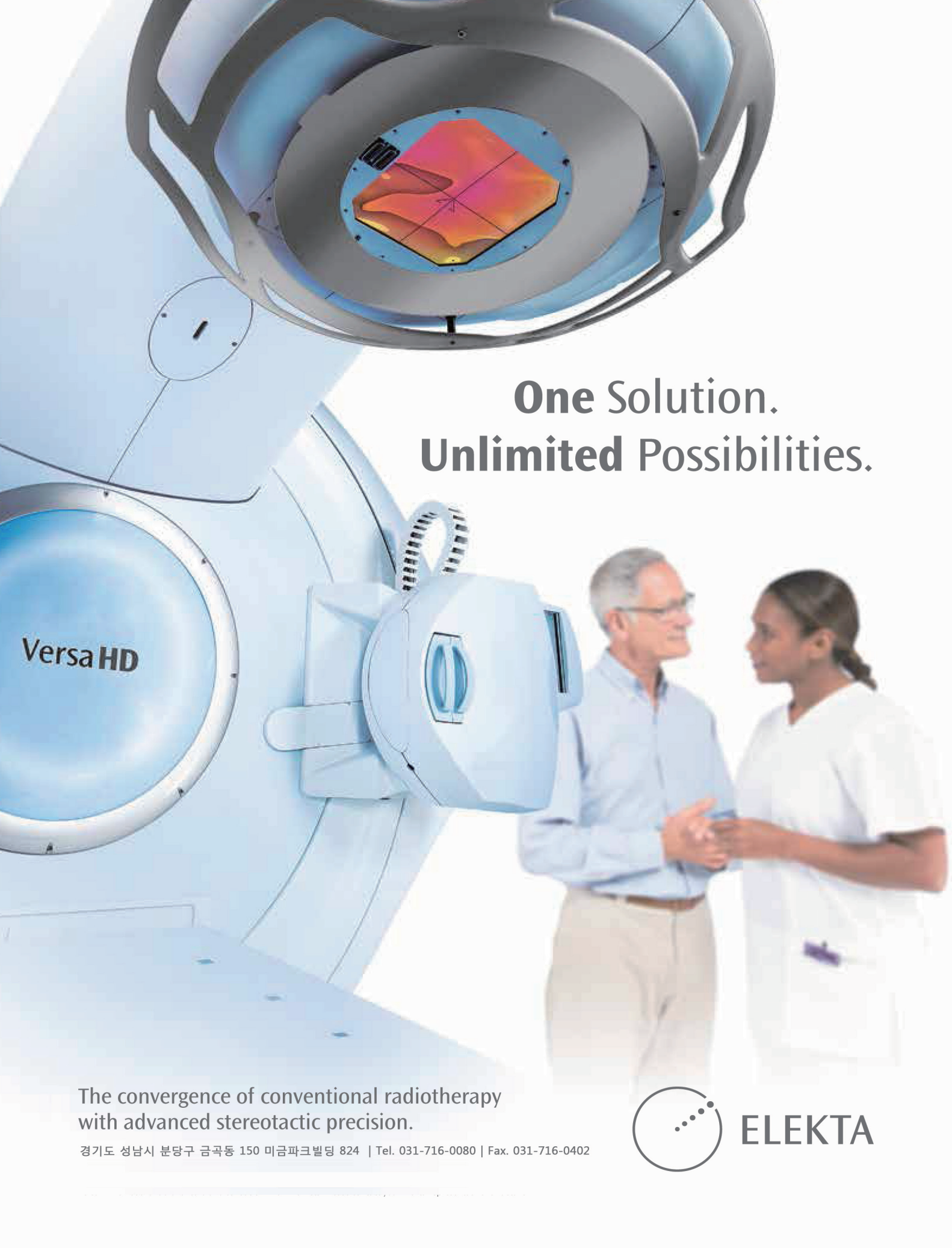

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Guideline on Acceptance Test and Commissioning of High-Precision External Radiation Therapy Equipment

Juhye Kim*, Dong Oh Shin†, Sang Hyoun Choi‡, Soonki Min†, Nahye Kwon§, Unjung Jung*, Dong Wook Kim‖

*Research Institute of Clinical Medicine, Kyung Hee University Hospital at Gangdong, †Department of Radiation Oncology, Kyung Hee University Hospital, ‡Division of Medical Radiation Equipment, Korea Institute of Radiological and Medical Sciences, Seoul, §Department of Nuclear Engineering, Kyung Hee University, Yongin, ‖Department of Radiation Oncology, Kyung Hee University Hospital at Gangdong, Seoul, Korea

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Corresponding author
Dong Wook Kim
(joocheck@gmail.com)
Tel: 82-2-440-7398
Fax: 82-2-440-7393

The complex dose distribution and dose transfer characteristics of intensity-modulated radiotherapy increase the importance of precise beam data measurement and review in the acceptance inspection and preparation stages. In this study, we propose a process map for the introduction and installation of high-precision radiotherapy devices and present items and guidelines for risk management at the acceptance test procedure (ATP) and commissioning stages. Based on the ATP of the Varian and Elekta linear accelerators, the ATP items were checked step by step and compared with the quality assurance (QA) test items of the AAPM TG-142 described for the medical accelerator QA. Based on the commissioning procedure, dose quality control protocol, and mechanical quality control protocol presented at international conferences, step-by-step check items and commissioning guidelines were derived. The risk management items at each stage were (1) 21 ionization chamber performance test items and 9 electrometer, cable, and connector inspection items related to the dosimetry system; (2) 34 mechanical and dose-checking items during ATP, 22 multileaf collimator (MLC) items, and 36 imaging system items; and (3) 28 items in the measurement preparation stage and 32 items in the measurement stage after commissioning. Because the items presented in these guidelines are limited in terms of special treatment, items and practitioners can be modified to reflect the clinical needs of the institution. During the system installation, it is recommended that at least two clinically qualified medical physicists (CQMP) perform a double check in compliance with the two-person rule. We expect that this result will be useful as a radiation safety management tool that can prevent radiation accidents at each stage during the introduction of radiotherapy and the system installation process.

Keywords: External radiation therapy equipment, Acceptance test, Commissioning, IMRT, Risk management

Introduction

Intensity modulated radiation therapy (IMRT) is a treatment that irradiates high dose to target volume while providing minimum dose to surrounding tissue by making optimal dose distribution with non-uniform fluence compared with 3-dimentional conformal radiation therapy (3D CRT).[1)] The introduction of such highly advanced treatment techniques has made the examination of the dose measurement also very important, not only increased the necessity of dose-based validation but also the importance of the dose distribution and the dose transfer characteristic

unique to the inverse planning technique. Accurate dose delivery in radiation therapy is highly dependent on the accuracy of the measured beam data during acceptance test procedures (ATP) and commissioning. Especially, the beam commissioning in the treatment planning system is very essential for clinical applications of IMRT. Most of the acquired beam data is input to the treatment planning system to determine or model the characteristics of the treatment device and is treated as standard data for clinical use. These standard data not only affect the treatment plan of all patients, but also serve as a basis for the quality assurance of the treatment device. Therefore, the linear accelerator ATP and commissioning phases are very important steps because they are the first step in the risk management system of the corresponding treatment equipment. When installation of linear accelerator, the clinically qualified medical physicist (CQMP) must take all the steps from the detailed construction plan to the treatment room design, installation supervision, ATP and beam data measurement to ensure the safety and accuracy of radiation therapy.[2] Furthermore, it is very important to maintain and guarantee the quality control standard value of radiotherapy equipment. The American Association of Physicists in Medicine (AAPM), European Society for Radiotherapy & Oncology (ESTRO), and International Atomic Energy Agency (IAEA) have published reports on dose quality control protocols[3,4] and mechanical quality control protocols.[5,6] Reports on beam commissioning related to accelerator beam data measurement or dose verification of advanced treatment techniques have also been published,[7-10] but there are no official reports for ATP items, yet. Despite the fact that new high precision radiotherapy devices are constantly being introduced in many hospitals in Korea, there are no guidelines for ATP or commissioning stages that are appropriate for domestic situations.

Thus, we propose risk management items for the dosimetry system itself, ATP and commissioning, and propose risk management guidelines for them.

Materials and Methods

ATP of high precision external radiation therapy equipment is part of an agreement to accept the acquisition, which means that the manufacturer verifies that the performance and operation of the device meet the specifications with the user. Step items and tolerances of ATP were derived based on the acceptance procedure of Varian (Varian Medical Systems, Inc. 3100 Hansen Way Palo Alto, CA, USA) and Elekta (Elekta Instrument AB Kungstensgatan 18, Stockholm, Sweden) linear accelerators. The extracted ATP items were confirmed by comparing the AAPM report items as the quality assurance items of medical accelerators and the IMRT recommendation criteria. Commissioning is classified based on the following: (1) acquisition of beam data for treatment planning and dose calculation, (2) modeling of beam data and various parameters entered into the treatment planning system, and classification and approval according to the calculation algorithm, and (3) the dose verification process, which compares the calculated dose with actual measurement results to verify that it is within the tolerance. The step-by-step procedures and risk management items for commissioning and dosimetry system preparation were derived based on reports from overseas associations such as the AAPM TG-106 report,[7] the TG-120 report,[10] the AAPM TG-142 report,[6] the AAPM TG-119[8] and ESTRO booklet no. 9 report.[9] The modeling and dose verification process were previously reported for the commissioning of the radiation treatment plan (RTP) system.[11] In this paper, we derive procedures focusing on the acquisition of beam data in high precision external radiation therapy equipment.

Dosimetry systems used in the ATP and commissioning phases include ionization chambers, electrometers for one-dimensional dose measurement, radiochromic films, and two-dimensional array detectors for two-dimensional dose distribution measurements. In this paper, it derived risk management items based on the procedures of using ionization chambers and electrometers, which are most widely used for profile and point dose measurement during beam commissioning. The ATP of high-precision radiotherapy devices were divided into three sub-steps: 1) mechanical and dose aspects, 2) multi-leaf collimator (MLC), and 3) imaging system. The risk management items for each procedure in the commissioning stage are subdivided into a measurement preparation step and an acquiring beam data.

Results

1. Dosimetry system

1) Ionization chamber

Humphries and Purdy[12] suggested that the ionization chamber should be tested first before using it for the first time or before calibrating the ionization chamber. When purchasing an ionization chamber, it is recommended that the enclosed calibration certificate and the results of the performance be recorded, documented, and backed up. When using an ionization chamber for measurement beam data, especially for ATP and commissioning, it is made of a tissue equivalent material or air equivalent material.[10] The center electrode should be made of a low atomic number material such as aluminum. The shape of ionization chamber should be a cylindrical type. The ionization chamber is selected considering the purpose of measurement, beam particle (photon, electron, proton, etc.), energy, and field size. It is necessary to select an ionization chamber with adequate spatial resolution to avoid measurement errors due to the abrupt dose distribution used in the IMRT treatment plan and the number of segments of the treatment field. Especially, it is recommended that the IMRT measurement start after the ionization chamber performance test and ionization chamber cross calibration as shown in Fig. 1.

2) Electrometers and cables

The basic requirements of the electrometer are measurement accuracy, linearity, stability, sensitivity, high impedance and low leakage dose. The performance of the electrometer should be further considered when using a small volume ionization chamber. It is recommended that cables and connectors used between the electrometer and the ionization chamber should be aware of the precautions for storage and cable connections, as they will affect the measurement results depending on the storage conditions or the setup connection. Electrometer, cable and connector inspection and risk management items were derived in total 21 items (Fig. 2).

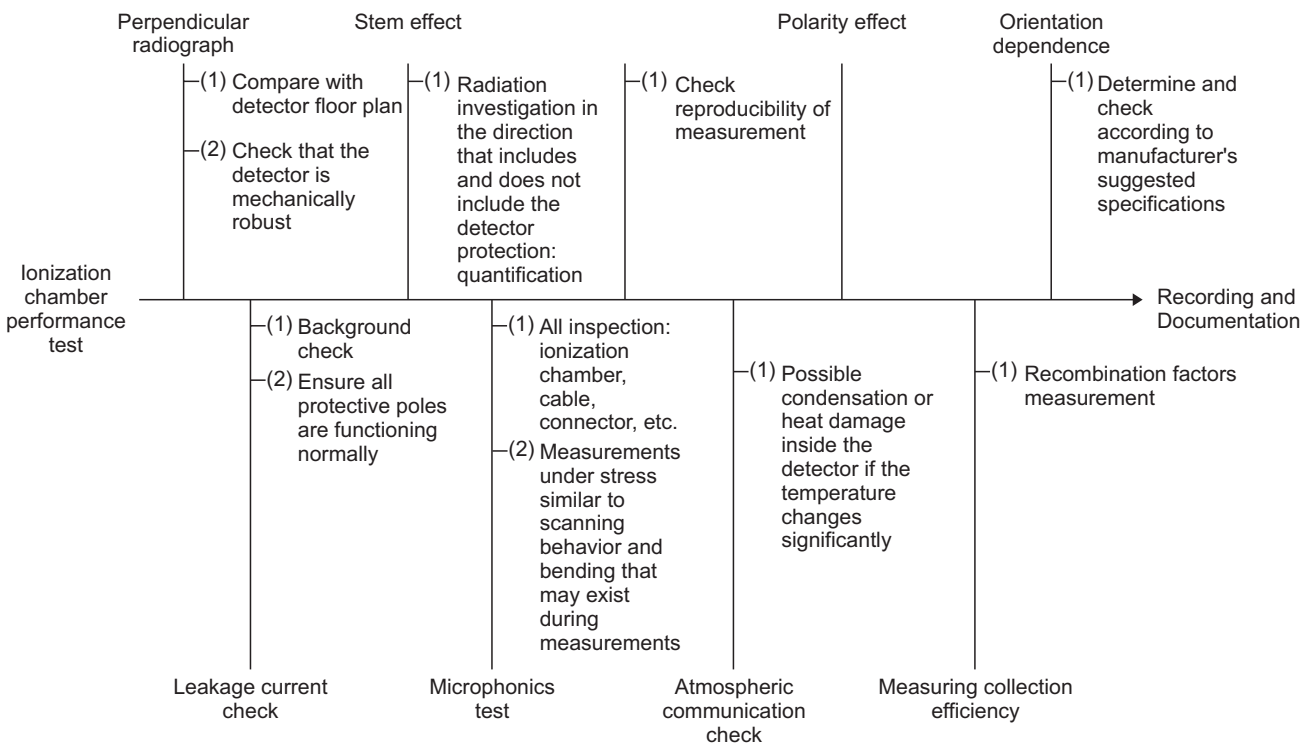

Fig. 1. Ionization chamber performance test.

2. ATP of high-precision radiotherapy equipment

The manufacturer must demonstrate that the radiotherapy unit is operating in accordance with the specifications required by the consignor. Then CQMP shall establish the therapeutic beam characteristics required for clinical use during ATP and commissioning, shall establish a reference value, and verify that it is operating within the specified tolerances. CQMP play a key role in the team conducting shielding, design of the radiotherapy room, and ATP of radiotherapy machine. Furthermore, CQMP should establish and conduct ATPs based on procedures (ATP or customer

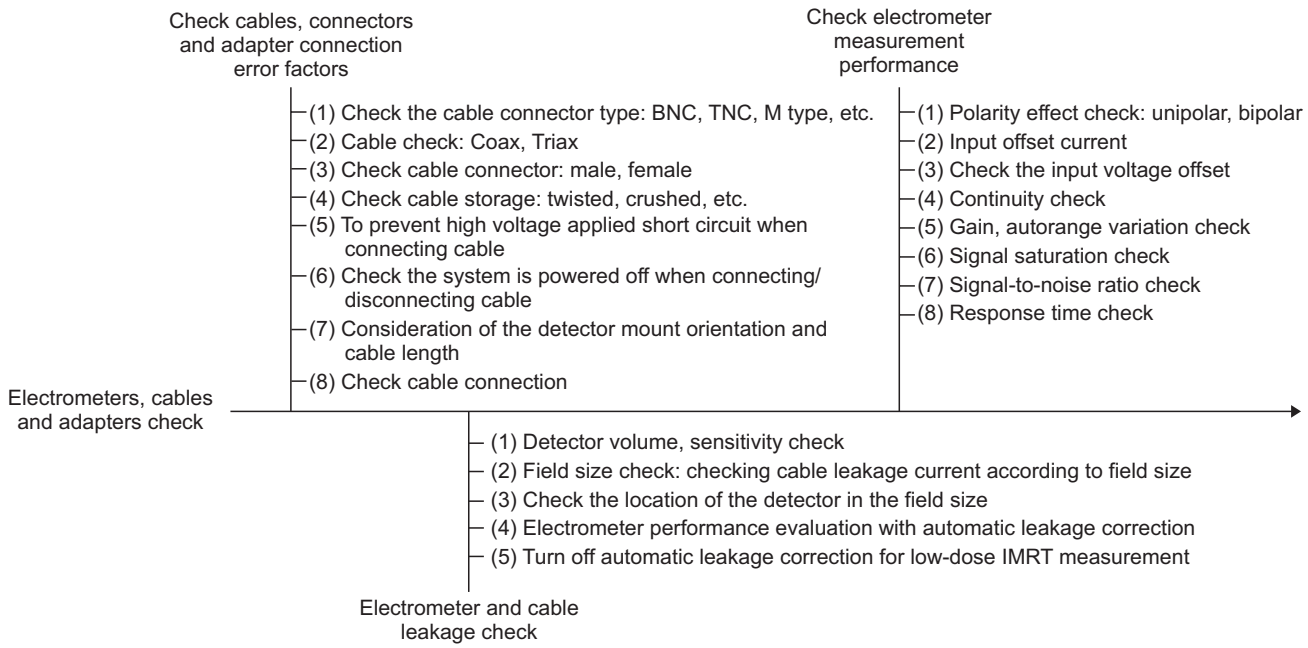

Fig. 2. The risk management items for electrometer, cable and connector check.

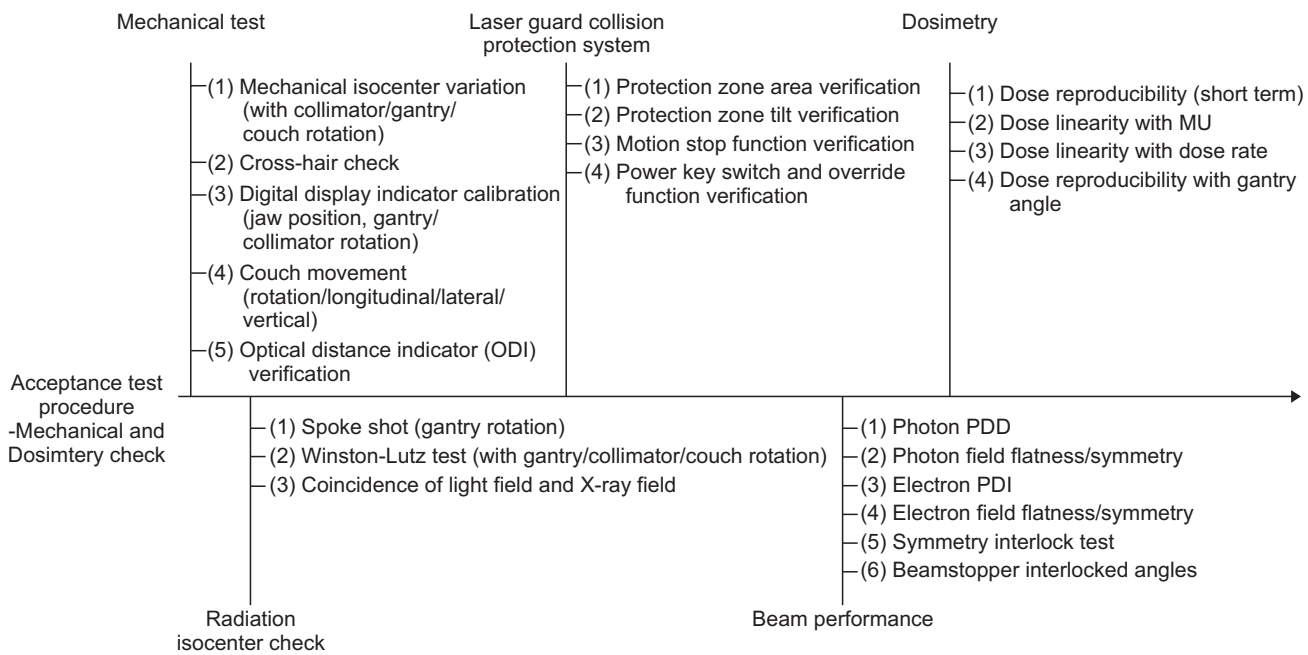

Fig. 3. The risk management items for acceptance test of external radiation therapy equipment: Mechanical and dosimetry test.

acceptance procedure, CAP documents) provided by the manufacturer. The CQMP will consult with the manufacturer engineers to coordinate the installation and maintenance programs of the equipment, ensure the safe and optimized performance of the equipment. In addition, CQMP performs installation, quality control to determine clinical use after each maintenance procedure, supervises calibration and measurement.

We have derived the ATP step-by-step check items and tolerances for high-precision radiotherapy devices with reference to the linear accelerator acquisition procedure recommended by Varian and Elekta. The step-by-step check-

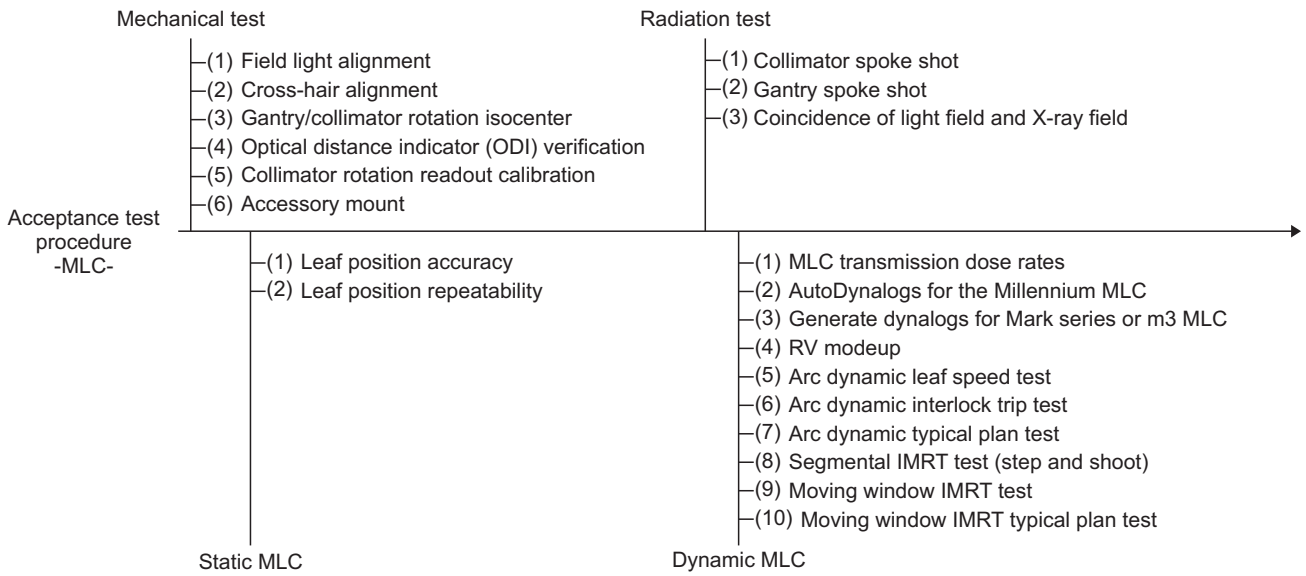

Fig. 4. The risk management items for acceptance test of external radiation therapy equipment: MLC.

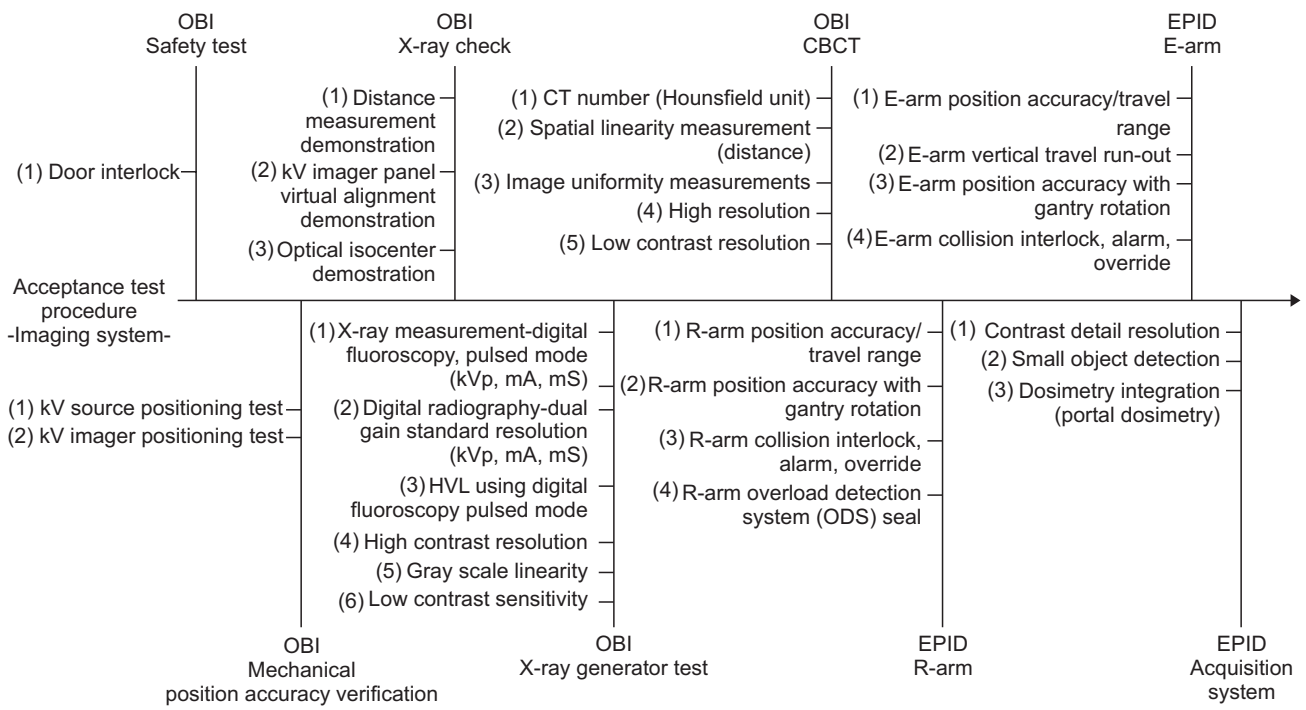

Fig. 5. The risk management items for acceptance test of external radiation therapy equipment: Imaging system.

list of ATP was divided into three divisions: "Dosimetry and mechanical check" (34 items), "multi-leaf collimator" (22 items), and "imaging system" (36 items). A total of 34 items were deduced from dosimetry and mechanical checklists as shown in Fig. 3. For The MLC was subdivided into 22 items by mechanical inspection, static MLC, radiological examination and dynamic MLC as shown in Fig. 4. The imaging system derives the risk management items as ATP based on the Varian linear accelerator's on-board imager (OBI) and electronic portal imaging device (EPID). Risk management items for ATP of imaging system were classified into 21 items for OBIs and 15 items for EPIDs (Fig. 5).

The risk management items in the derived ATP procedure were compared with the items listed in the AMPM TG-142 report as quality control inspection items and the IMRT recommendation criteria, and the linkages were evaluated as shown in Table 1. This is a step to confirm whether the equipment performance is in accordance with the manufacturer's recommendation specifications from the mechanical point of view when the ATP is introduced for the first time, and it will be linked with the quality control inspection item based on the reference value obtained from ATP and commissioning.

3. Commissioning of high-precision radiotherapy equipment

The risk management items in the commissioning phase were derived in detail to the performance evaluation and the clinical application evaluation of the high precision radiotherapy equipment, classified with preparation of beam measurement setup and beam measurement. Fig. 6 shows that the beam measurement preparation stage was 28 items, which were scanning system check, scanning system measurement preparation, and data acquisition preparation. In the beam measurement, the steps are divided into X-ray scan data, X-ray point dose data, MLC data, electron scan data, electron point dose data, data file acquisition and save, and data processing. In the beam measurement stage, step-by-step procedures and risk management items of 32 were derived based on reports from overseas associations such as the AAPM TG-106 report,[7] the TG-120 report,[10] the AAPM TG-142 report,[6] the AAPM TG-119[8] and ESTRO booklet no. 9 report,[9] etc., as shown in Fig. 7.

The reference data for comparing measured beam data can be used as the golden data provided by the manufacturer when conducting the beam data measurement. However, it is not recommended to replace or combine it with the commissioning data. After measured beam data, it is recommended that measurement results and technical reports be recorded and prepared for clarity of accountability. When creating a report, clearly describe and summarize the measurement range, target, method, the device used for measurement, and the results. It is recommended that CQMP check the collected data and reports and perform independent audits. The items to be measured and the reports include X-ray open field/wedge field percent depth dose (PDD) and tissue maximum ratio (TMR) table, phantom-scatter factor (S_p), total scatter factor (S_{cp}), in-air scatter ratio (S_c), wedge factor and soft wedge factor for various depths and field sizes, the transmission factor, open field off-axis ratio at selected depths of large field, the electron cone factor, the effective source-to-surface distance, and the electron PDD table. It is recommended to keep the iso-dose curve and scan data measured in the reference field of X-ray and electron, and record the data comparison to similar model of the institution (or other institution) or the golden data provided by the manufacturer. It is recommended that you also back up the analyzed data, spreadsheets, electronic data, etc., and include a detailed description of the beam data collection method and conditions.

Commissioning data may vary depending on the requirements and the measurement conditions, such as the requirements of the RTP and the clinical needs of the user. Under these conditions, the time required for commissioning can be expected to vary. According to the AAPM TG-106 report, the time allocated for beam data measurement during commissioning procedures is generally 1.5 weeks for photon beam scanning, 1 to 2 weeks for point dose data measurement, 1 to 2 weeks for verification and 1 to 2 weeks for verification. It was suggested that about 4 to 6 weeks were needed for whole commissioning.[7] For example, in two photon energies, the time required to scan single PDD and five depths profile for fifteen field sizes was estimated to be about 30 hours,[7] and the time required for the elec-

Table 1. The derived risk management items were compared for the correlation with TG-142 quality assurance items.

Step	Mechanical and Dosimetry check				
Sub-step	Risk management items	TG-142 Quality assurance items	Period	IMRT Tolerance	Remark
Mechanical test	Mechanical isocenter variation (with collimator, gantry, couch rotation)	Gantry/collimator angle indicators (digital only)	Monthly	1°	Cardinal angles
		Treatment couch position indicator	Monthly	2 mm/1°	
		Collimator rotation isocenter	Annual	±1 mm	Change from baseline
		Gantry rotation isocenter	Annual	±1 mm	Change from baseline
		Couch rotation isocenter	Annual	±1 mm	Change from baseline
	Cross-hair check	Cross-hair centering (walkout)	Monthly	1 mm	
	Digital display indicator calibration (Jaw position, gantry, collimator rotation)	Collimator size indicator	Daily	2 mm	
		Gantry/collimator angle indicators (digital only)	Monthly	1°	Cardinal angles
		Jaw position indicators (symmetry)	Monthly	2 mm	
		Jaw position indicators (asymmetry)	Monthly	1 mm	
	Couch movement (rotation, longitudinal, lateral, vertical)	Treatment couch position indicator	Monthly	2 mm/1°	
		Table top sag	Annual	2 mm	Change from baseline
		Table angle	Annual	1°	
		Table travel maximum range movement in all directions	Annual	±2 mm	
	Optical distance indicator (ODI) verification	Distance indicator (ODI) at isocenter	Daily	2 mm	
		Distance check device for lasers compared with front pointer	Monthly	1 mm	
Radiation isocenter check	Spoke shot (Gantry rotation)	Coincidence of radiation and mechanical isocenter	Annual	±2 mm	Change from baseline
	Winston-Lutz test (with gantry/collimator/couch rotation)	Collimator rotation isocenter	Annual	±1 mm	Change from baseline
		Gantry rotation isocenter	Annual	±1 mm	Change from baseline
		Couch rotation isocenter	Annual	±1 mm	Change from baseline
	Coincidence of light field and X-ray field	Light/radiation field coincidence (symmetry)	Monthly	2 mm or 1%	
		Light/radiation field coincidence (asymmetry)	Monthly	1 mm or 1%	
Laser guard collision protection system	Protection zone area verification	Laser guard-interlock test	Monthly	Functional	
	Protection zone tilt verification				
	Motion stop function verification				
	Power key switch and override function verification				

Table 1. Continued 1.

Step		Mechanical and Dosimetry check			
Sub-step	Risk management items	TG-142 Quality assurance items	Period	IMRT Tolerance	Remark
Beam performance test	Photon PDD	X-ray beam quality (PDD_{10} or $TMR_{20,10}$)	Annual	±1%	Change from baseline
	Photon field flatness/symmetry	Photon beam profile constancy	Monthly	1%	
		X-ray flatness change from baseline	Annual	1%	
		X-ray symmetry change from baseline	Annual	±1%	
	Electron PDI	Electron energy constancy	Monthly	2%/2 mm	
		Electron beam quality (R_{50})	Annual	±1 mm	Change from baseline
	Electron field flatness/symmetry	Electron beam profile constancy	Monthly	1%	
		Electron flatness change from baseline	Annual	1%	
		Electron symmetry change from baseline	Annual	±1%	
	Symmetry interlock check	Follow manufacturer's test procedure	Annual	Functional	
	Beamstopper interlocked angles	Follow manufacturer's test procedure	Annual	Functional	
Dosimetry	Dose reproducibility	X-ray output constancy	Daily	3%	All energies
			Monthly	2%	All energies
		Electron output constancy	Daily	3%	
			Monthly	2%	
		Backup monitor chamber constancy	Monthly	2%	
		X-ray/electron output calibration (TG-51)	Annual	±1%	Absolute dosimetry
		Spot check of field size dependent output factors for X-ray	Annual	2% <4×4 cm^2 1% ≥4×4 cm^2	Two or more field size check
		Output factors for electron applicators	Annual	±2%	- Change from baseline - Spot check of on applicator/energy
	Dose linearity with MU	X-ray monitor unit linearity output constancy	Annual	±2% (≥5 MU)	±5% (2-4 MU)
		Electron monitor unit linearity output constancy	Annual	±2% (≥5 MU)	
	Dose linearity with dose rate	Typical dose rate profile constancy	Monthly	2%	
		X-ray output constancy vs. dose rate	Annual	±2%	Change from baseline
	Dose reproducibility with gantry angle	X-ray output constancy vs. gantry angle	Annual	±1%	Change from baseline
		Electron output constancy vs. gantry angle	Annual	±1%	

Table 1. Continued 2.

Step		MLC			
Sub-step	Risk management items	TG-142 Quality assurance items	Period	IMRT Tolerance	Remark
Mechanical test	Field light alignment	Setting vs. radiation field for two patterns	Monthly	2 mm	
		Coincidence of light field and X-ray field	Monthly	±2 mm	All energies
	Cross-hair alignment	Cross-hair centering (walkout)	Monthly	1 mm	
	Gantry/collimator rotation isocenter	Gantry/collimator angle indicators (digital only)	Monthly	1°	Cardinal angles
		Collimator rotation isocenter	Annual	±1 mm	Change from baseline
		Gantry rotation isocenter	Annual	±1 mm	Change from baseline
	Optical distance indicator (ODI) verification	Distance indicator (ODI) at isocenter	Daily	2 mm	
		Distance check device for lasers compared with front pointer	Monthly	1 mm	
	Collimator rotation readout calibration	Gantry/collimator angle indicators (digital only)	Monthly	1°	Cardinal angles
	Accessory mount	Accessory trays (i.e., port film graticle tray)	Monthly	2 mm	
		Latching of wedges, block tray	Monthly	Functional	
Static MLC	Leaf position accuracy	Qualitative test (i.e., matched segments, aka "Picket fence")	Weekly	Visual inspection for discernable deviations such as an increase in interleaf transmission	
		Leaf position accuracy	Monthly	1 mm	Four cardinal angles
	Leaf position repeatability	Leaf position repeatability	Annual	±1 mm	
Radiation test	Collimator spoke shot	Leaf spoke shot	Annual	≤1.0 mm (radius)	
	Gantry spoke shot	Leaf spoke shot	Annual	≤1.0 mm (radius)	
	Coincidence of light field and X-ray field	Coincidence of light field and X-ray field	Monthly	±2 mm	All energies
Dynamic MLC	MLC transmission dose rates	MLC transmission (average of leaf and interleaf transmission)	Annual	±0.5%	Change from baseline All energies
	AutoDynalogs for the Millennium MLC	-	-	-	Only Varian
	Generate dynalogs for Mark series or m3 MLC	-	-	-	Only Varian
	RV modeup	-	-	-	
	Arc dynamic leaf speed test	Travel speed	Monthly	Loss of leaf speed>0.5 cm/s	
	Arc dynamic interlock trip test	Arc mode (Expected MU, degrees)	Annual	±1 mm	Change from baseline
	Arc dynamic typical plan test	Arc mode (Expected MU, degrees)	Annual	±1 mm	Change from baseline
	Segmental IMRT test (Step and shoot)	Segmental IMRT (step and shoot) test	Annual	RMS maximum of error<0.35 cm	
	Moving window IMRT test	Moving window IMRT	Annual	RMS maximum of error<0.35 cm	Four cardinal gantry angles
	Moving window IMRT typical plan test				

Table 1. Continued 3.

Step		Imaging system				
Sub-step		Risk management items	TG-142 Quality assurance items	Period	IMRT Tolerance	Remark
OBI	Safety test	Door interlock	-	-	-	
	Mechanical position accuracy verification	kV source positioning test	Positioning/repositioning	Daily	≤2 mm	
		kV Imager positioning test	Positioning/repositioning	Daily	≤2 mm	
	X-ray check	Distance measurement demonstration	Scaling	Monthly	Baseline	
		kV imager panel virtual alignment demonstration	Imaging and treatment coordinate coincidence	Daily	≤1 mm	
		Optical isocenter demostration	Imaging and treatment coordinate coincidence	Daily	≤2 mm	Single gantry angle
				Monthly	≤2 mm	Four cardinal angles
	X-ray generator test	X-ray measurement-digital fluoroscopy, pulsed mode (kVp, mA, mS)	Imaging dose	Annual	Baseline	
		Digital radiography-dual gain standard resolution (kVp, mA, mS)	Imaging dose	Annual	Baseline	
		HVL using Digital fluoroscopy pulsed mode	Beam quality/energy	Annual	Baseline	
	Cone beam CT	High contrast resolution	Spatial resolution	Monthly	Baseline	
		Gray scale linearity	Spatial resolution	Monthly	Baseline	
		Low contrast sensitivity	Contrast	Monthly	Baseline	
		CT number (Hounsfield unit)	HU constancy	Monthly	Baseline	
		Spatial linearity measurement (distance)	Geometric distortion	Monthly	Baseline	
		Image uniformity measurements	Uniformity and noise	Monthly	Baseline	
		High resolution	Spatial resolution	Monthly	Baseline	
		Low contrast resolution	Contrast	Monthly	Baseline	

Table 1. Continued 4.

Step		Imaging system				
Sub-step		Risk management items	TG-142 Quality assurance items	Period	IMRT Tolerance	Remark
EPID	R-arm	R-arm position accuracy/travel range	Positioning/repositioning	Daily	≤2 mm	
		R-arm position accuracy with gantry rotation	Imaging and treatment coordinate coincidence	Daily	≤2 mm	Single gantry angle
				Monthly	≤2 mm	Four cardinal angles
		R-arm collision interlock, alarm, override	Collision interlocks	Daily	Functional	
		R-arm overload detection system (ODS) seal	-	-	-	
	E-arm	E-arm position accuracy/travel range	Positioning/repositioning	Daily	≤2 mm	
		E-arm vertical travel run-out	Full range of travel SDD	Annual	±5 mm	
		E-arm position accuracy with gantry rotation	Imaging and treatment coordinate coincidence	Daily	≤2 mm	Single gantry angle
				Monthly	≤2 mm	Four cardinal angles
		E-arm collision interlock, alarm, override	Collision interlocks	Daily	Functional	
	Acquisition system	Contrast detail resolution	Spatial resolution	Monthly	Baseline	
			Contrast	Monthly	Baseline	
		Small object detection	Spatial resolution	Monthly	Baseline	
		Dosimetry integration (Portal dosimetry)	-	-	-	Optional

ODI, optical distance indicator; PDD, percent depth dose; TMR, tissue maximum ratio; PDI, percent depth ionization; MU, monitor unit; HU, hounsfield unit; SDD, source-detector distance.

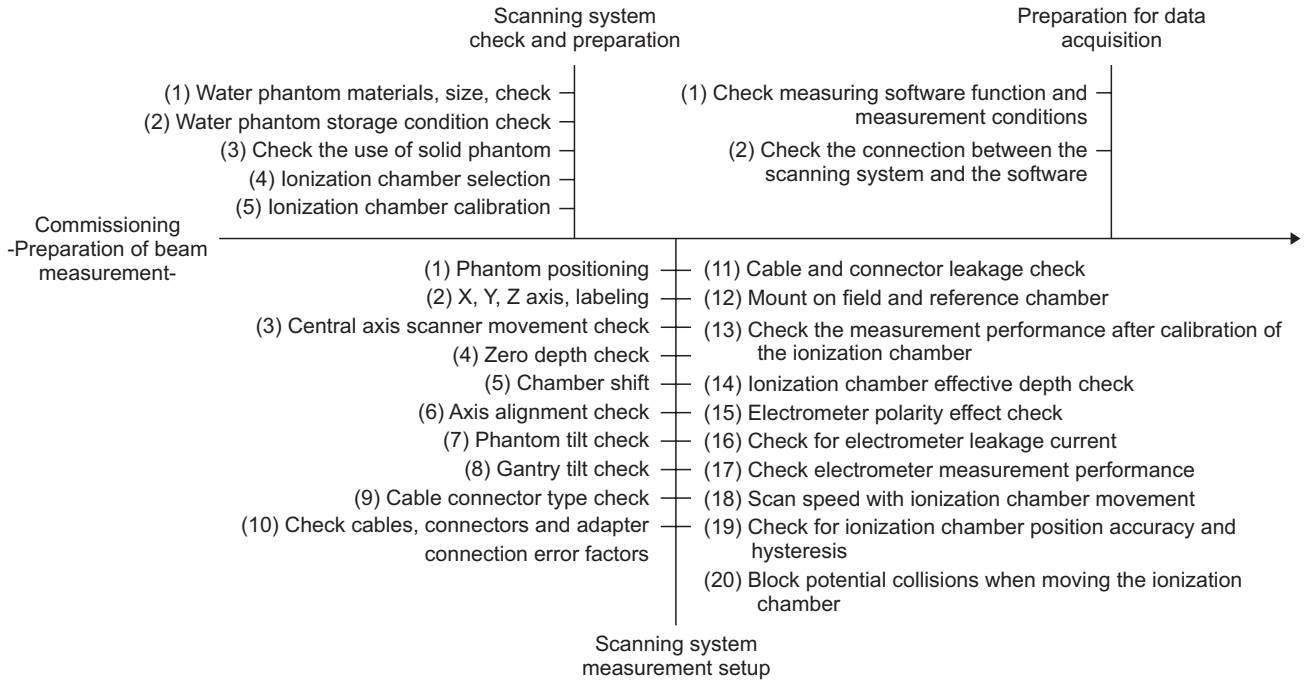

Fig. 6. The risk management items for commissioning of external radiation therapy equipment: preparation of beam measurement.

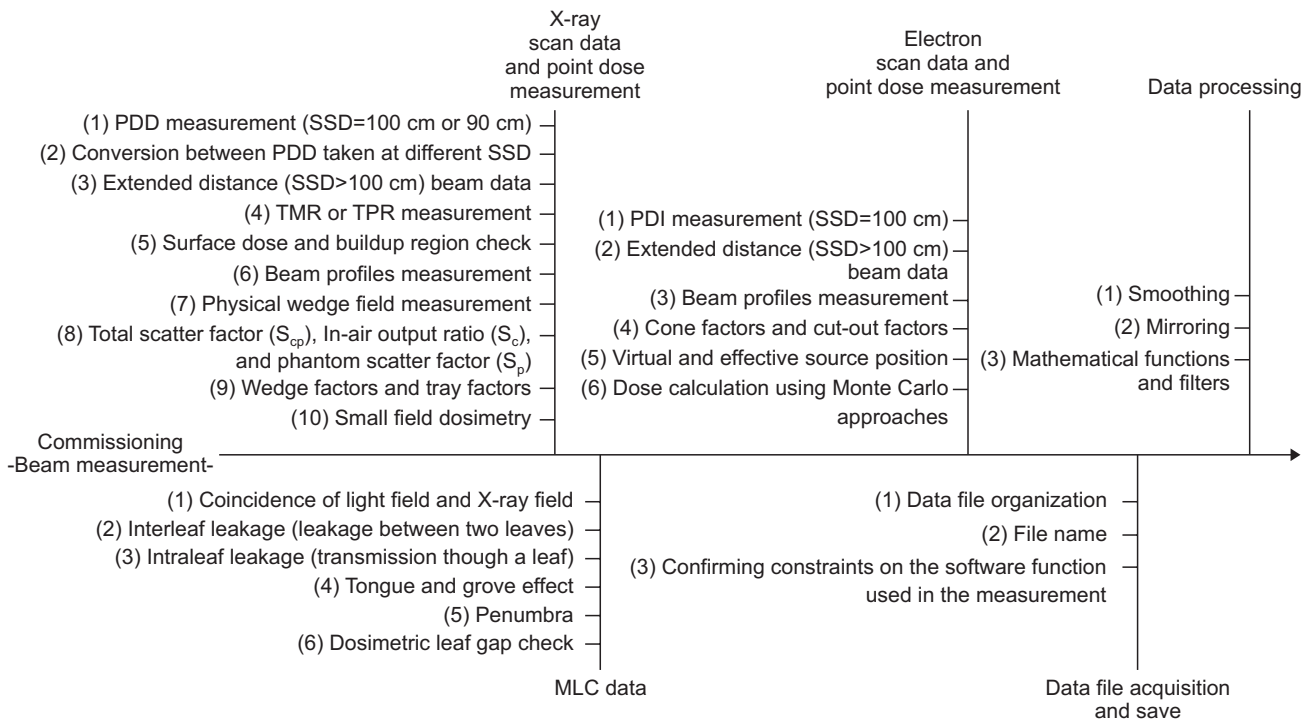

Fig. 7. The risk management items for commissioning of external radiation therapy equipment: beam measurement.

tron should also be considered. In addition, it has been suggested that there is a need to estimate additional time for non-scan data measurement and integration, quality assurance baseline reading, and treatment planning system data validation. The time required for commissioning is determined by the amount of measurement data to be

acquired and the work efficiency of the medical physicist participating in the measurement and should be estimated before the acceptance of the radiation therapy device. The data measured at the commissioning stage is the source for beam modeling. Therefore, It is recommended that at least two CQMPs from the measurement preparation phase apply the so-called "2 person rule",[2,13] which is carried out while performing a double verification. In the case of that facility has only single CQMP then we recommend that you perform a double verification through collaboration a CQMP from another facility.

Discussion

In this study, risk management items at each stage were derived based on the ATP documents of linear accelerators that are most representative of high precision external radiation therapy and reports from overseas associations. The literature related to the high precision external radiation therapy equipment's ATP does not exist, the ATP documents presented by manufacturers have been limited to ensure that they meet a certain range of criteria, both mechanically and dosimetry. This guideline provides step-by-step suggestions on the items of ATP, along with risk management items that may occur during each step. In addition, it could check that each step of the ATP is linked to the quality assurance items presented in AAPM TG-142 report.

Commissioning was presented step-by-step with possible risk management items in the process of measuring beam data and various parameters needed for beam modeling. The guidelines established each step based on the AAPM TG-106 report and ESTRO booklet no.9 report that describe what should be measured generally for beam data measurements and what criteria are acceptable. Possible risk management items for each step were presented on the basis of recommendations given in AAPM TG-120 report about dosimetry tool of IMRT, the AAPM TG-142 and TG-119 report as described for external radiation therapy equipment quality assurance and IMRT dose verification. Therefore, this guideline presented both step-by-step risk management items necessary for preparation of measuring beam data and risk management items that may occur when measuring beam data. Therefore, it will also be of interest to medical physicists who are introducing new radiation therapy equipment for safety and accuracy of measurement. It recommends that each item presented in the guideline apply the clinical situation of the user and, in necessary, can be modified and used it. While measuring beam data and the dose verification process must be carried out with a "2 person rule".

Conclusion

In this study, the introduction and installation process of high precision radiotherapy equipment is presented through a process map. And the guidelines for carrying out the ATP and commissioning steps of high-precision radiotherapy devices are presented. When using the guideline given in this study, it is recommended that the manufacturer, characteristics, institutional procedures by the relevant agency be duly reflected. The result of this study is expected to be able to prevent radiation accidents in stages by introducing a risk management system from introduction of radiotherapy and system installation process beyond machine-centered quality control. Furthermore, it is anticipated that risk management based technologies for radiation therapy will be developed and applied to the development of risk management guideline in the field of nuclear medicine and radiology in the future.

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Conflicts of Interest

The authors have nothing to disclose.

Availability of Data and Materials

All relevant data are within the paper and its Supporting Information files.

References

1. Gary A. Ezzell, James M. Calvin, Daniel Low, Isaac Rosen, Michael B. Sharpe, Ping Xia, et al. Guidance document on delivery, treatment planning, and clinical implementation of IMRT: Report of the IMRT subcommittee of the AAPM radiation therapy committee. Med. Phys. 2003;30(8): 2089-2115.
2. IAEA Human Health Series No.25: Roles and Responsibilities, and Education and Training Requirements for Clinically Qualified Medical Physicists. International Atomic Energy Agency. 2013.
3. IAEA TRS-398 report: Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water. International Atomic Energy Agency. 2006.
4. P. R. Almond, P. J. Biggs, B. M. Coursey, W. F. Hanson, M. Saiful Huq, Ravinder Nath, et al. AAPM's TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams. Med. Phys. 1999;26(9):1847-1870.
5. Gerald J. Kutche, Lawrene Coia, Michael Gillin, Wiliam F. Hansom, Steven Leibel, Robert J. Morton, et al. Comprehensive QA for radiation oncology y: Report of AAPM Radiation Therapy Committee Task Group 40. Med. Phys. 1994;21(4):581-618.
6. Eric E. Klein, Joseph Hanley, John Bayouth, Fang-Fang Yin, Wiliam Simon, Sen Dresser, et al. Task Group 142 report: Quality assurance of medical accelerators. Med. Phys. 2009;36(9):4197-4212.
7. Indra J. Das, Chee-Wai Cheng, Ronald J. Watts, Anders Ahnesjö, John Gibbons, X. Allen Li, et al. Accelerator beam data commissioning equipment and procedures: Report of the TG-106 of the Therapy Physics Committee of the AAPM. Med. Phys. 2008;35(9):4186-4215.
8. Gary A. Ezzell, Jay W. Burmeister, Nesrin Dogan, Thomas J. LoSasso, James G. Mechalakos, Dimitiris Mihailidis, et al. IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119. Med. Phys. 2009;36(11):5359-5373.
9. ESTRO booklet no.9: Guidelines for the verification of IMRT. 2008.
10. Daniel A. Low, Jean M. Moran, James F. Dempsey, Lei Dong, Mark Oldham, Dosimetry tools and techniques for IMRT. Med. Phys. 2001;38(3):1313-1338.
11. Yoonjin Oh, Dong Oh Shin, Juhye Kim, Nahye Kwon, Soon Sung Lee, Sang Hyoun Choi, et al. Proposal on Guideline for Quality Assurance of Radiation Treatment Planning System. Progress in Medical Physics. 2017;28(4):197-206.
12. L. J. Humphries and J. A. Purdy, In Advances in Radiation Oncology Physics Dosimetry, Treatment Planning, and Brachytherapy. 1992; AAPM Monograph Vol. 19, edited by J. A. Purdy AAPM.
13. Per H. Halvorsen, Indra J. Das, Martin Fraser, D. Jay Freedman, Robert E. Rice III, Geoffrey S. lbbott, et al. AAPM Task Group 103 report on peer review in clinical radiation oncology physics. Journal of Applied Clinical Medical Physics. 2005;6(4):50-64.