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A review of surface guidance in extracranial stereotactic body radiotherapy (SBRT/SABR) for set-up and intra-fraction motion management

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ABSTRACT

Introduction: Surface guidance (SG) radiotherapy (RT) is now used by many radiotherapy departments globally and has expanded in popularity over the last number of years. A number of commercial systems are available. SG has routinely been used and is well established for cranial stereotactic radiosurgery (SRS) patient set ups and intra-fraction motion monitoring.
However, data is limited in relation to its clinical use for extracranial stereotactic body radiotherapy (SBRT), particularly for targets which are impacted by respiratory motion such as the lung and liver.
Objective & Information Source: A review of available literature was carried out on 24th October 2021 to assess the clinical feasibility and use of SG in SBRT via PubMed.
Methods: Eligibility Criteria
The search criteria involved identifying articles where SG is used in extracranial SBRT.
Risk of Bias
To eliminate the risk of bias, any particular commercial system was not the focus of the review and not included in the search criteria. Numerous clinical terms for similar things were used to reduce the risk of missing papers e.g. SBRT and SABR.
Search Criteria
The PRISMA checklist was used. Searching for "surface guidance and radiotherapy" yielded 3271 results, where as "SGRT" alone returned 72 results, when the search term was narrowed down using different iterations of SG and SBRT, only 6 results were available. Of these, 4 had reviewed clinical data in relation to SG and SBRT for patient set up and intra-fraction motion monitoring.
Results: The 4 studies indicate positive results for using SG with sufficient image guidance (IG) for both patient set up and intra-fraction monitoring during SBRT. This was observed both in free breathing and in patients with respiratory motion management being employed such as deep inspiration breath-hold (DIBH) techniques. All used multiple IGRT solutions to verify localisation pre-treatment in conjunction with SG.
Limitations
The number of studies available which report using SG in SBRT is extremely limited. All centres had also installed SG systems therefore this could result in an unconditional bias in using the system positively.
Conclusion: SG can be used for SBRT set-ups and intra-fraction motion monitoring once sufficient IG is used to verify target localisation for treatment.

Introduction

Surface guidance radiotherapy (SGRT) involves the use of a camera/pod system which is non-invasive, to project a pseudo-random speckle pattern on to a patient's surface. The pod system is within the treatment room, hence can be used to set-up the patient and during treatment delivery. The system analyses the projection on to the patient's surface and then compares the current surface on that day, to a reference (DICOM) CT surface image for any changes and highlights them. The user defines a region of interest (ROI) within the projection to particularly focus on for motion with SG. It means you can move and adapt the patient's position during patient set-up, prior to leaving the room, to be within close tolerance of their CT simulated position based on the readings the SG system provides. The user can define their acceptable tolerances for the match. Theoretically, using the system should reduce the potential for gross shifts on imaging and the requirement for re-set-

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ups. A number of commercial systems are available [1,2,3,4]. The additional benefit is that the system can also be used to monitor the patient throughout treatment for intra-fraction motion [5,6,7,8].

SG has been well established and widely used for cranial SRS [9,10,11]. It has also been used extensively for extremities and pelvic areas successfully [12,13]. SG has also resulted in a number of centres eliminating skin tattoos in favour of relying on SG for set-up. This was comprehensively investigated for breast patients as a result of the psychological impact permanent tattoos had on them. Using SG for set-up instead of tattoos has been shown to be non-inferior to tattoos alone [14,15,16].

However, there is limited data on SG for extracranial stereotactic body radiotherapy/stereotactic ablative radiotherapy (SBRT/SABR). Many sites treated with SBRT require motion management solutions, lung and liver for example [17,18,19,20]. There is also reservation regarding how representative the patient's surface position/motion is of the internal tumour target motion, hence potential hesitancy for programmes to implement SG-SBRT.

Objective

A literature review was conducted using Pubmed.gov on 24th Oct 2021 to assess the current clinical use of SG in SBRT.

Participants(Participant) were patients, treated by extracranial stereotactic ablative radiation(Intervention) set up or monitored with SG (plus IG) during treatment compared to non-SG (tattoos for set up and IG) (Control) alone.

Materials & methods

The PRISMA checklist was used and initially searching the Pubmed database using the terms "surface imaging and radiotherapy" yielded 3271 results [21]. However with focus on the inclusion criteria for articles clinically using SG in SBRT, amending the search criteria for surface guided radiation retrieved 1779 results.

This database was then further scrutinised to eliminate duplicate results or data not pertaining to the review objective. A number of different search terms were used either alone or in combination to comb through the 1779 results and further exclude papers not relevant. For example, "Surface guided cranial radiation" accounted for 47 results, while "Surface guided SRS" achieved 19 and "SGRT breast" accounted for 20 results.

Different combinations were used to further eliminate and refine the data including "SGRT" or "surface guided radiotherapy/radiation therapy", "surface imaging", "surface guidance" "extracranial stereotactic body radiotherapy", "Stereotactic Ablative Body Radiation", "SABR" and "SBRT". Different phrasing for similar naming conventions was used to eliminate potential bias or duplication and eradicate potentially missing results based on excluding specific terms e.g. SBRT and SABR. Papers that had non-clinical implications were automatically excluded.

The results were continually scrutinised and excluded to only have papers clinically using SG in SBRT. Unfortunately, only 6 papers matched the inclusion criteria. 5 of these involved the clinical use of SG in SBRT and 1 involved a phantom study (Fig. 1). The full text was only available for 4 at the time of review with 1 being due to publish and

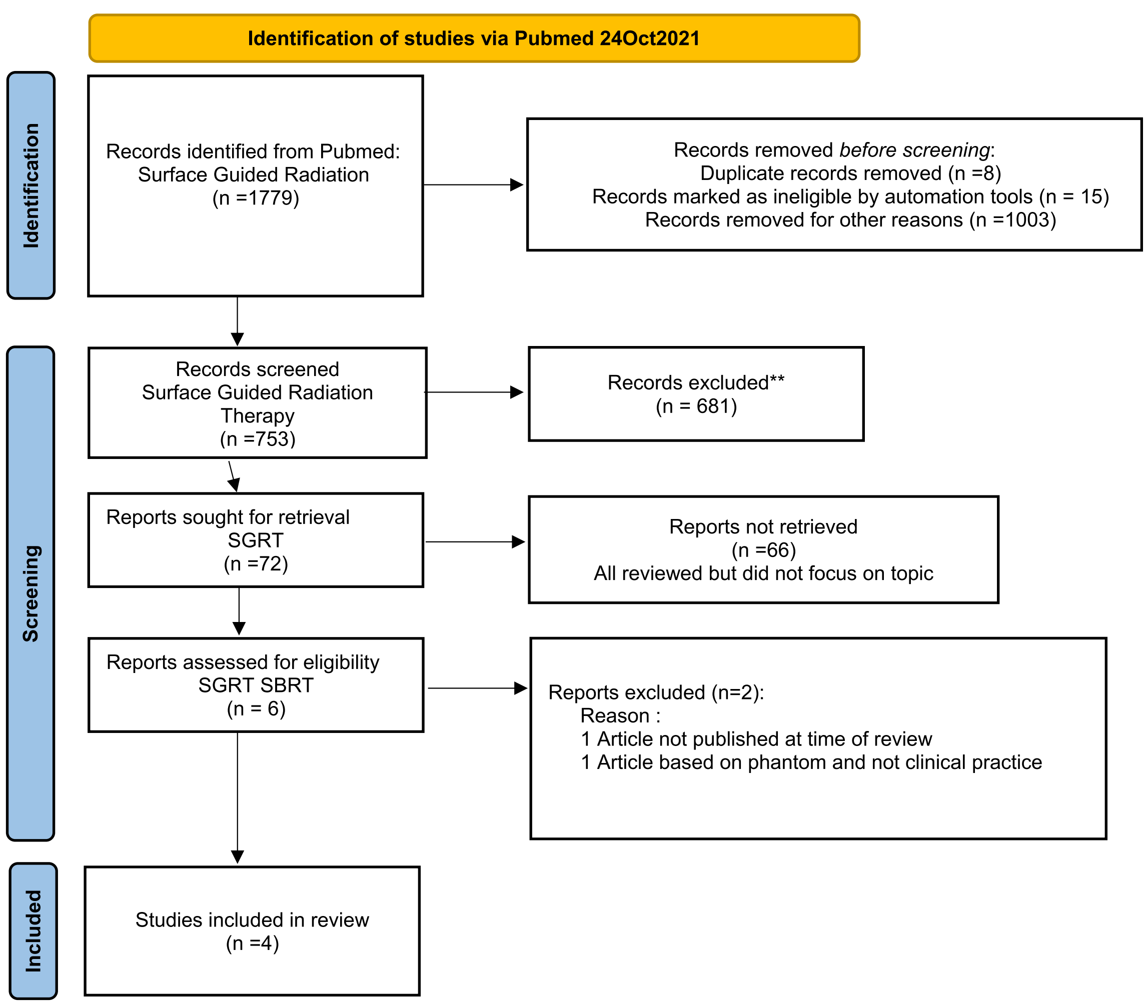

Fig. 1. Prisma 2020 Flow Diagram.

these 4 were then analysed for results [22]. This could potentially mean papers were missed, however given the extensive review, scrutiny of results and multitude of search criteria terminology used, there is limited potential for this, highlighting the current lack of evidence.

Results

Heinzerling et al. examined the data of 71 patients that had 85 thoracic or abdominal tumours. They established SG could be used for SBRT set up with CBCT resulting in intra-fractional shifts of <5 mm and <0.5 degrees in all directions. Patients were set up on alternative days either using tattoos or SGRT and then they reviewed the differences between kV/kV imaging between the two set-up techniques. For SGRT they used tolerances of 2 mm for translations and 1 degree for rotations. They also detected intra-fraction motion on 25 patients during the study using SG during treatment [5].

Leong et al. investigated if SG in conjunction with tattoos assisted in reducing shifts pre-treatment compared to tattoo set-ups alone. SG reduced the pre-treatment shifts and the requirement for orthogonal kVs for bone alignment. 284 fractions were examined retrospectively, 113 SG-SBRT and 171 Non-SG-SBRT for comparison [6].

Sarudis et al. examined 137 fractions delivered to 25 patients using SG for set-up, followed by orthogonal kVs and CBCT. The shift of the *patient* (bony anatomy) in the CBCTs intra-fractionally was ≤2 mm for 132/137 fractions in the vertical (vrt) and lateral (lat) directions, and 134/137 fractions in the longitudinal (lng) direction and ≤4 mm in 134/137 (vrt) and 137/137 (lat, lng) of the fractions. The shift of the *tumour* was ≤2 mm in 116/137 (vrt), 123/137 (lat) and 115/137 (lng) fractions and ≤4 mm in 136/137 (vrt), 137/137 (lat), and 135/137 (lng) fractions [7].

Naumann et al. observed 7 lung and 3 liver patients. Patients were treated deep-inspiration breath-hold resulting in planning target volumes being significantly reduced to 110 ml in DIBH from 148 ml in free breathing ($p < 0.001$, paired t-test). Liver targets required more corrections compared to lung targets on IGRT after SG set up (9 mm vs. 5 mm, $p = 0.017$). Lung target variability was low, indicating a better correlation of patients' surface to lung targets (intra-fractional IQR 2.5 mm and inter-fractional IQR 1.7 mm) [8].

Discussion

Reservations may exist with regards using SG in SBRT due to the patient's surface potentially not being representative of internal tumour motion. The patient's outer surface, may not correlate with internal motion. Many studies have reviewed the internal motion of targets, particularly in the lung, however there is limited data to correlate this against surface motion.[17-20] It is imperative given the hypo-fractionated regimes used in SBRT to use adequate image guidance (IG) regardless of the set-up technique employed to ensure accurate target localisation. All studies reviewed, used a combination of either orthogonal kVs and CBCT or CBCT pre-, mid- or post treatment to assess the impact of using SG for treatment set-up and intra-fraction motion management. All agree also that a rigorous IGRT protocol is required for SBRT regardless of SG use.

Heinzerling et al. employed abdominal compression for their liver and lung patients, immobilised with a full CIVCO Body ProLok ONE SBRT Immobilization System and vacuum cushion [5]. They treated patients free-breathing without fiducials. They compared SG versus kV orthogonal images for set-up on alternative days followed by CBCT pre-treatment for tumour assessment. Other than longitudinally, there were no differences noted between set-up techniques. The longitudinal direction may have been underestimated depending on the region of interest selected to be monitored for SG. With the extensive immobilisation system an unobstructed area clear of immobilisation with distinguishable landmarks to locate sup/inf positioning on patients and free from camera/pod blocking by the gantry movement would be limited to define on these patients. Hence, a uniform shaped person would appear similar in a sup/inf direction depending on the region of interest being used for the SG system to monitor.

Similarly, during intra-fraction monitoring, when the SG system detected motion and patients were re-imaged, it over estimated the required shift compared to CBCT on underweight, normal and overweight patients however underestimated it on obese patients. The patients shape may have given rise to this, as a large patient's surface can appear quite uniform within a small ROI hence the underestimation and conversely for the other weight categories. It is reassuring that the motion was detected however. The impact of the immobilisation and the ROI selected appear to be important factors to streamline and refine the sensitivity of the SG system. A rigid immobilisation system that ensures accurate reproducibility could account for the positive results in both the SG and non-SG groups. The under/over-estimation of intra-fraction shifts also highlight the importance of adequate IGRT for localisation post-SG.

Leong et al. treated thoracic, abdominal and bony metastases. Of the 113 SG-SBRT patients treated, 50 employed Active Breathing Control for breathing management and were treated on inspiration [6]. The remainder were treated free breathing. They did not disclose the immobilisation system used. SG was used for set-up followed by orthogonal kVs and CBCT imaging. The use of SG reduced the magnitude of overall shift required compared to using tattoos. This highlights how SG can be used to remove tattoos for set-up. The centre had a 4 degrees of freedom (DOF) couch, hence rotations were manually corrected after CBCT imaging, however SG significantly reduced the rotations in all directions. This is important particularly for centres with 4DOF couches as SG can reduce unnecessary imaging dose given to patients by detecting rotations and reducing them prior to imaging. kV imaging was retained as the group found it reduced the requirement for re-CBCT as per their protocol tolerances in a fifth of SG patients. However, this means it was unnecessary in 80% of the SG patients treated. Further assessment of their immobilisation and process with refinement of their protocol would be recommended to reduce this further, to improve patient set-up. This could possibly negate the requirement for kV imaging in conjunction with CBCT pre-treatment given the large number of patients it was not beneficial for and resulted in unnecessary dose.

Saduris et al. reviewed 137 fractions delivered to 25 lung cancer patients treated free breathing [7]. Patients were set-up using SG, then the bony anatomy checked using orthogonal kV imaging and any additional shifts made. A CBCT was then taken to review the tumour localisation. SG was used throughout the treatment to assess intra-fraction motion and a further CBCT taken to review the accuracy of this. They do describe using immobilisation involved, but also helpfully the ROI delineation which may have impacted their results. Unfortunately, the set-up shifts from SG detected by the kV orthogonal set is not provided. Clear evidence is presented to highlight the impact of using SG for intra-fraction motion management. Over 54% of fractions experienced a beam hold due to intra-fraction motion, which have otherwise went undetected without SG. The impact on tumour dose was also extrapolated and positively re-enforced using SG for intra-fraction motion management to ensure adequate dose delivery to the tumour. This particularly important with the ablative doses being used during SBRT.

Naumann et al. had a smaller patient cohort of 10 patients, treated using DIBH [8]. Liver targets required significantly larger corrections, than lung targets on IGRT after SG set up. This is not surprising given no other localisation method was employed (e.g. fiducials were not used however these are invasive and carry their own risks), the segments of the liver are not often easily identifiable on CBCT and deformation of the liver that can occur during treatment [19,20]. Patients were also required to hold their breath for at least 30 s. This can be possible in this cohort, this study being evidence of it, however depending on patient tolerance, clinically it may rule out many patients that may only be able to hold for shorter time periods. They used 2 CBCTs to verify the DIBH and target localisation. DIBH was voluntary and did not use a system such as ABC. If agreement was less than 2 mm between the CBCT sets then a set of MV images were taken for isocentre verification and treatment delivered. Their findings illustrate the importance of using IG with SG for SBRT with lung mean intra-fractional differences calculated as 0.9 mm versus 3.8 mm for liver patients. The ROI was selected as the lower thorax for monitoring. The authors highlight the surface whilst correlative to the lung, was not representative of internal motion particularly for liver tumours and this aligns with Velec et al.'s findings [23]. The small number of lung patients included may bias the reality of this correlation however and it would be interesting to evaluate if the findings hold on a larger data set in similar circumstances. The other issue they recognise is in relation to the voluntary DIBH. Lung volumes can change throughout inspiration repetitions during treatment, however the surface within the ROI may remain similar giving a false sense of security. Lung volume changes during treatment may impact target localisation and this needs to be further evaluated when using SG [24].

The four studies used a range of different patient numbers, however this results overall in large data sets when reviewing individual fractions/patient in totality. They also employed different immobilisation and motion management techniques however found similar results using SG for patient set up and intra-fraction motion management positively impacted and reduced translational and rotational shifts required. It also managed to detect shifts during treatment which could have impacted dose delivery to the target, crucially for SBRT ablative doses. The sensitivity and specificity of SG intra-fraction motion detection and dosimetric impact needs to be further quantified. A limitation of the review, is the small number of published articles available, hence further data would be valuable to support the findings of these 4 papers. However, the 4 share the opinion that SG can be used in SBRT. Similarly, all 4 had installed SG systems hence this may have resulted in an unknown bias.

Conclusion

SG may be implemented and used for patient set up and intra-fraction motion management, in the presence of a rigorous IG protocols for SBRT. Further clinical studies are warranted particularly for patient set up and the impact of intra-fraction motion detection and the potential consequences to target dose delivery.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] VisionRT, London, UK. Available from: www.visionrt.com/.
[2] Catalyst, C-RAD, Uppsala, Sweden. Available from: www.c-rad.se/catalyst-plus.
[3] Varian Identify, Palo Alto, California, USA. Available from: www.varian.com/products/radiotherapy/real-time-tracking-motion-management/identify.
[4] Brain Lab, Exactrac Dynamic, Munich, Germany. Available from: www.brainlab.com/radiosurgery-products/exactrac/.
[5] Heinzerling JH, Hampton CJ, Robinson M, Bright M, Moeller BJ, Ruiz J, et al. Use of surface-guided radiation therapy in combination with IGRT for setup and intrafraction motion monitoring during stereotactic body radiation therapy treatments of the lung and abdomen. J Appl Clin Med Phys 2020;21(5):48–55.
[6] Leong B, Padilla L. Impact of use of optical surface imaging on initial patient setup for stereotactic body radiotherapy treatments. J Appl Clin Med Phys 2019;20(12):149–58.
[7] Sarudis S, Karlsson A, Bäck A. Surface guided frameless positioning for lung stereotactic body radiation therapy. J Appl Clin Med Phys 2021;22(9):215–26.
[8] Naumann P, Batista V, Farnia B, Fischer J, Liermann J, Tonndorf-Martini E, et al. Feasibility of optical surface-guidance for position verification and monitoring of stereotactic body radiotherapy in deep-inspiration breath-hold. Front Oncol 2020;10. https://doi.org/10.3389/fonc.2020.573279.
[9] Cerviño LI, Detorie N, Taylor M, Lawson JD, Harry T, Murphy KT, et al. Initial clinical experience with a frameless and maskless stereotactic radiosurgery treatment. Pract Radiat Oncol 2012;2(1):54–62.
[10] Li G, Ballangrud A, Chan M, Ma R, Beal K, Yamada Y, et al. Clinical experience with two frameless stereotactic radiosurgery (fSRS) systems using optical surface imaging for motion monitoring. J Appl Clin Med Phys 2015;16(4):149–62.
[11] Wen N, Snyder KC, Scheib SG, Schmelzer P, Qin Y, Li H, et al. Technical note: evaluation of the systematic accuracy of a frameless, multiple image modality guided, linear accelerator based stereotactic radiosurgery system. Med Phys 2016;43(5):2527–37. https://doi.org/10.1118/1.4947199.
[12] 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.
[13] Stanley DN, McConnell KA, Kirby N, Gutiérrez AN, Papanikolaou N, Rasmussen K. Comparison of initial patient setup accuracy between surface imaging and three point localization: a retrospective analysis. J Appl Clin Med Phys 2017;18(6):58–61.
[14] 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.
[15] Hattel SH, Andersen PA, Wahlstedt IH, Damkjær S, Saini A, Thomsen JB. Evaluation of setup and intrafraction motion for surface guided whole-breast cancer radiotherapy. J Appl Clin Med Phys 2019;20(6):39–44.
[16] Hamming VC, Visser C, Batin E, McDermott LN, Busz DM, Both S, et al. Evaluation of a 3D surface imaging system for deep inspiration breath-hold patient positioning and intra-fraction monitoring. Radiat Oncol 2019;14(1). https://doi.org/10.1186/s13014-019-1329-6.
[17] Keall PJ, Mageras GS, Balter JM, et al. The management of respiratory motion in radiation oncology report of AAPM task group 76. Medical Phys 2006;33:3874–900. https://doi.org/10.1118/1.2349696.
[18] Thengumpallil S, Racine D, Germond J-F, Péguret N, Bourhis J, Bochud F, et al. Retrospective analysis of the impact of respiratory motion in treatment margins for frameless lung SBRT based on respiratory-correlated CBCT data-sets. J Appl Clin Med Phys 2020;21(10):170–8.
[19] Lu L, Ouyang Zi, Lin S, Mastroianni A, Stephans KL, Xia P. Dosimetric assessment of patient-specific breath-hold reproducibility on liver motion for SBRT planning. J Appl Clin Med Phys 2020;21(7):77–83.
[20] Oliver PAK, Yewondwossen M, Summers C, Shaw C, Cwajna S, Syme A. Influence of intra- and interfraction motion on planning target volume margin in liver stereotactic body radiation therapy using breath hold. Adv Radiat Oncol 2021;6(1):100610. https://doi.org/10.1016/j.adro.2020.10.023.
[21] Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.
[22] Heinzerling JH, Biester EC, Robinson M, Moeller BJ, Prabhu RS, Ward MC, et al. Prospective study of surface guided radiation therapy (SGRT) for breath hold SBRT treatments of the lung: analysis of reliability of surface guidance alone for internal tumor position during breath hold. Int J Radiat Oncol Biol Phys 2021;111(3):e539. https://doi.org/10.1016/j.ijrobp.2021.07.1468.
[23] Velec M, Moseley JL, Craig T, et al. Accumulated dose in liver stereotactic body radiotherapy: positioning, breathing, and deformation effects. Int J Radiation Oncol Biol Phys 2012;83:1132–40. https://doi.org/10.1016/j.ijrobp.2011.09.045.
[24] Lee S, Zheng Y, Podder T, et al. Tumor localization accuracy for high-precision radiotherapy during active breath-hold. Radiother Oncol 2019;137:145–52. https://doi.org/10.1016/j.radonc.2019.04.036.