ORIGINAL ARTICLE

CONTROL FACTORS FOR SITE ERRORS MANAGEMENT OF RADIOTHERAPY DELIVERY

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ABSTRACT

The aim: This study aimed to define the factors related to irradiation field equality and target accuracy which will further influence the irradiation result.

Materials and methods: This is a prospective-qualitative study, conducted by observation of image data verification from cervical cancer patients in the Department of Radiotherapy, dr. Moewardi Hospital, Surakarta who had undergone several times a week irradiation utilizing Telecobalt60 device and by conducting an in-depth interview to ten Indonesian radiotherapy experts, in October 2018. The data was further analyzed using correlation – regression test.

Results: From 30 verification image data of the irradiated patients, we conclude that the scheme, body size, and patient positioning factors have all revealed statistically significant correlations to the irradiation field equality. On the other hand, factors such as patient and tele-therapy device set-ups, tele-therapy device calibration, human resources quality, and tele-therapy device malfunctions have all revealed statistically significant correlations to the irradiation target accuracy. These facts were further strengthen by the supporting statements from 10 Indonesian radiotherapy experts.

Conclusions: The impact factors of field equality and accuracy of the irradiation target could serve as an important control factors which is substantially required to manage and minimize site errors of the radiotherapy delivery.

KEY WORDS: Control factors, site errors, radiotherapy delivery, portal imaging, cancer

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INTRODUCTION

Radiotherapy still serves as one of the important modality for cancer treatment to date, recommended by the Inter-Society Council for Radiation Oncology (ISCRO) USA and the World Health Organization (WHO) [1,2]. Radiotherapy inventions continuously developing since early 20th century and resulting in the two main radiotherapy techniques which are Tele-therapy and brachytherapy [3–5]. These techniques were further improving certainty of the irradiation targets along with the invention of MLC device and CT-Scan [2–4, 6–8]. However, radiotherapy also remains as a high risk treatment. Site error of radiotherapy delivery is one of the most significant risk which is resulting from the sophisticated and complex technology which involves many processes, specific knowledge and requires human expertise from the operating staff for radiotherapy delivery. All of which contributes to the increasing risk for radiotherapy errors to occur [8–13].

Radiotherapy delivery errors may include errors of the site being treated, errors of radiation dose delivered to the patient, and errors of the patient being treated. The control factor strategies theoretically should be effective in verifying irradiation field equality and accuracy of the irradiation targets by portal imaging utilization, standard of procedures (SOP) checking and re-checking and utilization of record and verify (RV) checklist system device to identify the correct patient, which are all included in the guidelines of the quality assurance radiotherapy (QART). Of all the errors, the radiation site error is the main error in radiotherapy which may resulted from the error in determining either the irradiation field equality (affected by factors such as the scheme of the simulator image, patient's body size and positioning) or accuracy of the irradiation target (affected by factors such as patient and Tele-therapy device set-ups, Tele-therapy device calibration, quality of operating human resources, and mechanical malfunctioning the Tele-therapy device) [9, 11, 12, 14, 15].

THE AIM

The aim of this study was to define factors which are theoretically carries significant impacts to irradiation field equality (such as the scheme of the simulator image, patient's body size and positioning) as well as factors which

Table I. The relationship of the factors to the equality of the irradiation field according to the patient's data observation

No	Independent variable	Dependent variable	R (strength of confidence)	p (significance– p-standard)
1	S	Equality of the field	59%	0.001 (p<0.05)
2	BZ	Equality of the field	42%	0.021 (p<0.05)
3	PP	Equality of the field	54%	0.002 (p<0.05)

S: The scheme of the simulator image; BZ: Body size of the patient; PP: Patient positioning.

Table II. The relationship of the factors to the accuracy of the target irradiation according to the patient's data observation.

No	Independent variable	Dependent variable	R (strength of confidence)	p (significance– p-standard)
1	SP	Accuracy of the target	54%	0.002 (p<0.05)
2	STD	Accuracy of the target	54%	0.002 (p<0.05)
3	C	Accuracy of the target	54%	0.002 (p<0.05)
4	QHR	Accuracy of the target	54%	0.002 (p<0.05)
5	MT	Accuracy of the target	54%	0.002 (p<0.05)

SP: Set-up of the patient; STD: Set-up of the Tele-therapy device; C: Calibration of the Tele-therapy device; QHR: Quality of the conducting human resources; MT: Mechanical malfunctioning of the Tele-therapy device.

Table III. The influeance of the factors to the irradiation field or accuracy of the target irradiation according to the radiotherapy expert.

No	Subject	To equality of the irradiation field			To accuracy of the irradiation target				
		Sheme of the simulator image	Body size of the patient	Petient positioning	Set-up the patient	Set-up the teletherapy device	Calibration the teletherapy device	Quality of conducting human resource	Mechanical malfunctioning of the teletherapy device
1	RO1	I	I	I	I	I	I	I	I
2	RO2	I	I	I	I	I	I	I	I
3	RO3	I	I	I	I	I	I	I	I
4	RO4	I	I	I	I	I	I	I	I
5	MP1	I	I	I	I	I	I	I	I
6	MP2	I	I	I	I	I	I	I	I
7	MP3	I	I	I	I	I	I	I	I
8	RTT1	I	I	I	I	I	I	I	I
9	RTT2	I	I	I	I	I	I	I	I
10	RTT3	I	I	I	I	I	I	I	I

RO: Radiation Oncologist, MP: Medical Physicist, RTT: Radiation Therapis, I: Influenced

are theoretically carries significant impacts to irradiation target accuracy (such as patient and Tele-therapy device set-ups, Tele-therapy device calibration, operating human resources quality, and Tele-therapy device mechanical malfunctions) which all would influence the irradiation certainty using Telecobalt-60.

MATERIALS AND METHODS

The materials which were involved in this qualitative study comprised of the NPIC GWXJ80 Telecobalt^{60} and simulator machine units, manually X-beamed block, assembled verification model devices consisted of computed radiography (CR) device, CR-cassette and reader (CR-workstation), CR cassette-seat holder and magnification software (new invention devices assembled and set in Telecobalt^{60}), as well as the check lists.

This study was conducted, by data observation from cervical cancer patients who had undergone irradiation aswell as conducting in depth interview to Indonesian's Radiotherapy experts. Data observation study was conducted by data collection and observation of the verified computed radiography from cervical cancer patients in the Department of Radiotherapy - dr. Moewardi General Hospital, Surakarta, Central Java, Indonesia who had undergone several times a week irradiation utilizing Telecobalt-60 in October 2018. Meanwhile, the in-depth interview study was conducted to ten radiotherapy experts at several Indonesian radiotherapy centers/installation which comprised of 4 (40%) radiation oncologist

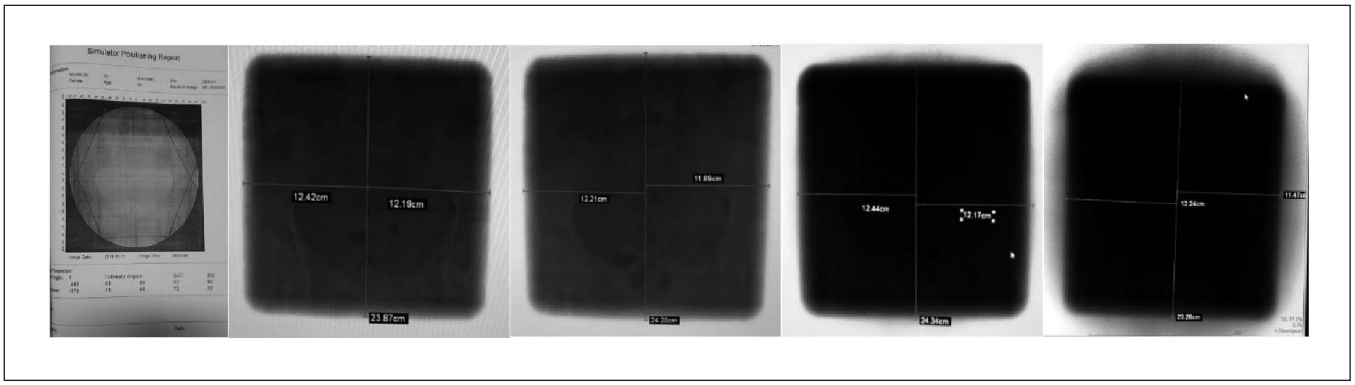

Fig. 1. Radiation field verification using computer radiography

subjects, 3 (30%) medical physicist subjects, and 3 (30%) radiation therapist subjects.

The research subject were positioned in a supine position on the Telecobalt^{60} device couch and the source was applied to the patient's body with skin to source distance (SSD) of 80 cm. We placed the CR cassette on the cassette seat-holder 2 cm below the couch and exposed the radiation to the patient twice (without and with the manual block), using the CR cassette as the verification portal image detector with beam field size of 40 x 40 cm and treatment duration of 0.02 minute, before we finally took and brought the CR cassette to the CR reader to obtain the image-CR data.

RESULTS

THE OBSERVATION DATA TO THE IRRADIATED PATIENTS

The data observation result of the irradiation field equality which was verified by CR (as the verification portal image) mostly showed an average deviation of 0.91 cm. (ranged from 0.04 to 2.46 cm), compared to the scheme in the simulator image. Meanwhile, the other result of data observation from the simulator image scheme, patient's body size and positioning factors which theoretically should have carry a significant correlation to the irradiation field equality are showed to the Table I.

Table I revealed that the scheme, patient's body size, and positioning factors have significant statistical correlations to the irradiation field equality with significance and confidence values of 0.001 - 59%; 0.021 - 42%; and 0.002 – 54% respectively. Meanwhile, the linear regression values of the 3 factors correlated to the irradiation equality are 0.372(S) + 0.651(BZ) + 0.651(PP) – 0.837 ($p < 0.03$). The linear regression values showed that the simulator image scheme (S) factor is statistically and significantly correlated to the irradiation field equality by 0.372 fold. Furthermore, the patient's body size (BZ) and positioning (PP) factors also correlated significantly as each of them have the same linear regression values of 0.651 fold influence to the irradiation field equality. Therefore, the simulator image scheme, patient's body size, and positioning do have influences towards the irradiation field equality.

Furthermore, the results of data observation from factors such as the patient, and Tele-therapy device set-ups, Tele-therapy device calibration, operating human resources quality and Tele-therapy device mechanical malfunctions which all are theoretically correlated significantly to the irradiation target accuracy are showed in the Table II.

Table II revealed that the factors of patient, and Tele-therapy device set-ups, Tele-therapy device calibration, operating human resources quality and Tele-therapy device mechanical malfunctions, all have statistically significant correlations to the irradiation target accuracy, in accordance to the previous theories. The significances and strength of confidence values were respectively 0.002 and 54%. Meanwhile, the linear regression pattern values for each factors to the irradiation target accuracy were similar, which are $0.667(SP) - 8.8.10^{-17}$ ($p=0.002$), $0.667(STD) - 8.8.10^{-17}$ ($p=0.002$), $0.667(C) - 8.8.10^{-17}$ ($p=0.002$), $0.667(QHR) - 8.8.10^{-17}$ ($p=0.002$), and $-0.667(MT) + 0.667$ ($p=0.002$) respectively. All of the patient set-up (SP), Tele-therapy device set-up (STD), Tele-therapy device calibration (C), and operating human resources quality (QHR) factors have statistically significant correlations and each have the same linear regression values of 0.667 fold influence to the irradiation target accuracy. On the other hand, linear regression value of the Tele-therapy device mechanical malfunctions (MT) was -0.667 fold influence to the irradiation target accuracy. Hence, the patient and Tele-therapy device set-ups, Tele-therapy device calibration, operating human resources quality and Tele-therapy device mechanical malfunctions do have influences towards the irradiation target accuracy.

THE OPINIONS FROM RADIOTHERAPY EXPERTS

The result of in-depth interview of the radiotherapy experts were showed in the Table III.

Table III revealed that all subjects suggest that factors such as simulator image scheme, patient's body size and positioning do have influences towards the irradiation field equality. On the other hand, factors such as patient and Tele-therapy device set-ups, Tele-therapy device calibration, operating human resources quality, and Tele-therapy device mechanical malfunctions are also have influences towards the irradiation target accuracy.

The opinions describe that simulator image scheme from x-ray simulator would allow the irradiation certainty by justification and determination of irradiation field equality. Meanwhile, the patient's body size would influence the irradiation field equality along with a justified, consistent and proper determination of clinical skin marking according to the patient's body size and/or the tumor size alteration (shrinkage) after several weeks of irradiation exposure. Furthermore, patient positioning would also influence the irradiation field equality along with a justified and convenient positioning of the patient's body position during the irradiation.

The experts also explained that factors such as patient and Tele-therapy device set-ups, Tele-therapy device calibration, operating human resources quality and Tele-therapy device mechanical malfunctions would influence the irradiation target accuracy along with a justified, consistent and proper determination of clinical skin marking and Tele-therapy device which will all contribute to the overall result of irradiation field Tele-therapy program. On the other hand, factors such as Tele-therapy device calibration and mechanical malfunctions harness more influences towards the delivered irradiation dose.

DISCUSSION

Radiotherapy remains as a high risk cancer treatment modality to date. The greatest risk comes from the site error of radiotherapy delivery due to its sophisticated and complex technology as well as involvement of many processes and operating staffs which require specific knowledge and expertise, hence increasing the risk for errors to occur in the operation of the radiotherapy delivery [8-13].

The main error in the radiotherapy delivery is the wrong site being treated which is due to the errors in determining or obtaining the irradiation field equality factors (comprise of the simulator image scheme, patient's body size and positioning) or irradiation target accuracy factors (comprise of the patient's and Tele-therapy device set-ups, Tele-therapy device calibration, operating human resources quality, and Tele-therapy device mechanical malfunctions). Theoretically, the control factor strategies to handle these errors consisted of continuous verification of irradiation field equality and irradiation targets accuracy utilizing verification portal imaging (such as CR), as well as standard of procedures (SOP) checking and re-checking [9,11,12,14,15].

This study presented the deviations of irradiation field equality to the simulator image scheme following verification by CR as a verification portal device. This study also revealed that both the irradiation field equality factors as well as irradiation target accuracy factors carries a significant impacts in the efforts to minimize the treated site errors in radiotherapy delivery, in coherence with radiotherapy expert opinions which may further support the previous theories. Furthermore, all of the factors are appear to serve as substantial control factors to manage the site errors of the radiotherapy delivery.

Moreover, the existence of CR plays an important role as a verification portal image device to support control strategy in order to minimize errors of radiation treated site which had never been done in Telecobalt^{60} radiotherapy delivery before. On the other hand, the screen film radiography (gamma-graph film) which is still used widely in Telecobalt^{60} radiation, had started to undergone a significant popularity decline which may strongly related to its limitations, such as the low quality of radiography imaging, fixed grey-scale response in its screen film, fixed latitude, fixed dose to the patient, high cost, hazardous material used for the process, labor intensive, inefficient archive storage, and file retrieve difficulty [16].

CONCLUSIONS

The factors which consisted of the scheme, patient's body size and positioning have statistically significant correlations to the irradiation field equality. Moreover, other factors consisted of the patient's and Tele-therapy device set-ups, Tele-therapy device calibration, operating human resources quality and Tele-therapy device mechanical malfunctions all have significant statistical correlations to the irradiation target accuracy. Therefore, all of the mentioned factors may serve as the control factors which need to be well managed in order to minimize site errors of the radiotherapy delivery.

In the future, we suggest the requirement of standard of procedures (SOP) formulation as a quality assurance guideline in radiotherapy delivery which would clearly be able to define check/re-check and verification processes of the control factors to manage and minimize the site errors of radiotherapy delivery.

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