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REVIEW

Quality Assurance Program for Surface-guided Radiation Therapy: A Review of Guidelines

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SUMMARY

Surface-guided radiation therapy (SGRT) has gained wide popularity across radiation oncology community due to its non-radiographic characteristic and real-time motion monitoring capability. Nevertheless, it has not yet gained its full potential in routine clinical practice. Implementing SGRT system into the clinical practice requires not only the definition of steps in clinical workflow, but also establishment of the comprehensive quality assurance (QA) program including commissioning, acceptance and periodic QA test to facilitate a safe, and efficient use of SGRT system in clinical settings. This review focuses on the latest recommendation of American Association of Physicists in Medicine and European Society for Radiotherapy and Oncology guidelines about the implementation of comprehensive QA program for SGRT system.

Keywords: Patient positioning; radiotherapy; surface guidance.

INTRODUCTION

Surface-guided radiation therapy (SGRT) has emerged as a special form of image-guided radiation therapy (IGRT). Since its first introduction as a useful IGRT tool, many researcher have explored the feasibility of SGRT system for patient positioning, real-time motion management, four-dimensional imaging for motion tracking and threshold gating.[1–8] In several studies, it was proved to improve initial patient positioning by correcting posture differences before online imaging.[9,10] Nevertheless, after initial patient setup with SGRT, online imaging modalities such as planar imaging (kV or MV) and cone-beam computed tomography still needs to be performed in many anatomical sites especially located in thorax and abdomen since the changes in internal motion remain undetected through surface scanning with current technology.[9] However, up to that time, limited guidelines and the complexity of the clinical settings have led to diverse patterns of practice between the clinics. In 2019, Padilla et al.[11] conducted an electronic survey under the auspices of American Association of Physicists in Medicine (AAPM) Task Group Report 302 (TG-302) to identify the necessity of formal guidance and to gain more insight on prevalence of the SGRT system in USA, length of its use, existing recommendation for commissioning procedures and clinical implementation. According to questionnaire, 36% of the users (n=86) only followed the vendor's guidelines and 49.1% of the respondents (n=115) used more than one reference during commissioning. In terms of the question about the use of any end-to-end (E2E) test verification approaches, 12% of the users (n=28) response this question as "No" and 14.1% of the respondents (n=33) do not know whether they performed any E2E test, or not. Similarly, in 2022, another international survey was conducted with the collaboration of European Society for Radiotherapy and Oncology (ESTRO) and AAPM to provide an

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overview about the current status of SGRT in clinical practice with a focus on the user's experience in terms of implementation, commissioning, periodical quality assurance (QA), training, and clinical workflow.[12] According to results of the survey, clinical implementation of the SGRT systems was predominantly based on the vendor's recommendation. Indeed, 94% of the respondents (n=132) primarily followed vendor's guidelines during clinical implementation, commissioning and periodical QA. About 42% of the participant (n=59) used two different sources and only 19% (n=27) used at least three different sources including vendor's guidelines and published studies in the literature or peer-to-peer consultation. In addition, 54% of the respondents (n=76) exclusively used QA tools provided by the vendors during the commissioning and periodical QA tests. About 44% of the users (n=62) preferred to use vendor-provided phantom in combination with the third party commercially available phantoms (n=34) and/or with in-house phantoms (n=28). However, 8% of the respondents (n=12) reported the use of only either third-party commercial phantoms (n=6) or adapted in-house phantoms (n=6) instead of vendor-provided phantoms. According to results of both surveys, it was strongly emphasized that consensus guidelines on SGRT are needed for standardization in clinical practice since the use of different techniques during implementation, commissioning and periodical QA test may cause a systematic errors in patient setup and monitoring. Recently, two different guidelines were published by AAPM, called as TG-302[1] building on the TG-147[13] report, and ESTRO-ACROP[2] to expedite its safe adaptation in clinical practice. AAPM TG-302 also referred other guidelines such as AAPM TG-76[14] and AAPM TG-142[15] for several QA tests. Although both of these guidelines (AAPM TG-302 and ESTRO-ACROP) were comprehensive and informative, there are still several differences in terms of suggested parameters and tolerance values that need to be considered during QA program including acceptance, commissioning, and periodical QA tests. We aimed to compare both guidelines in terms of recommended parameters based on system specification (simulation room vs. treatment rom, C-arm vs. ring gantry, photon vs. particle etc.), type of tests and tolerances/specifications during the acceptance, commissioning, and periodical QA tests. In addition, phantom selection criteria for SGRT QA and current challenges in SGRT QA were discussed in detail.

QA PROGRAM FOR SGRT

Acceptance Test

The acceptance process need to include all required tests including static/dynamic localization accuracy, spatial reproducibility and drift to illustrate the safe operation and proper functionality of the SGRT system with the integrated treatment or simulation platform. In most cases, the acceptance test document is provided by the vendor and it may not include all necessary tests that need to be checked. However, it is important to keep in mind that the acceptance procedure is an integral part of the purchasing process to ensure whether the product or solution meet the clinical need, or not. Therefore, primary responsible person, generally qualified medical physicist expert, needs to be familiar with the fundamental or basic tests recommended in the commissioning and if these tests are not included in the vendor's acceptance documents, it is generally recommended to negotiate with the vendor to perform these tests during acceptance. According to AAPM TG-302, vendor's recommendation and other AAPM reports such as TG-142, TG-147, and TG-76 need to be followed together for checking the localization accuracy and reproducibility of the system. In addition, safe operation and proper functionality of the system with all other unit interface, including imaging system (if necessary), treatment machine, treatment planning system, data transfer and information system, and need to be validated as described in Table 1. In contrast to TG-302, ESTRO-ACROP guideline provides a more detailed information about the description of each parameters.[2] Moreover, all tests are categorized with respect to importance level (x- mandatory, o-optional, pass-within Vendor's system specifications), type of systems (computer tomography [CT], closed-bore linac, C-arm linac and particle therapy), and subgroups for each suggested parameters.

Commissioning

The commissioning of the SGRT system is a substantial part of the comprehensive QA program before implementing it into clinical practice. This part also includes measuring the system accuracy/precision and determining system limitations for all clinically relevant scenarios. Since the commissioning data are accepted as a reference for future measurement, all tests need to be reproducible to assess the consistency of the system performance over the period of time for periodical QA tests or for later measurements after maintenance and repair of the system. In addition, according to AAPM TG-147 recommendation, commissioning test need to

Table 1 Recommended parameters for acceptance tests in ESTRO-ACROP and AAPM guidelines

Parameters[a]	Subgroups	Tolerances/ specifications		Recommendation for different type of machine/platforms[b]				
				ESTRO				AAPM[c]
		ESTRO	AAPM[c]	CT	C-Arm	Closed-bore	Particle therapy	C-Arm
Static accuracy	i) Isocenter coincidence with other isocentric Systems	1 mm/1°	2 mm SRS/SBRT: 1 mm	x	x	x	x	x
	ii) Translational shift accuracy: introduced versus detected	1 mm (<5 cm shift) 2 mm (>5 cm shift)	2 mm SRS/SBRT: 1 mm	–	x	x	x	x
	iii) Rotational shift accuracy: introduced versus detected	1°	Pass (No specified threshold)	–	x	x	x	x
	iv) Camera occlusion: Introduced versus detected Shift when one or more camera blocked	1 mm/1°	Pass (No specified threshold)	–	x	x	x	x
	v) Couch rotation: introduced versus detected	Pass- 1 mm/0.5°	2 mm for isocenter	–	o	–	x	x
Dynamic accuracy	i) Beam-Hold performance (AAPM TG-142): functionality and dosimetric accuracy	Pass/2%	Pass/2%	o	x	x	x	x
	ii) Tracking performance-Ability of the system to correctly measure translations and/or rotation of moving target	Mechanical: 1 mm/1° SRS: 0.5 mm/0.5°	Mechanical: NA Dosimetric: 2%	x	x	x	x	x
	iii) Respiratory trace: detectability of amplitude and frequency	Pass	NA	x	o	o	o	NA
	iv) Frame rate characteristic for different clinical scenarios	Pass	Per specification (Vendor's guidelines-VG)	x	x	x	x	x
	v) Latency threshold	NA	Within 100 ms	NA	NA	NA	NA	x
	vi) Trigger performance-phase correct triggering and data reconstruction	Pass	Pass (for CT)	x	–	–	–	x
E2E test	i) End-to-end positioning test: including all clinical workflow	Mechanical: 2 mm/1°	Mechanical: 2 mm SRS/SBRT: 1 mm Dosimetric: ≤1% dose change; ≤2% dose Change for beam hold	–	x	x	x	x
System Performance	i) Thermal drift: effect of temperature on camera performance	1 mm/1° (20 min after 20 min in stand-by)	≤2 mm over 1 h ≤1 mm after stabilizing	x	x	x	x	x
	ii) Room-light level on the system accuracy	0.5 mm/1°	NA	x	x	x	x	NA
	iii) Field-of-view (FOV)	Pass	Per specification- VG	x	x	x	x	x
	iv) Quality of surface image	Pass	NA	x	x	x	x	NA
	v) Integration system interface with all peripheral system	Pass	Pass	x	x	x	x	x
	vi) Patient interface	Pass	Pass	x	x	x	x	x

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Table 1 Cont.

Parameters[a]	Subgroups	Tolerances/ specifications		Recommendation for different type of machine/platforms[b]				
				ESTRO				AAPM[c]
		ESTRO	AAPM[c]	CT	C-Arm	Closed-bore	Particle therapy	C-Arm
Safety and documentation	i) Interlocks functionality	Pass	Pass	x	x	x	x	x
	ii) Data import and export	Pass	Pass	x	x	x	x	x
	iii) Database Backup and security	Pass	Pass	x	x	x	x	x
	iv) Mechanical integration: Collision test	Pass	Pass	x	x	x	x	x
	v) system configuration: User rights and settings	Pass	Pass	o	o	o	o	x
	vi) Export patient QA report	Pass	Pass	x	x	x	x	x
	vii) User manuals/guidelines	Pass	Pass	x	x	x	x	x

[a]: All recommended tests were described in ESTRO-ACROP guideline and AAPM reports (TG-302, TG-147 and TG-142). [b]: Recommendations in Vendor's guidelines were not included to current Table. [c]: This part included the combination of all recommendations in AAPM TG-302, TG-147, and TG-142. (x – mandatory, o – optional, pass – the system is accepted in clinical use for a specific indication and application). QA: Quality assurance; NA: Not available

be repeated in case of special situation, ranging from major upgrade and power outages to earthquake and building vibration, to check the stability of the system before using it in clinical practice. All suggested parameters for system commissioning in AAPM TG-302 and ESTRO-ACROP guidelines are summarized in Table 2. Some specification and tolerance values were tightened in ESTRO-ACROP guidelines and new tests were described based on the availability of new technologies and updated clinical needs.

Periodic QA Program

The main goal of the periodical QA program is to ensure about the stability of the system over a period of time (e.g., daily, weekly, monthly, and annually) and to catch the unexpected errors or changes in system performance due to the many factors such as component failure, machine malfunction or aging of the system component. ESRTO-ACROP guideline also recommended to start with a higher frequency and higher number of tests until the RT team feel more comfortable about the stability of the system based on the test outcome preferably including a failure modes and effective analysis specific to the clinic. In addition, ESTRO-ACROP guideline reported the list of failure modes and potential errors in SGRT workflows with possible solutions. Similar to acceptance and commissioning part, ESTRO-ACROP guideline provides more comprehensive periodic QA program compared to AAPM TG-302 and TG-147 recommendations as presented in Table 3. Detailed information and description of each test are also provided in both AAPM TG-147 and supplement of ESTRO-ACROP guidelines.

QA Phantoms for SGRT

SGRT requires dedicated QA phantoms with specific properties (e.g., color, reflectivity, texture, and topography) that make it accurately trackable. Although some commercially available SGRT systems allow the user to change imaging parameters (e.g., camera light and exposure time) for capturing surface information from the bodies/phantoms with variety skin/surface tones, opaque/matte and light colored phantoms yields the best monitoring results during QA due to the better reflection characteristic for the projected light pattern. In fact, the use of SGRT system in variety skin tones, especially in case of dark skin, is still one of the challenging issues to consider in clinical practice. However, ESTRO-ACROP guidelines recommended to check localization accuracy of the SGRT system with both light- and dark-toned phantoms when it is possible, especially in clinics where a larger proportion of patients with darker skin

Table 2 Suggested parameters in ESTRO-ACROP and AAPM guidelines to consider during system commissioning

Parameters[a]	Subgroups	Tolerances/ specifications		Recommendation for different type of machine/platforms[b]				
				ESTRO				AAPM[c]
		ESTRO	AAPM[c]	CT	C-Arm	Closed-bore	Particle therapy	C-Arm
Static accuracy	i) Isocenter coincidence with radiographic imaging	1 mm/1° SRS: 0.5 mm/0.5°	2 mm SRS/SBRT: 1 mm	–	x	x	x	x
	ii) Translational shift accuracy: introduced versus detected	1 mm	2 mm SRS/SBRT: 1 mm	x	x	x	x	x
	iii) Rotational shift accuracy: Introduced versus detected	1°	Pass (no specified threshold)	–	x	x	x	x
	iv) Camera occlusion: Introduced versus detected shift when one or more camera blocked	1 mm/ 1°	Pass (No specified threshold)	–	x	x	x	x
	v) Couch rotation: Introduced versus detected	1 mm/ 0.5°	2 mm for isocenter	–	o	–	x	x
Dynamic accuracy	i) Beam-Hold performance: Dosimetric accuracy	2% or 2 mm/2%, γ=95% (10% threshold)	Pass/2%	–	x	x	x	x
	ii) Tracking performance-Ability of the system to correctly measure translations and/or rotation of moving target	1 mm/ 1° SRS: 0.5 mm/ 0.5°	Mechanical: NA Dosimetric: 2%	–	x	x	x	x
	iii) Respiratory trace: detectability of amplitude and frequency	Pass	NA	x	o	o	x	NA
	iv) Frame rate characteristic for different Clinical scenarios	Pass	Per specification (Vendor's guidelines- VG)	x	x	x	x	x
	v) Latency threshold (LT1)/Lag Time (LT2)	LT2: 200 ms	LT1: within 100 ms	-	o	o	x	x
	vi) Trigger performance–phase correct Triggering and data reconstruction	pass	Pass (for CT)	o	o	o	o	x
E2E test	i) End-to-end positioning test: including all clinical workflow: Mechanical and dosimetric	Mechanical: 2 mm/ 1°	Mechanical: 2 mm SRS/SBRT: 1 mm Dosimetric: ≤1% dose change; ≤2% dose Change for beam hold	–	x	x	x	x
	ii) Winston-Lutz for SRS applications	NA	<1 mm	NA	NA	NA	NA	x
System performance	i) Thermal drift: Effect of temperature on camera performance	0.5 mm/ 1° (20 min after 20 min in stand-by)	≤2 mm over 1 h ≤1 mm after stabilizing	x	x	x	x	x
	ii) Room-light level on the system accuracy	1 mm/ 1°	NA	x	x	x	x	NA
	iii) Field-of-view (FOV)	Pass	Per specification- VG	x	x	x	x	NA
	iv) Quality of surface image	Pass	NA	x	x	x	x	NA
	v) Integration system interface with all peripheral system	Pass	Pass	x	x	x	x	x
	vi) Patient interface	Pass	Pass	x	x	x	x	x

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Table 2 Cont.

Parameters[a]	Subgroups	Tolerances/ specifications		Recommendation for different type of machine/platforms[b]				
		ESTRO	AAPM[c]	ESTRO				AAPM[c]
				CT	C-Arm	Closed-bore	Particle therapy	C-Arm
Safety and documentation	i) Interlocks functionality	Pass	Pass	x	x	x	x	x
	ii) Data import and export	Pass	Pass	x	x	x	x	x
	iii) Database backup and security	Pass	Pass	x	x	x	x	x
	iv) Mechanical integration: Collision test	Pass	Pass	–	–	–	x	x
	v.) system configuration: User rights and settings	Pass	Pass	o	o	o	o	x
	vi) Export patient QA report	Pass	Pass	x	x	x	x	x
	vii) User manuals/guidelines	Pass	Pass	x	x	x	x	x

[a]: All recommended tests were described in ESTRO-ACROP guideline and AAPM reports (TG-302, TG-147 and TG-142). [b]: Recommendations in Vendor's guidelines were not included to current Table. [c]: This part included the combination of all recommendations in AAPM TG-302, TG-147, and TG-142. (x – mandatory, o – optional, pass-the system is accepted in clinical use for a specific indication and application). QA: Quality assurance; NA: Not available

tones are treated. In addition, it needs to be taken in to account that if the surface of the phantom is shiny, it may also cause numerous or unwanted reflection pattern of the projected light. Therefore, in case of necessity, it is generally recommended to cover the phantom surface with a paint coat or light colored tape. In addition to color and reflectivity properties, topography and texture of the QA phantom may significantly affect the result of the QA tests. Indeed, in case of insufficient topography, it is difficult to discern position or motion of the phantom during the check of localization accuracy of SGRT system. To overcome this issue, vendors provide dedicated phantoms that mimic anatomical surfaces such as the head, leg, or breast. In many clinics, homemade Styrofoam phantom with a different topography is also used as an inexpensive way of 3D surface phantom for SGRT. However, we need to be careful that Styrofoam with expanded polystyrene beads may cause uncertainties due to the abundance of texture and the projected light pattern may not be identified correctly. Therefore, smoot foam phantoms satisfying the outlined recommendation in both ESTRO-ACROP and AAPM guidelines can be also good alternative to commercially available phantoms. Several types of commercially available phantoms were also demonstrated in AAPM TG-302 and ESTRO-ACROP guidelines.

Challenges in SGRT QA

As also defined in AAPM TG-302, there are still several major issues that cause in uncertainties during both QA and clinical practice of SGRT. For instance, the use of DICOM based surface structure generated from CT imaging is considered as the one of the challenging issue for accurate localization of the phantom/body. In fact, many parameters (e.g., CT voxel size, scan speed, respiratory phase effect for moving phantom/surface, Hounsfield unit threshold for surface segmentation, and image quality) can significantly affect the topography of reference body surface ant it may cause a systematic bias during localization. Similarly, the size and the shape of the selected region-of-interest for surface tracking can also affect the response of the system during QA. In addition to these parameters, the tracking accuracy of the SGRT system can decreases when the component of treatment unit (e.g. gantry head and kV imaging arms) occlude the SGRT cameras, especially in non-coplanar treatment techniques with couch angle. Therefore, all these parameters need to be checked for different scenarios to evaluate the impact of defined issues on the tracking and localization accuracy of the implemented SGRT system before using in clinical practice.

Table 3 Periodical QA tests for SGRT

Parameters[a]	Subgroups	Tolerances/ Specifications		Recommendation for different type of machine/platforms[b]				
				ESTRO				AAPM[c]
		ESTRO	AAPM[c]	CT	C-Arm	Closed-Bore	Particle Therapy	C-Arm
Static Accuracy	i) Isocenter coincidence with other isocentric systems	1 mm/ 1° SRS: 0.5 mm/ 0.5°	2 mm SRS: 1 mm	D	D** M**	D	D	D/M*** M/A
	ii) Translational shift accuracy: introduced versus detected	2 mm	2 mm	–	M	M	M	D/M
	iii) Rotational shift accuracy: introduced versus detected	1°	2 mm	–	M	M	M	A
	iv) Camera occlusion: introduced versus detected shift when one or more camera blocked	1 mm/ 1°	NA	A/R	A/R	A/R	A/R	NA
	v) Couch rotation: Introduced versus detected	1 mm/ 1° SRS: 0.5 mm/ 0.5°	2 mm	–	M	–	A/R	A
Dynamic Accuracy	i) Beam-Hold performance: Dosimetric accuracy	2% or 2 mm/2% γ= 95% (10% threshold)	2%	–	A	A	A	A
	ii) Tracking performance-Ability of the system to correctly measure translations and/or rotation of moving target	1 mm/1°	2 mm or Verndor's spesification	–	M/A	A	A	M/A
	iii) Respiratory trace: Detectability of amplitude and frequency	Pass	NA	D/M	D/M	–	D/M	NA
	İv) Trigger performance-phase correct triggering and data reconstruction	Pass	NA	A	–	–	–	NA
E2E Test	i) End-to-end positioning test	2 mm/1°	2 mm/1 mm for SRS	A/R	A/R	A/R	A/R	A
System Performance	i) Thermal drift: effect of temperature on camera performance	0.5 mm	<2 mm over 1 h <1 mm after stabilizing	A	A	A	A	A
	ii) Field-of-view (FOV)	Pass	pass	A	A	A	A	D/M
	iii) Quality of surface image	Pass	NA	A/R	A/R	A/R	A/R	NA
	iv) Integration system interface with all Peripheral system	Pass	functional	–	–	–	–	M/A
	v) Patient interface	Pass	NA	D	D	D	D	NA
Safety and Documentation	i) Interlocks functionality	Pass	pass	M/A	M/A	M/A	M/A	D/M/A
	ii) Database backup and security	Pass	pass	A	A	A	A	M/A
	iii) Mechanical integration	Pass	pass	D	D	D	D	M/A
	iv.) System configuration: User rights and settings	Pass	pass	A	A	A	A	M/A
	v) Export patient QA report	Pass	pass	M/A	M/A	M/A	M/A	M/A

[a]: All recommended tests were described in ESTRO-ACROP guideline and AAPM reports (TG-302, TG-147 and TG-142). [b]: Recommendations in Vendor's guidelines were not included to current Table. [c]: This part included the combination of all recommendations in AAPM TG-302, TG-147, and TG-142. (A – annually, M – monthly, D – daily, R – following repair or maintenance). SGRT: Surface-guided radiation therapy; QA: Quality assurance; NA: Not available

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CONCLUSION

AAPM TG-302 mainly focused on the implementation of SGRT in C-arm linac. However, the use of SGRT system is also getting widespread in other platforms (like closed-bore linac, robotic gantry system, particle therapy, and CT simulator). Therefore, as also emphasized ESTRO-ACROP guidelines, each system need to have a different parameters and corresponding tolerance values for acceptance, commissioning, and routine QA. In terms of this aspect, an ESTRO-ACROP guideline is more comprehensive than AAPM TG-302. Nevertheless, AAPM TG-302 provides more detailed information about the phantom selection criteria and QA issue unique to SGRT and possible solution for these issues. Therefore, both of these reports need to be used together during the implementation of QA program in clinical settings.

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REFERENCES

1. Al-Hallaq HA, Cerviño L, Gutierrez AN, Havnen-Smith A, Higgins SA, Kügele M, et al. AAPM task group report 302: Surface-guided radiotherapy. Med Phys 2022;49(4):e82–e112.
2. Freislederer P, Batista V, Öllers M, Buschmann M, Steiner E, Kügele M, et al. ESTRO-ACROP guideline on surface guided radiation therapy. Radiother Oncol 2022;173:188–96.
3. Kügele M, Mannerberg A, Nørring Bekke S, Alkner S, Berg L, Mahmood F, et al. Surface guided radiotherapy (SGRT) improves breast cancer patient setup accuracy. J Appl Clin Med Phys 2019;20(9):61–8.
4. González-Sanchis A, Brualla-González L, Fuster-Diana C, Gordo-Partearroyo JC, Piñeiro-Vidal T, García-Hernandez T, et al. Surface-guided radiation therapy for breast cancer: more precise positioning. Clin Transl Oncol 2021;23(10):2120–6.
5. Mannerberg A, Kügele M, Hamid S, Edvardsson A, Petersson K, Gunnlaugsson A, et al. Faster and more accurate patient positioning with surface guided radiotherapy for ultra-hypofractionated prostate cancer patients. Tech Innov Patient Support Radiat Oncol 2021;19:41–5.
6. Li Z, Xiao Q, Li G, Wu X, Zhang Y, Wang G, et al. Performance assessment of surface-guided radiation therapy and patient setup in head-and-neck and breast cancer patients based on statistical process control. Phys Med 2021;89:243–9.
7. Hoisak JDP, Paxton AB, Waghorn BJ, Pawlicki T. Surface guided radiation therapy. Boca Raton: CRC Press; 2020.
8. Freislederer P, Kügele M, Öllers M, Swinnen A, Sauer TO, Bert C, et al. Recent advances in surface guided radiation therapy. Radiat Oncol 2020;15(1):187.
9. Batista V, Meyer J, Kügele M, Al-Hallaq H. Clinical paradigms and challenges in surface guided radiation therapy: Where do we go from here? Radiother Oncol 2020;153:34–42.
10. Bert C, Metheany KG, Doppke KP, Taghian AG, Powell SN, Chen GT. Clinical experience with a 3D surface patient setup system for alignment of partial-breast irradiation patients. Int J Radiat Oncol Biol Phys 2006;64(4):1265–74.
11. Padilla L, Havnen-Smith A, Cerviño L, Al-Hallaq HA. A survey of surface imaging use in radiation oncology in the United States. J Appl Clin Med Phys 2019;20(12):70–7.
12. Batista V, Gober M, Moura F, Webster A, Oellers M, Ramtohul M, et al. Surface guided radiation therapy: An international survey on current clinical practice. Tech Innov Patient Support Radiat Oncol 2022;22:1–8.
13. Willoughby T, Lehmann J, Bencomo JA, Jani SK, Santanam L, Sethi A, et al. Quality assurance for nonradiographic radiotherapy localization and positioning systems: report of Task Group 147. Med Phys 2012;39(4):1728–47.
14. Keall PJ, Mageras GS, Balter JM, Emery RS, Forster KM, Jiang SB, et al. The management of respiratory motion in radiation oncology report of AAPM Task Group 76. Med Phys 2006;33(10):3874–900.
15. Klein EE, Hanley J, Bayouth J, Yin FF, Simon W, Dresser S, et al; Task Group 142, American Association of Physicists in Medicine. Task Group 142 report: quality assurance of medical accelerators. Med Phys 2009;36(9):4197–212.