ANSWER WITH + SIGN BEING CHOSEN, IMPLEMENT THE APPROPRIATE BEAM MODIFYING DEVICE OR TREATMENT PLAN MODIFICATION
# SEND PATIENT FOR RADIOTHERAPY.

a

CHECKLIST FOR TREATMENT DELIVERY ON A TELECOBALT MACHINE

Treating Radiation Technologist : Treatment Machine :
Name of patient : Date of treatment : Time of treatment :

SECTION A: TO BE FILLED ONLY PATIENT'S FIRST TREATMENT DAY ONLY

1.	Check if patient's name & **registration number** on casefile match with the treatment card?	YES	NO*	
2.	Check if an informed **consent** has been signed by patient, doctor & an independent witness?	YES	NO*	
3.	If the patient is a female, has history of **pregancy** been taken?	YES	NO*	NA
4.	Check if the **diagnosis** has been mentioned on the treatment card?	YES	NO*	
5.	Has the **stage** of disease been mentioned?	YES	NO*	
6.	Has the **side** (Left/Right) of disease been mentioned?	YES	NO*	NA
7.	Has the **histopathology** been mentioned with biopsy report number?	YES	NO*	
8.	Check if all simulation & treatment **planning details** have been entered in the card.	YES	NO*	
9.	Has **total dose** planned for treatment been mentioned on the card?	YES	NO*	
10.	Has planned **total number of fractions** been mentioned on the card?	YES	NO*	
11.	Has planned **number of fractions per week** been mentioned?	YES	NO*	
12.	Check if treatment fields have been marked on skin / thermoplastic mould?	YES	NO*	
13.	Check if treatment fields contours have been drawn on the card?	YES	NO*	
14.	Has the plan been signed by **Radiation Oncologist**?	YES	NO*	
15.	Has the plan been signed by **Medical Physicist**?	YES	NO*	

SECTION B: TO BE FILLED ON EVERY TREATMENT DAY

1.	Ask patient's **name** and match with name on treatment card	YES	NO*	
2.	Check if treatment **position** matches what is written on card.	YES	NO*	
3.	Check if the thermoplastic **mould** is fitting the patient properly.	YES	NO*	NA
4.	Check if **size** of fields on card match field size on patient.	YES	NO*	
5.	Check if **site** of field on patient match with disease site mentioned on card.	YES	NO*	
6.	Check if **side** (Right / Left) of field match with side of disease mentioned on card.	YES	NO*	
7.	Check if **shielding blocks** marked on card match the shielding marks on patient.	YES	NO*	NA
8.	Has it been checked if patient has to be setup at **SSD or SAD**?	YES	NO*	
9.	Has the **depth** of dose prescription been checked?	YES	NO*	
10.	Is the dose **per fraction** is as per treatment card?	YES	NO*	
11.	Is the dose **per fields** is as per treatment card?	YES	NO*	
12.	Is the **treatment time** entered as per the treatment card?	YES	NO*	
13.	Which treatment fraction is being delivered?			

FIRST	LAST	MID TREATMENT
CALL Radiation Oncologist & Medical Physicist to approve treatment setup	Deliver treatment & **SEND** to Radiation Oncologist for further instructions	**CONTINUE** with checklist

14.	Has the patient been **reviewed** by Radiation Oncologist in last 7 days?		YES	NO*	
15.	Has the patient undergone a **blood test** (Hemogram) within the last 7 days?		YES	NO*	
16.	Is the patient free from **fever or vomiting or diarrhea or pain**?		YES	NO*	
17.	Is the patient free from any radiation associated **skin reactions**?		YES	NO*	
18.	Check if a beam modifying device has been advised.				
	(a)	If **BOLUS** is advised has it been placed?	YES+	NO*	NA
	(b)	If **WEDGE** is advised has it been placed?	YES+	NO*	NA
	(c)	If **TISSUE COMPENSATOR** is advised has it been placed?	YES+	NO*	NA
19.	Check if a treatment plan modification is due.				
	(a)	If **Spine Sparing** is due, has field been changed and dose calculations re-done?	YES+	NO*	NA
	(b)	If **Cone Down** is due, has field been changed and dose calculations re-done?	YES+	NO*	NA
	(c)	If **Tumour Boost** is due, has field been changed and dose calculations re-done?	YES+	NO*	NA

CIRCLE THE APPROPRIATE RESPONSE FOR EVERY QUESTION.

* IN CASE OF ANY ANSWER WITH * SIGN OR IN RED BOX, SEND PATIENT BACK TO RADIATION ONCOLOGIST FOR REVIEW.

+ IN CASE OF ANY ANSWER WITH + SIGN, IMPLEMENT THE BEAM MODIFYING DEVICE / PLAN MODIFICATION AND CALL RADIATION ONCOLOGIST & MEDICAL PHYSICIST TO APPROVE SET UP.

ALL QUESTIONS ARE ANSWERED IN GREEN PROCEED WITH TREATMENT DELIVERY.

b

Figure 2: (a) First version of checklist used for pilot testing (see text). (b) Final iteration of the checklist used in the study (see text)

other would read out and check each element during the pretreatment pause. We then conducted limited pilot testing of the checklist for 100 radiotherapy sittings or fractions, after a preimplementation training and familiarization exercise for the RTTs. Feedback was taken after this pilot phase and checklist design was re-evaluated. The major problems identified were the time taken (between 6 and 10 min per patient) to go through the list and some questions having neither yes nor no as an appropriate response.

After multiple such iterations, the final draft was accepted after incorporating several changes [Figure 2b]. Instead of three, the list was divided into two sections with section A having all questions relevant only on the 1st day of treatment. Section B contained questions for all treatment days.

The color coding was further simplified and some questions reframed to make them simpler and reduce confusion. A "not applicable" option for certain questions was also provided. After retraining four RTTs this final version was tested for 1000 treatment fractions over a period of 6 weeks. The average time taken to go through the list was also recorded for first 10 and last 10 fractions. The observations made during these 1000 fractions are now presented.

Results

Out of the 1000 checklists that were run, 902 had no observations with all parameters that were checked being in green or acceptable zone. In the remaining 98 checklists, there were 111 observations (89 had one observation, 6 had two, 2 had three, and 1 had four observations). The distribution of observations into types and the actual observations made are displayed in Figure 3a-d.

In the first 10 fractions, the average time taken to go through the list was 6 min on the 1st day of treatment and 5 min on other days. During the last 10 fractions this had improved to 3 min and 2.5 min, respectively.

Discussion

Though appearing complicated and error-prone, radiotherapy is one of the safest fields of medicine today.[15] The error rate during radiotherapy process reported in an American study was as low as 0.005%.[16] Others have reported it to vary between 0.017% when using computerized systems to 0.2% without the same.[17] In a safety review of radiotherapy facilities by the World Health Organization (WHO) and International Atomic Energy Agency (IAEA), 3125 patients suffered adverse effects due to radiotherapy treatment errors over 30 years.[18] Furthermore, 90% of radiotherapy errors reported in literature

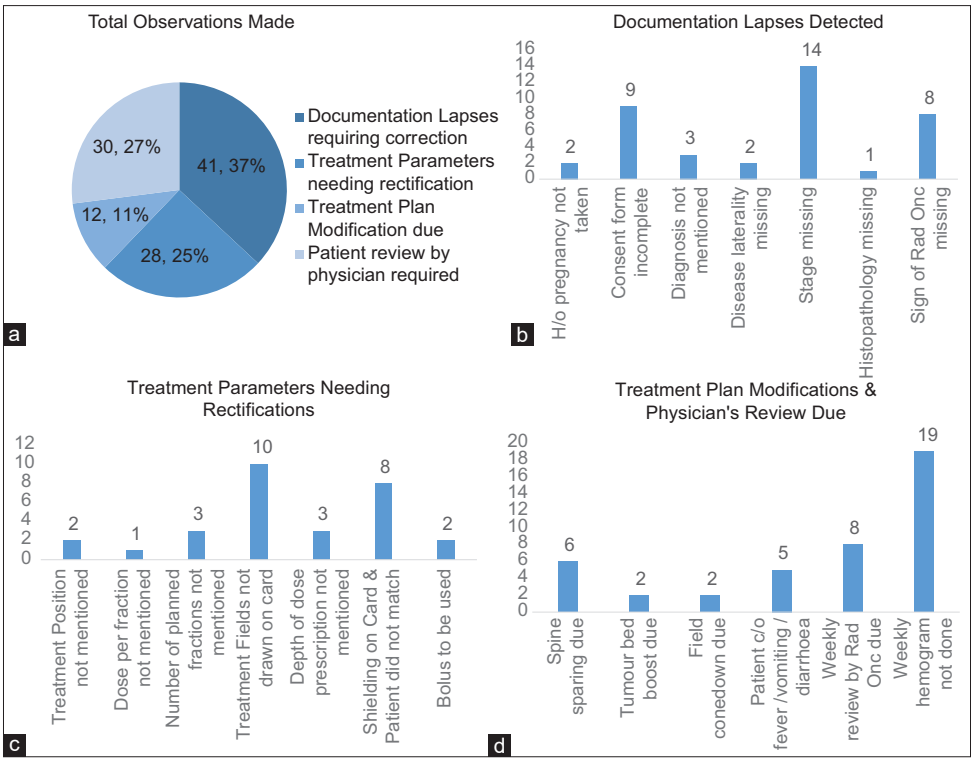


Figure 3: (a) Distribution of observations made into types. (b) Observations of documentary lapses made. (c) Observations of treatment parameters requiring rectification that were made. (d) Observations of treatment plan modifications and physician's review that were due and were timely identified

are clinically insignificant. However, due to the nature of ionizing radiation, it always has the potential to cause severe and lasting damage leading to permanent disability or even death. In the WHO review, 1% (38) of the errors did lead to death of the patient as a consequence of radiation toxicity.[18]

Studies on radiation error rates primarily originate from the developed parts of the world. negligible radiotherapy incidents are reported by most developing nations of Asia and Africa, including India though some studies have shown otherwise. A postal audit of Thermoluminescent dosimeter (TLD) between 1997 and 2004 by IAEA/WHO in developing countries suggested that only 84% patients received radiotherapy dose within the acceptable range.[19] Recently, a paper on an audit of radiotherapy processes at Tata Memorial Centre has been published which detected an error rate of 0.16 per 100 fractions or 4.1 per 100 patients.[13] Clearly, errors occur but are underreported.

In our study, we have focused on reducing errors and improving performance during treatment delivery using a checklist which can be a simple but effective tool at every step of the radiotherapy workflow.

Use of the checklist in our department brought about some obvious and positive improvements. First among these was the standardization and streamlining of workflow. The majority of the observations in our study were documentary lapses (41% or 37%). While they may be put down to simple clerical errors, a tendency of working with incomplete patient records shows an inattentive and careless workforce and can be hazardous under some circumstances. Missing details like disease diagnosis and laterality can make the process of doing an audit meaningless. Incomplete consent forms and absent signatures of doctors and physicists can lead to regulatory and medicolegal issues as well [Figure 3b].

The checklist ensured all our treatment records were meticulously checked and corrected. It also increased the overall inclination of all team members toward maintaining completed records even before the treatment card is subjected to a checklist. The number of documentary errors per week fell from 15 in the 1st week to none in the last week following a constant downward trend [Figure 4].

A total of 28 discrepancies in treatment parameters were detected in our study constituting 25% of observations made. Several minor omissions like mentioning of treatment position or depth of dose prescription or marking of treatment fields and shielding blocks on treatment cards, which were affecting the workflow and protocol of the department as well as the quality of care were identified [Figure 3c]. Thanks to the strict following of the checklist protocol, all such mistakes were sent back for immediate rectification. This certainly enhanced the quality of care delivered at our center. There was a downward trend with the passage of weeks on the number of treatment parameters requiring correction [Figure 4].

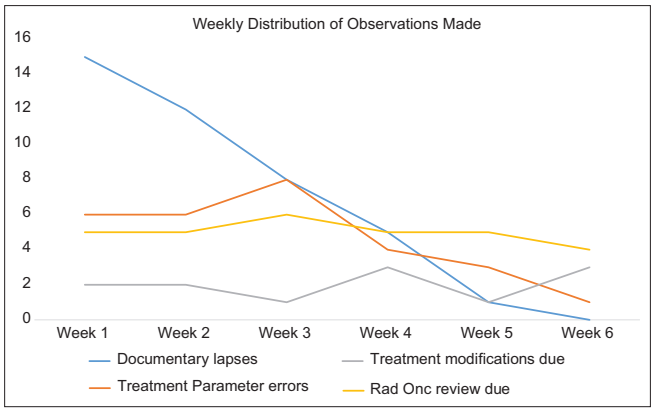


Figure 4: Weekly changes in observations made using the checklist

The reduction in both documentary and treatment planning mistakes after the introduction of the checklist might be reflective of its positive effect on the streamlining of workflow, standardization of department practices, and improved compliance with laid-down protocols and procedures. These are benefits that would help any medical practice in improving patient safety and clinical outcomes.

The checklist also acted as a memory guide reminding the RTTs about timely treatment plan modifications and radiation oncologists' review of the patients whenever they were due, reducing the chances of missing out on these critical events.

While the checklist is simple and effective, its success cannot be attributed only to the use of a memory aid to avoid forgetting tasks. It was important to use it in the background of sensitization and empowerment of all stakeholders in the RT process to take responsibility for identifying and accepting mistakes in a professional manner. The idea to be categorically conveyed was that the ultimate goal of the checklist was to find errors without laying blame, and to improve the overall quality of workflow.

Finally, a subjective opinion of the RTTs on the use of the checklist. In the postimplementation feedback, the RTTs were unanimous in their approval. They felt a greater sense of confidence in their own work while treating patients with the checklist as they felt sure they had not missed any minor details. The feeling of empowerment and responsibility that came with using the checklist also added to their confidence. They felt less stressed while carrying out large volumes of repetitive tasks. They also submitted that their channel of communication with the doctors and physicists had also improved. Their only complaint was about the additional work, as expected.

Limitations of the study

Nothing comes without a price, and in this case, it was the extra time. As mentioned previously, changes were made to the checklist specifically to reduce the time taken to run it. By the end of the trial, the RTTs were accustomed to using the list and without compromising on deliberations could finish the list within 3½ min on the 1st treatment day and 2½ min on other days. Two and a half minutes does not sound like much but when done for 40 consecutive patients it works out to an hour and 40 min of additional work. Most departments in India have many more patients than that per shift. The other hardship faced was auditing all of the checklists which can be tedious and time consuming as an additional task.

A possible solution to this according to the authors is the use of an electronic checklist on a standalone computer terminal or even a hand-held device. With the ubiquity of smartphones and Wi-Fi internet, this should not be a problem. There are several proprietary software available in the market that allow one to customize their own checklist. With an electronic checklist, not only is the requirement of printed paper reduced but with the user-friendly interface the checklist tends to be run through faster also. And of course, auditing the lists becomes much simpler and quicker. We have developed such a checklist using a freely available software but are yet to test or validate it.

The true evidence of the success of an intervention is in the measurement of clinical outcomes before and after the intervention is introduced in a closed setting. However, to do so with checklists in radiotherapy can be challenging. This is due to the time it takes for clinical outcomes and toxicities to become evident in our field. On the other hand, detection of "near misses" and "radiation incidents" before and after the intervention would require detailed and extensive audits of the department and should be done after the checklist has been used for a longer period of at least 6 months. As a result, we could not use these parameters to assess the impact of the checklist on our practice. However, it can be planned for a subsequent longer study.

Conclusions

The development and use of the checklist has helped in reducing errors and also improving workflow in our department. In institutes that use telecobalts and do not use computerized systems of planning and treatment the chances of radiotherapy errors are higher. We recommend that till the time that computer-based treatment planning systems and modern LINACS replace the older telecobalts, our checklist can be used as an effective way of improving quality of care at such centers. Longer trials may be able to detect improvement in clinical outcomes as well. Finally, the checklist was effective because of good leadership, a positive sense of teamwork and an organizational acceptance of a need to inculcate a "safety culture" with voluntary error-reporting and to be willing learners from such errors.

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Conflicts of interest

There are no conflicts of interest.

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