Multi-institutional case studies of surface guided radiotherapy in USA and Germany

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Abstract

AlignRT® is a form of Surface Guided Radiotherapy (SGRT). Its use has recently been increased in various parts of the world. The aim of this study is to find out the current status of Surface Guided Radiotherapy especially AlignRT® in Proton therapy treatment and identify challenges and benefits associated with the application of Align RT from point of view of Radiation oncology professionals. A survey was created to assess clinical, technical, organizational and Educational strategies and resources employed to provide Surface Guided RT mainly AlignRT® based Proton therapy treatment in the responders' Radiation Oncology centres. Another objective of the study is to discover if AlignRT® can completely replace IGRT. Survey was sent to four Radiation oncology professionals in USA and Germany. This has led to four case studies. The responses provide understanding of the current AlignRT® practices and though these responses are important they should not be considered to be representative of radiation oncology as a whole. The study was conducted in 2020.

Keywords: Align RT®, Catalyst system, Surface Guided Radiotherapy, Proton therapy

1. Introduction

Surface Guided Radiotherapy (SGRT) consists of surface imaging (SI) technology and Surface imaging is a form of optical Image guidance used in Radiation therapy to position patient accurately, to monitor intra-fraction motion and to carry out respiratory gating. Surface imaging technology uses 4 different types of optical surface scanning techniques i.e. Laser scanners, Time of Flight systems, stereovision systems and Structured light systems [1-4].

Various SGRT systems are operational in Radiotherapy worldwide such as AlignRT®, Optical surface monitoring system (Varian Edge Radiosurgery system), Catalyst, Identify (Humedi Q), Active Breathing Co-ordinator (Elekta), Real time position management system (Varian) [5]. AlignRT® and Catalyst utilize 3D optical stereovision scan of the body surface to verify patient position. AlignRT® is developed and marketed by vision RT (London, UK) to track patient skin surface in real-time with sub millimetre accuracy. If patient moves the AlignRT® automatically send signal to delivery system to pause the Radiation beam [6]. The AlignRT® system consists of three ceiling mounted scanners which in turn consists of two stereoscopic camera to produce 3D surface of the patient using passive triangulation, texture camera to provide grey scale image of the patient and a projector to project grey scale pattern onto the patient to reduce inaccurate reflections and a light flash [5, 7]. The 3D surface images from two scanners are combined by the AlignRT® software to generate a full 3D surface of the patient. This 3D surface is then registered with reference image. The align RT uses rigid registration whereas Catalyst uses Deformable registration algorithm [8]. Catalyst system is developed by C-Rad Uppsala, Sweden and consists of three ceiling mounted scanners and associated c4D software (Carl *et al*, 2018). For detailed knowledge of Catalyst System readers are referred to [9-10].

SGRT is associated with a number of advantages such as no radiation dose (visual tracking of the Patient surface), availability of large surface for patient positioning compared to a few isolated marks such as in traditional tattoo and laser based setup, ability to monitor intra-fractional motion of the patient surface and isocentre in 6D and radiation is permitted when patient is within the given threshold [11-13]. All these capabilities have resulted in increasing use of SGRT in Radiation oncology departments. However the uptake of SGRT has been slow and many centres using SGRT are not availing all the features and full potential of the SGRT systems (AlignRT® and Catalyst).

This warrants a case study of various Radiation oncology institutes where SGRT is being installed and used to determine not only its current status but also to identify the challenges facing the implementation and uptake of AlignRT® and Catalyst technologies especially in proton therapy centres and hospitals.

The objectives of this study are listed below
1. Determine the current status of mainly AlignRT® and to some extent Catalyst SGRT system in USA and Germany.
2. Identify the challenges and problems that Radiation oncology professionals face when implementing SGRT in their departments.
3. Determine what organizational, clinical, treatment and technical resources and strategies are employed with respect to SGRT treatment and delivery.

2. Materials and Methods
A. **Study Overview** An E- questionnaire was designed to evaluate the current status of Surface Guided RT in the USA and Germany and to achieve better understanding and awareness of challenges faced in its implementation. The study evaluated AlignRT® (Vision RT) and Catalyst (C-Rad) surface guided Imaging systems in four proton therapy centres. The questionnaire was designed in MS word and consisted of 30 questions, most of which were close ended questions. Survey questions were structured in four sections namely i) Demographic, ii) *SGRT institutional Background & Organizational resources, iii)* Information about SGRT Technology, iv) Proton Therapy System Information and Problems associated with AlignRT®. A sample questionnaire is shown in Appendix A under supporting Information section.

Social media Website platform (LinkedIn) was used to reach out the respondents and provide them with a Questionnaire and study participation invitation letter. Professionals from Four different Radiation Centres from United States and Germany participated in this study. Three respondents were from Proton therapy Centre based in three states of USA (Cleveland, Ohio, Miami, Florida and Iowa city, Iowa) and one from Germany (Cologne). This resulted in 4 case studies (three in USA and one in Germany). Thus the present study is based on the views and opinions of four Radiation therapy

professionals working in four different Proton therapy Radiation centres. The views and experiences of these professionals showed the clinical practices with respect to SGRT in 4 Institutes and these views provide important awareness about clinical, technical, organizational and Educational strategies and resources employed in these institutes with respect to SGRT. However by no means these views are representative of entire Radiation oncology field. The study was carried out in 2020. The Questionnaire length was 10-15mins depending on the experience of the respondent.

B. **Ethical Consideration:** This study was deemed IRB exempt as it was a quality enhancement and evaluation study. Responses were anonymous so no ethical approval was required. No patients were approached. No medical or personal data of participants collected. By answering the questionnaires, the professionals agreed to give their informed consent.

C. **Statistical Analysis:** Descriptive analysis was used to examine the results of the study.

3. Results
A. *Responses*: Four professionals from USA and Germany responded to E-survey. All four professionals worked in different institutes/organizations. Each respondent is assigned a code as shown in Table 1. The socio demographic profile of respondents is summarized in Table II.

Table I: Respondent codes

Respondent code	Countries	N (4)
R1US	USA	1
R2US	USA	1
R3US	USA	1
R4DE	Germany	1

B. **Respondent Characteristics:** 75% (3) of the respondents were male and 25% were (1) females. The most common age range was 40-50 years among respondents i.e. 50% of respondents belonged to 40-50 years of age range. Three respondents were married (75%) and one was divorced (25%). One respondent was Radiation therapist from USA, two were medical physicists from USA and one was Research medical physicist from Germany. Results are show in Figures 1-2.
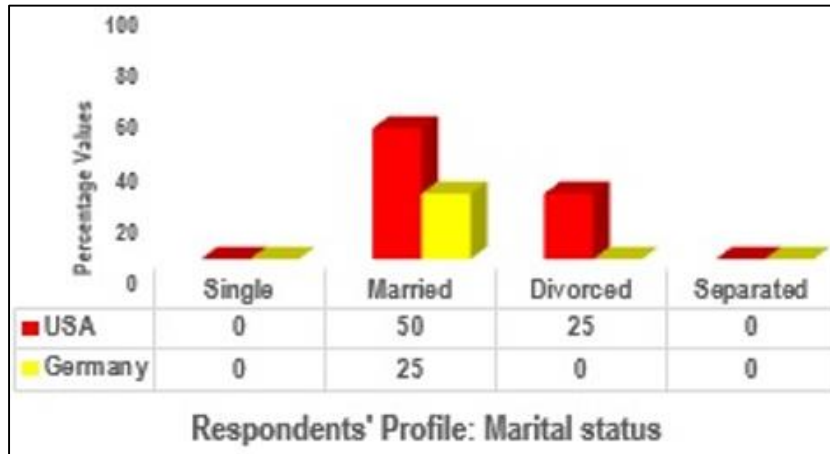

Socio-Demographic Profile of Respondents - Gender
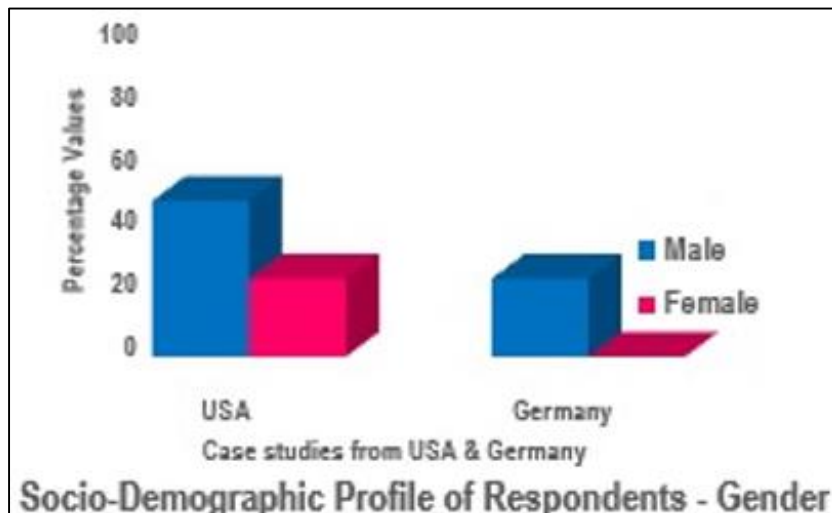
Fig 1: Socio-Demographic profile of Respondents: Gender & Marital status
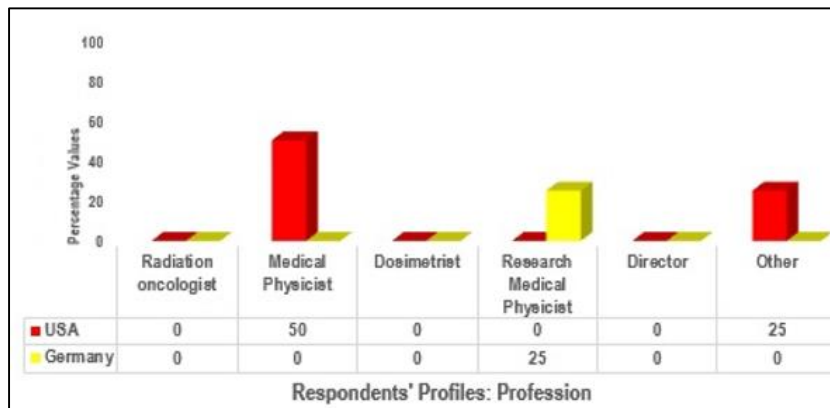

Fig 2: Socio-Demographic profile of Respondents: Profession & Age

Note: RT = Radiation Therapist, MP= Medical Physicist, RMP= Research Medical Physicist, OH= Ohio, FL= Florida, IA= Iowa.

A. ***SGRT institutional Background & Organizational resources:*** Results are shown in Figure

1. Location of the Institute and Type of Practice
R1US who was a Radiation therapist (25%) was working in a public Institute (hospital) in Cleveland Ohio, R2US was working in a not for profit institute in Miami, Florida and R3US, a medical physicist was working in an academic institute (University) in Iowa city, USA whereas R4DE, a Research Medical Physicist from Germany was working in a multinational Radiation oncology Hardware and software manufacturing (vendor) company in Cologne. Results are shown in Fig. 3
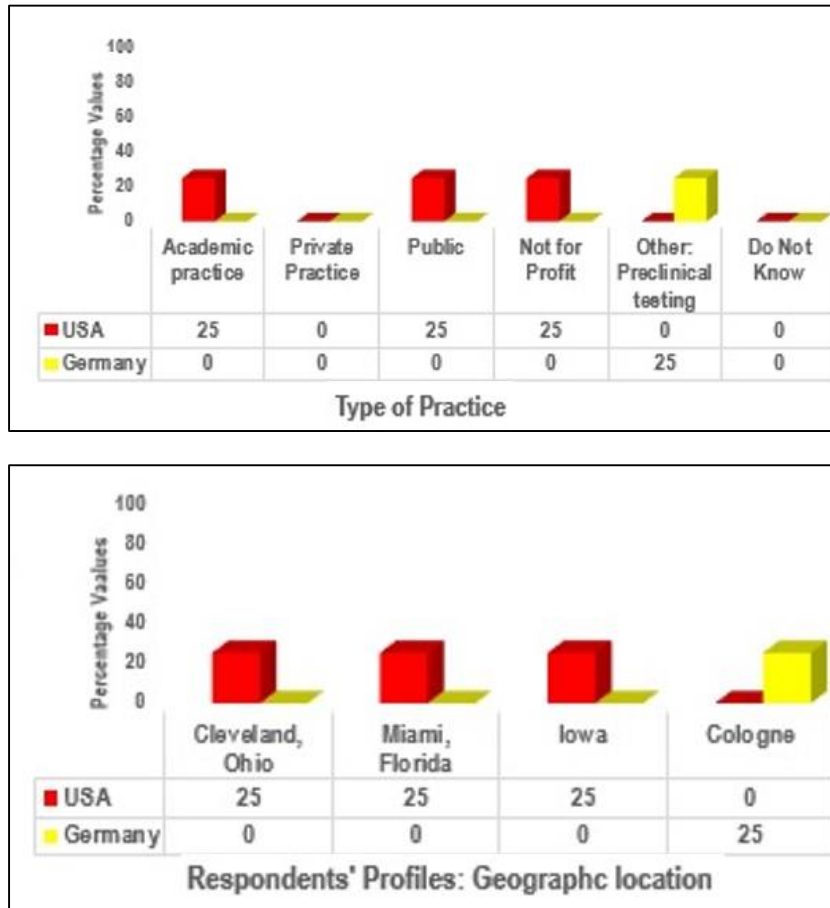
Fig. 3 Socio-Demographic profile of Respondents: Type of practice & Geo-graphic location of working place

Table 2: Summary of Socio Demographic profile of Respondents

Respondents	Gender	Age Range	Occupation	Marital status	Geo Location of Institute
R1US	Female	50-60	RT	Divorced	Cleveland, OH, USA
R2US	Male	40-50	MP	Married	Miami, FL, USA
R3US	Male	30-40	MP	Married	Iowa city, IA, USA
R4DE	Male	40-50	RMP	Married	Cologne, Germany

2. Do you use SGRT in RT delivery?   Results are shown in Fig. 4

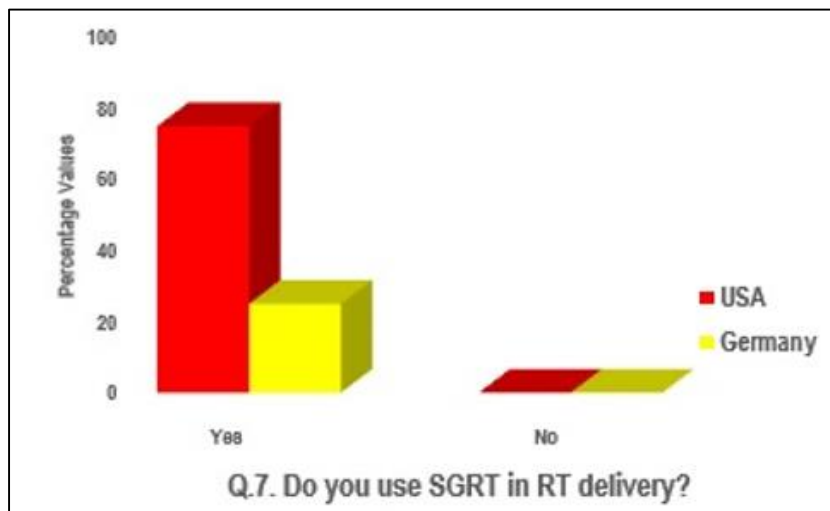100% of respondents said that they use SGRT in RT delivery.

Fig 4: SGRT usage in RT

3. Type of SGRT

75% of the respondents said that they use AlignRT®. One respondent (25%) from USA said that they use Catalyst (C-Rad). Results are shown in Fig. 5
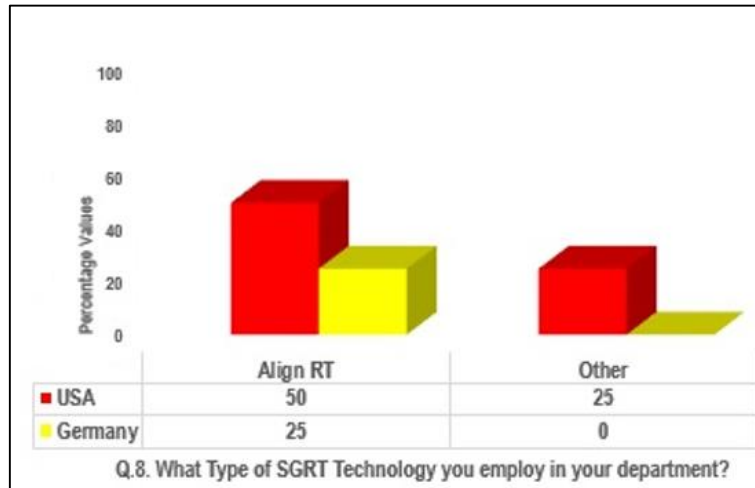
Fig 5: SGRT Technology

4. Do you think SGRT usage has resulted in needing more staff?
All the respondents from USA (75%) said No but respondent from Germany said Yes (25%) Results are shown in Fig. 6
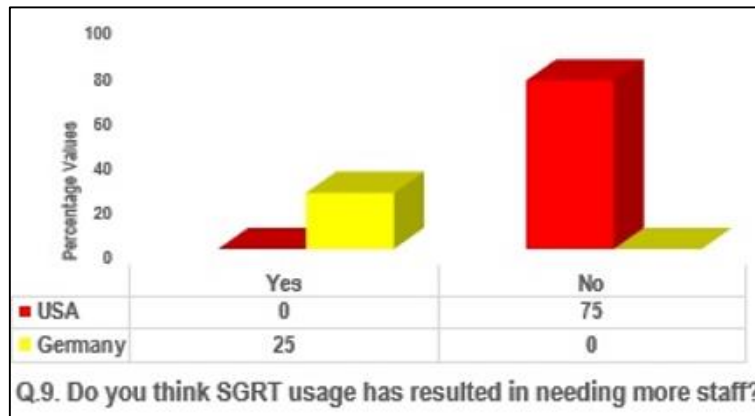

Fig 6: SGRT and staff requirements

5. Professionals involved in SGRT delivery
Only two (50%) respondents from USA specified the number of professionals needed to give SGRT treatment where as other two respondents only specified which professionals are needed to give SGRT treatment. R2US said 4 professionals are involved in SGRT treatment delivery i.e. 1 medical physicist, 2 Radiation technologists and one dosimetrist whereas R3US said 5 professionals are needed to give SGRT treatment i.e. one Medical Physicist, 2 radiation technologists, one dosimetrist and one Radiation oncologist.

6. Implementation of SGRT
The Respondent (25%) from Germany said Implementation & integration of SGRT is complicated whereas Radiation therapist (25%) from Cleveland, Ohio said it can be confusing if procedures are not well defined. The Medical Physicist (25%) from Iowa said he do not know as he was not present in the institute at the time of SGRT implementation whereas the other Medical Physicist (25%) from Miami, Florida considered SGRT implementation an Easy process. Results are shown in Fig. 7
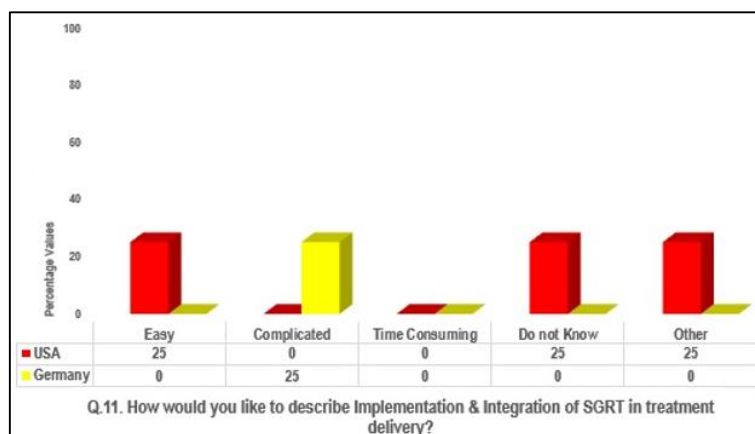

Fig 7: SGRT implementation in the department

7. Challenges

The radiation Therapist from Cleveland, Ohio, USA said Lack of knowledge, training and Lack of compatibility with proton delivery system are some of the challenges faced during Implementation of SGRT for Proton therapy. The Medical Physicist from Miami, Florida said shortage of QA guidelines for SGRT setup and implementation was challenging whereas the other Medical Physicist from Iowa did not answer the question. The research Medical Physicist from Germany said timing delays in proton therapy are some of the challenges faced by them. Results are shown in Fig. 8.
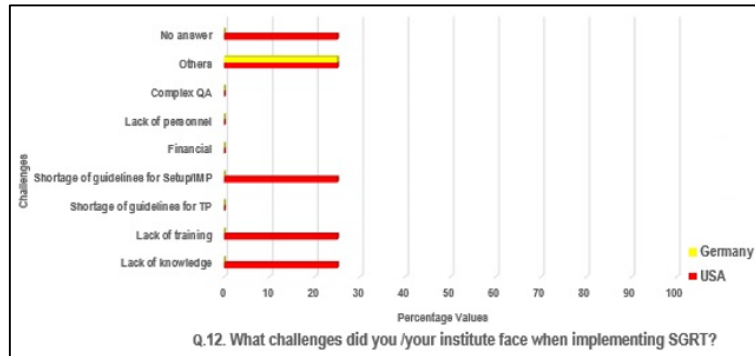

Fig 8: Challenges

D. Information about SGRT Technology

Results are shown in Fig. 9 -18

1. Duration of SGRT usage

50% of respondents said that they have been using SGRT for 5 years. Both these respondents were from USA (R1US, R3US). One respondent (25%) from USA (R2US) said he has been using SGRT for 2 years and the Research Medical Physicist from Germany (R4DE) said he has been suing SGRT for 1 year.
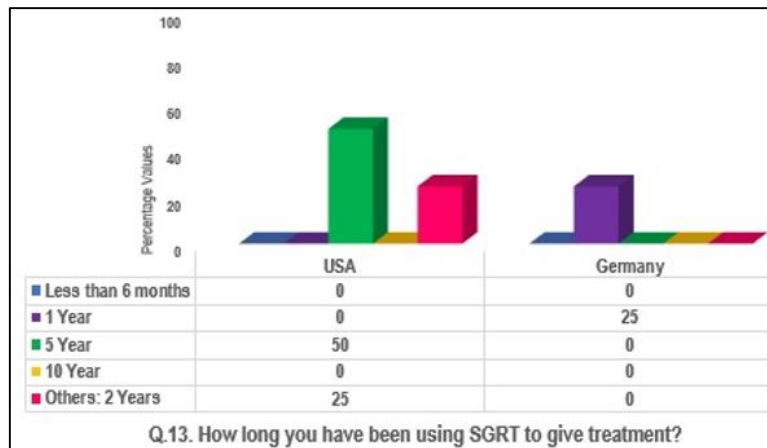

Fig 9: Duration of SGRT usage in the department/organization

2. Registration

Research Medical Physicist from Germany said they use both types of registration techniques in their institute whereas the 50% of the respondents from USA (Cleveland and Miami centres) said they use Deformable registration in their institutes. Medical Physicist from Iowa, USA said they only use SGRT to monitor SBRT treatment and for DIBH (Deep Inspiration Breath Hold). The results are shown in Fig. 10.
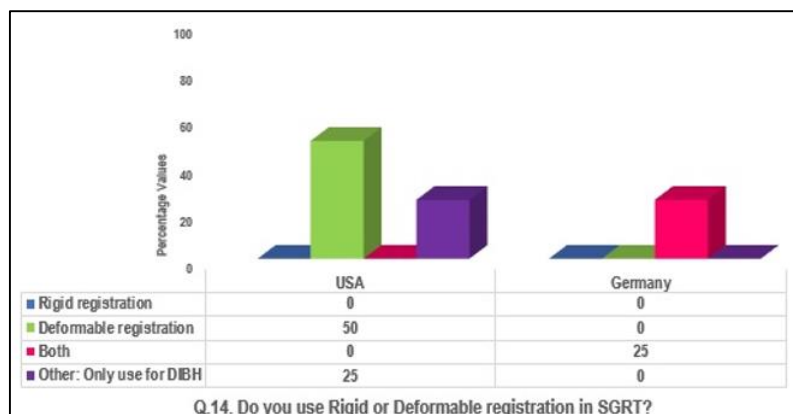

Fig 10: Rigid versus Deformable registration

3. Translational Uncertainty and Residual Setup Error

The translational setup errors are indicated in x, y, and z directions where x= RT/LT, y= AP and z= Sup/Inf. The Radiation therapist from Cleveland Ohio, USA said they found 3mm Translation setup Uncertainty in their institute for lung and breast cancer patients whereas Medical Physicist from Iowa said they found 5mm or less. Medical physicist from Miami, Florida did not answer the question for Carcinoma of lung. However he said they found 8mm translational setup certainty for breast cancer patients. The Research Medical Physicist from Germany did not answer the question. Results are shown in the Fig. 50% of the respondents (RIUS, R2US) reported 3mm residual setup error for breast using both AlignRT® and Sentinel / Catalyst C-Rad SGRT systems while 50% of the respondents did not answer the question. 25% (R1US) of the respondents reported 3mm residual setup error for lung cancer patients with AlignRT® while 75% of the respondents did not answer the question.
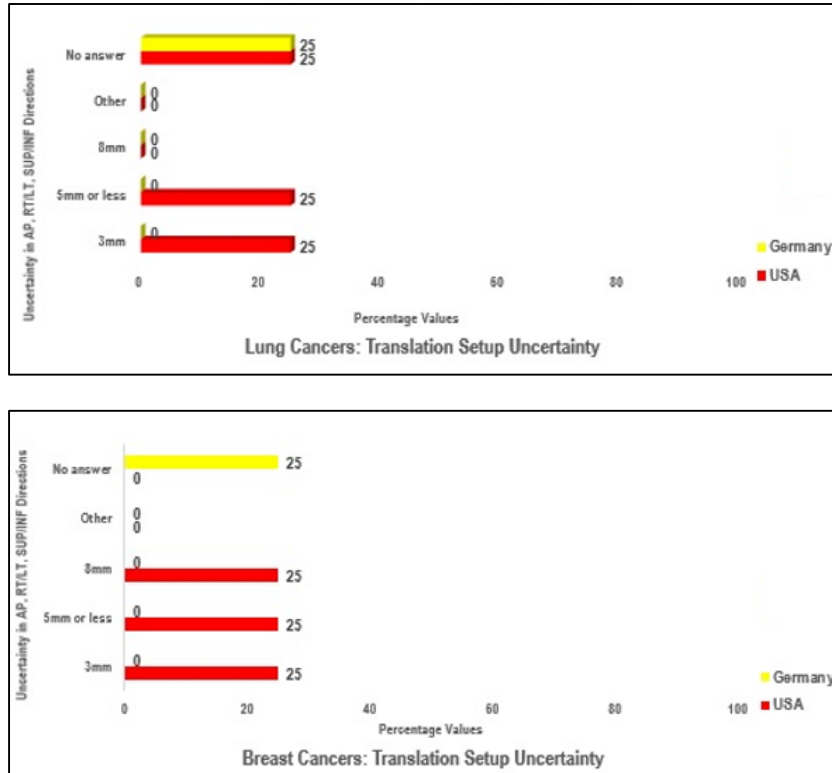

Fig 11: SGRT translation setup uncertainty in breast and lung cancer patients

4. Types of Tumours suitable for SGRT setup

100% of the respondents said that Breast cancer patients are suitable for SGRT treatment, 50% said lung cancer patients are suitable for SGRT, 25% said SGRT is suitable for Pancreas, Liver and for Mediastinal cancers. The radiation Therapist from Cleveland Ohio (R1US) said they find Breast, Pancreas and Liver cancer patients more suitable for SGRT setup. Medical Physicist from Miami, Florida (R2US) said they find SGRT suitable for Breast and Mediastinal cancer patients whereas Medical Physicist from Iowa (R3US) and Research Medical Physicist from Germany (R4DE) both said they find SGRT suitable for Breast and Lung patients. R3US further said that they use AlignRT® with DIBH in Breast cancer patients and for monitoring of SBRT treatment for lung cancer patients. Results are shown in Fig. 12
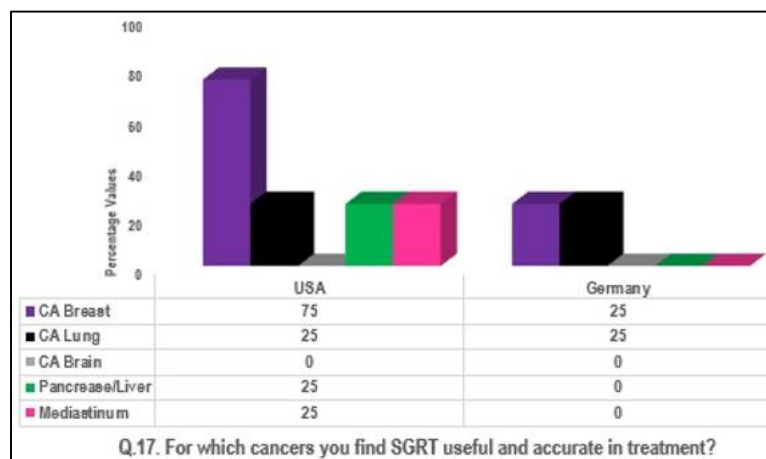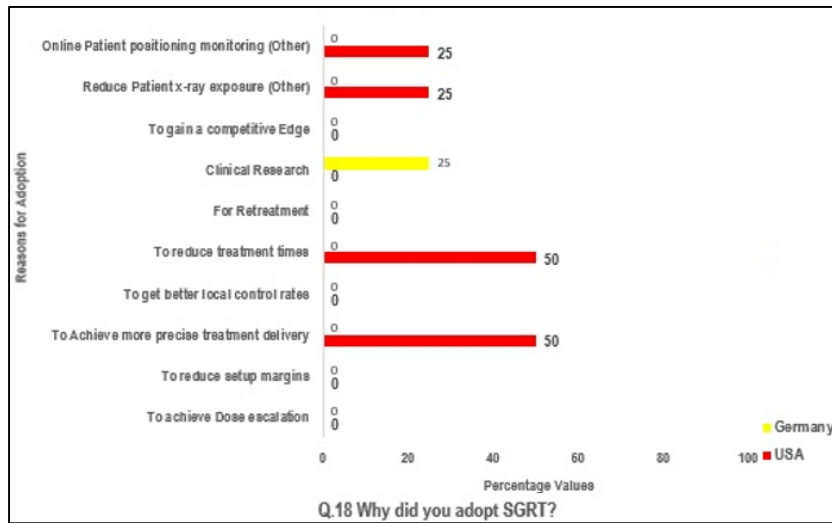

Fig 12: Cancers suitable for SGRT

5. Reasons for SGRT Adoption

50% of Respondents said to achieve more precise treatment delivery and another 50 % said to reduce treatment times, 25% said to reduce patient exposure, another 25% said to carry out online patient positioning monitoring and still another 25% said for Clinical research. Results are shown in Fig. 13
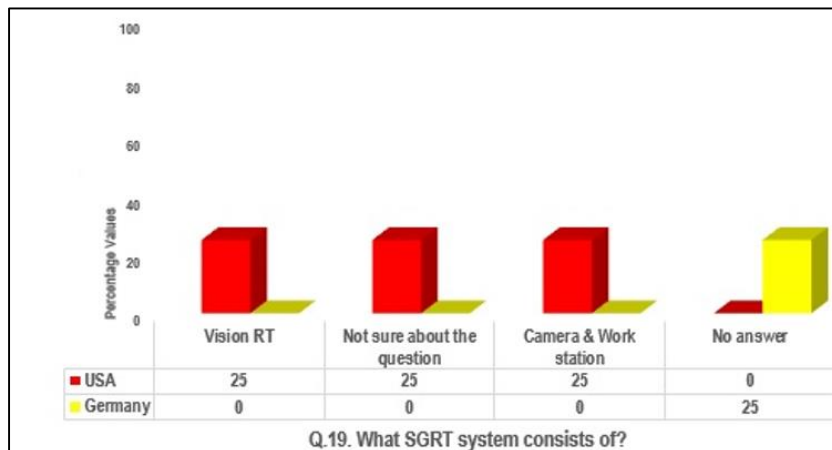

Fig 13: SGRT adoption reasons

6. SGRT System components

R1US (25%) said SGRT system consists of Vision RT, the R3US (25%) from Iowa, USA said camera and work station whereas R2US (25%) from Miami Florida was not sure what question is about and R4DE (25%) from Germany did not answer the question. Results are shown in Fig. 14.

Fig 14: Responses regarding SGRT system components

7. SGRT and other IGRT techniques

Results for Question 20 and 24 are shown in Fig. 15. All respondents (100%) said that they use SGRT in combination with other IGRT techniques i.e. SGRT complements plus other IGRT techniques such as Cone beam CT and KV orthogonal imaging. No respondent said SGRT can replace entirely KV or MV imaging. 50% of respondents from US (R1US, R2US) said that they do not think SGRT can replace entirely KV or MV imaging. R3USA said do not know and R4DE did not give any answer.
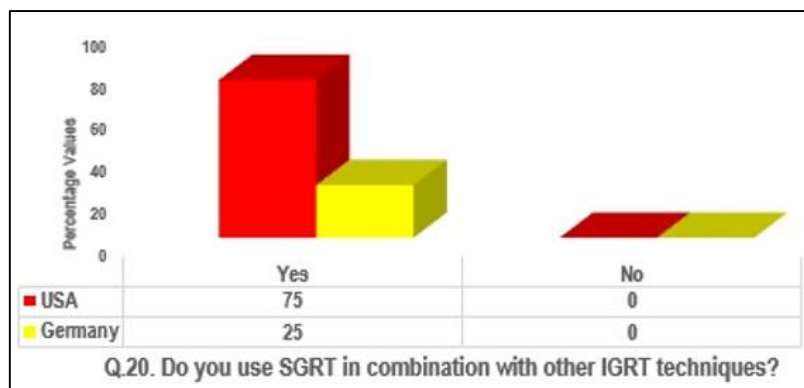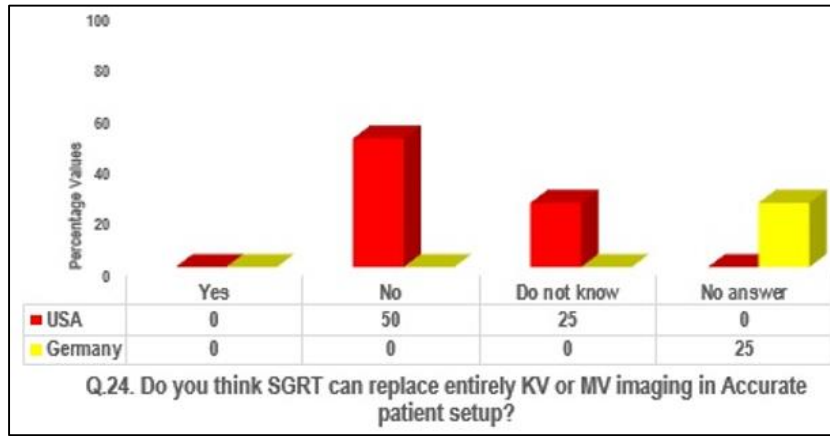
Fig 15: SGRT versus IGRT

8. Improvements needed in SGRT
R2US (25%) said offline review and better database Management is needed in SGRT system SGRT and reduced setup margins whereas R4DE (25%) said

that really fast reaction time is required with total delay less than 20ms. 50% of the respondents (R1US and R3US) gave no answer. Results are shown in Fig. 16
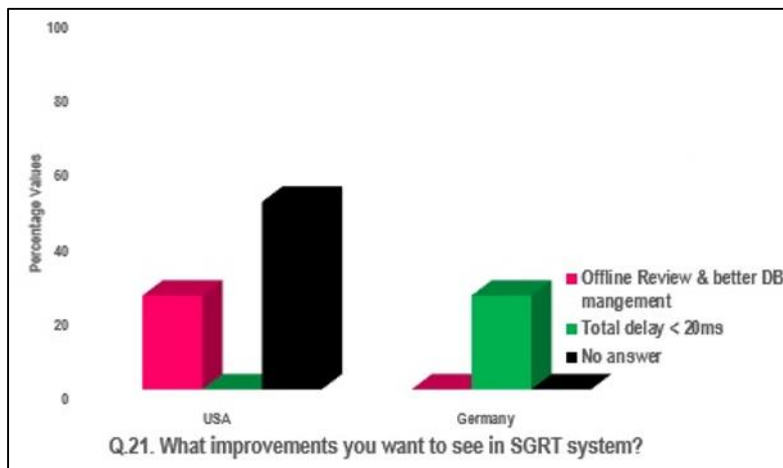
Fig 16: Improvements needed in AlignRT® & Catalyst SGRT systems

9. SGRT and Setup margins
100 % of the respondents said SGRT has resulted in reduced setup margins in breast cancer patients. 50% of the

respondents (R3US, R4DE) said SGRT has resulted in reduced setup margins in lung cancer patients. Results are shown in Fig. 17.

Fig 17: Reduction in setup margins with AlignRT® and Catalyst

10. SGRT and Inter and intra-fractional motion
50% of the respondents (R2US, R4DE) said yes. R1US said No and R3US said do not know. Results are shown in Fig. 18

Fig 18: Intra & inter-fractional motion management with AlignRT® & Catalyst
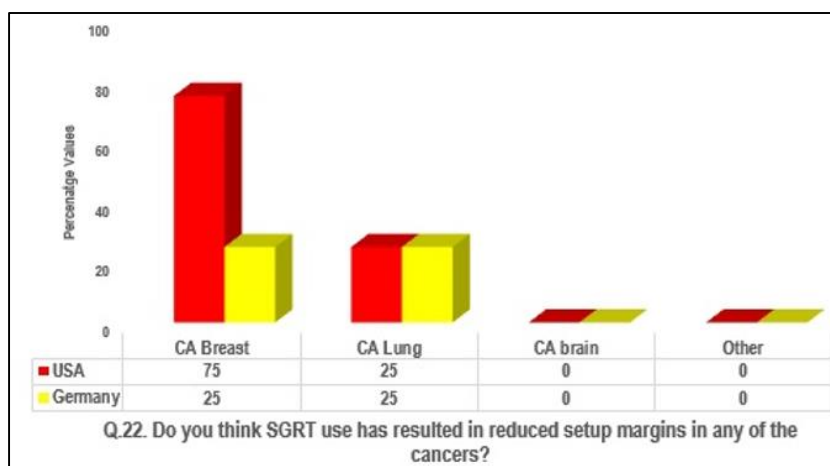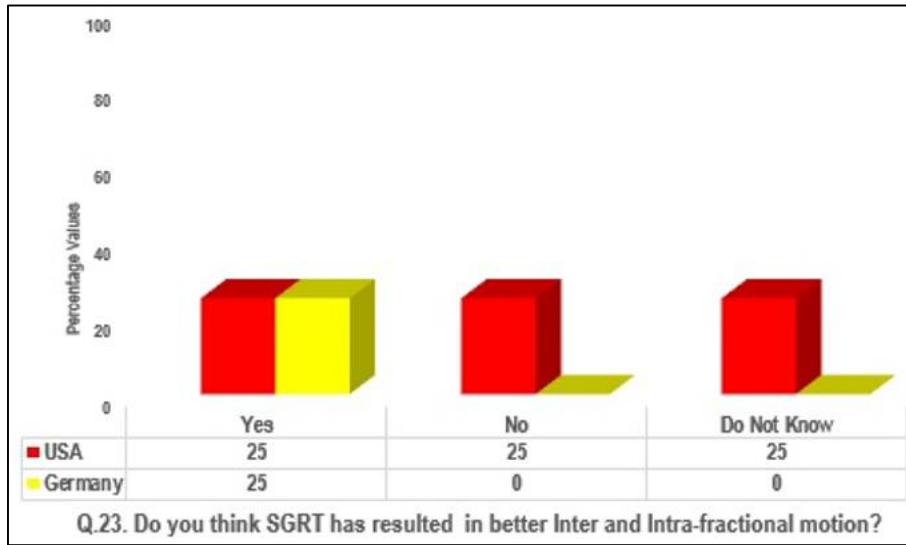
E. Proton Therapy System Information and Problems associated with AlignRT®
In this section questions related to Proton therapy system and problems with AlignRT® were asked.

1. Type of Proton Therapy system
R1US said Mevion S250 Proton Therapy system, R2US said IBA (Author has assumed they meant IBA Proteus) and R3US did not give any answer. R34DE said Varian Probeam. Results are shown in Fig. 19
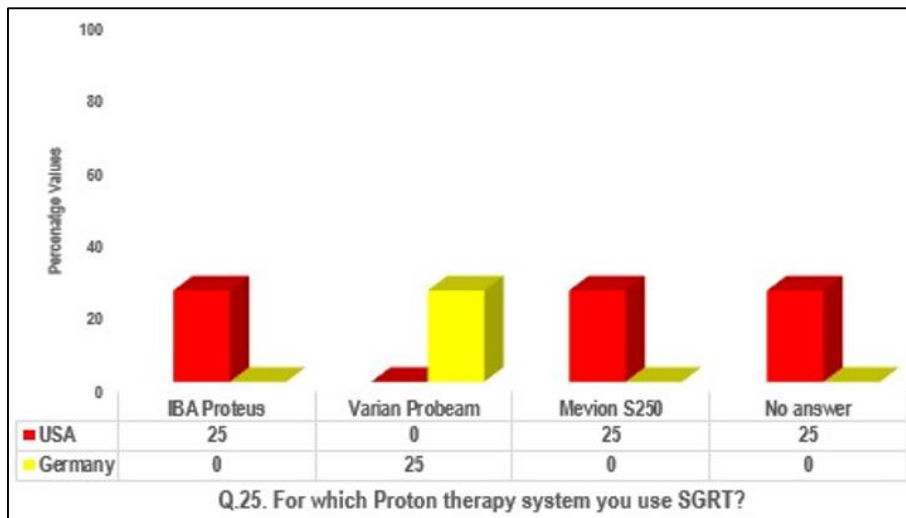
Fig 19: SGRT and Proton therapy system

2. Real-Time Tracking
R4DE (25%) from Germany said yes whereas R1US and R2US (50%) said No. R2US further said it find real time tracking useful but not sure about the accuracy of the internal organs. Author has taken his answer as a No. R3US (25%) did not give answer.

3. Problems with AlignRT®/Vision RT
R1US (25%) said there is a lack of compatibility with the proton therapy delivery system components. The snout that is extended at the treatment position, obscures surface anatomy from infrared cameras. The treatment room is cold and patients can not be left uncovered for accurate alignment and surface tracking. R2US said when cameras are bumped we can not recalibrate ourselves. R3US said no answer. R4DE said positioning of SGRT systems is problematic i.e. facility room and gantry are different than in conventional Radiotherapy. He further mentioned gating requires much faster reaction time. Results are shown in Fig. 20

Fig 20: Problems with Align RT® & Catalysts

4. Couch Deviations
Results are shown in Table III. 50% of the respondents do not answer the question. 25% said yes and 25% respondents do not use Align RT® but use CRAD instead.

Table 3: Answers to Q.28

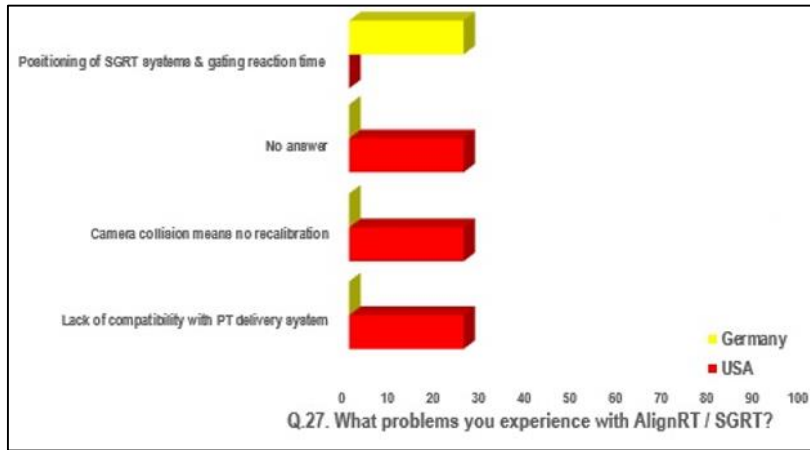| Respondents	Q.28. Do you find any couch error/deviation when using Align RT® or SGRT?
R1US	Yes, sometimes when the proton components interfere with infrared camera on patient surfaces
R2US	Does not use Align RT®. Use CRAD that does not have offline Review
R3US	No answer
R4DE	No answer

5. Arm positioning in breast cancer patients
25% of respondents consider AlignRT® useful in arm positioning if there are clear tolerances set. 25% of the respondents uses CRAD and finds this SGRT system specially good in this respect. 50% of the respondents did not answer. Results are shown in Table IV.

Table 4: Answers to Q. 29

Respondents	Q.29. Do you think arm positioning and surface alignment using Align RT® in Breast Cancer is perfect or do you experience any problems?
R1US	It's definitely not perfect but is helpful in patient setup and arm positioning, If there are clear tolerances set for surface alignment in relation to bony anatomy and clear indication of which tolerances are acceptable and which are not.
R2US	CRAD is particularly good on this as it does project by how much arms need to be moved and where it is off.
R3US	No answer
R4DE	No answer

6. OSMS Tracking system
Results are shown in Table V.

Table 5: Answers to Q. 30

Respondents	Q.30. Do you think OSMS / tracking system captures smaller patient movements very well in lung cancer, breast cancers and sarcomas?
R1US	No
R2US	Yes in breast cancer. Do not have experience with other sites.
R3US	No answer
R4DE	Yes for positioning

Discussion
The present study is different from other studies as it has tried to uncover the current status of AlignRT® and C-Rad Catalyst based Surface guided RT in four Proton Therapy Radiation Oncology Centres/hospitals in USA and Germany. All of the respondents had SGRT in their organization. Half of the respondents have been using SGRT for 5 years.

The present study has shown that SGRT offers complementary information and cannot replace entirely KV or MV based Image guided Radiotherapy. The current study also showed that SGRT is used in combination with IGRT such as CBCT and KV orthogonal IGRT. Padilla *et al.* 2019 also argue that SGRT provides complementary and not contradictory information for image guidance and therefore despite the lack of correlation between surface and internal tumour motion, SGRT should not be rejected.

Majority of respondents reported Vision RT as their vendor that supplied AlignRT® SGRT system. In One respondent's institute C-Rad, Uppsala acted as SI vendor and supplied Catalyst SGRT system.

The results of the present study show that SGRT is most commonly used for Breast cancer patients followed by lung, liver, pancreas and mediastinum cancer patients.

The study by Padilla *et al.* [14] also reported Vision RT, Varian OSMS and C-Rad as SGRT vendors while SGRT most commonly was used in Breast cancer patients. A

number of IG modalities such as KV imaging, MV imaging, CBCT or CBCT on rails and fluoroscopy were used to verify SI Gated position during the treatment.

A large proportion of respondents (75%) reported that SGRT (both AlignRT® and C-Rad) usage did not result in needing more staff. The data on number and type of professionals required to give SGRT based treatment is varied. Half of the respondents specified that in order to give SGRT based Radiotherapy treatment one Medical physicist, two radiation technologists and one dosimetrist are required.

Majority of the respondents found implementation and integration of SGRT complicated and confusing especially if procedures are not well defined. The present study showed that respondents faced various challenges when implementing SGRT for Proton Therapy. These challenges included time delay in Proton therapy, lack of QA guidelines, training and knowledge. This probably indicates the need for well-defined SGRT implementation and usage guidelines and perhaps standardization of SGRT usage and implementation protocols. This is in line with the recommendations of study conducted by Padilla et al. [14] that concluded guidelines and recommendations on commissioning and clinical use are needed to handle slow uptake of SGRT technology.

In a review conducted by Batista et al. [15] one of the challenges in implementing SGRT is the training and transition from using conventional 3 point setup to more complicated setup data and this can be managed by introducing SGRT related concepts such as troubleshooting, creation of clinical work flows and patient specific issues in the scope of RTT training. Author of the present study thinks that same sort of SGRT based training and educational modules should be introduced in the curriculum and training of Medical Physicist and oncologists. Other methods described by Batista et al. [15] to improve SGRT training is by permitting sufficient time to practice, by removing other distractions so that clinical team can focus and acquire new knowledge, using SGRT in one cohort of patients (e.g. breast cancer patients) or learning about one of the applications of SGRT (e.g. use of SGRT for initial patient setup) before moving on to other cohorts of patents (lung cancer patients) and applications of SGRT (e.g. intra-fraction monitoring), vendor based training and assistance during commissioning and clinical implementation and vendors should communicate system and work flow pitfalls upfront to avoid violation of trust between users and vendors.

The reasons for SGRT technology adoption in the present study included online monitoring of patient positioning, to reduce patient X-ray exposure, to reduce treatment time, to achieve more precise treatment delivery and for clinical research purposes. A prospective study by Zagar et al. [16] showed that RT treatment with AlignRT® and DIBH in 18 left sided breast cancer patients resulted in no RT-induced cardiac perfusion abnormalities 6 months post-RT. The results are based on Post-RT SPECT in 8 out of 16 evaluable patients. The mean heart does in all 18 patients was very low (range from 42 – 160cGy). A study by **Marks et al. [17]** without AlignRT® and DIBH resulted in 27% of the breast cancer patients developing volume dependent perfusion defects 6 months post-RT. 10-20% of the patients developed perfusion defects post-RT if less than 5% of the left ventricle volume was in the radiation field whereas 50-60% of the patients developed perfusion defects if more than 5% of the left ventricle was in treatment field. A case study of Northside Hospital Cancer Institute, Alpharetta was conducted to assess how AlignRT can improve treatment and work flow challenges. The study resulted in 50% decrease in patient treatment block times as a result of less frequent repeat imaging and more accurate initial setup with AlignRT®, 50% reduction in initial setup and verification appointment times and 14% reduction in tattoo-free in-room time [18].

The present study found a number of improvements that respondents want to see in SGRT system such as really fast reaction time with a total delay < 20ms, offline review and better Database management. This is something vendors need to work on to make SGRT more useful and accurate.

As far as inter and intra-fractional motion is concerned mixed responses were received with 50% of the respondents said that better inter and intra-fractional motion was achieved with SGRT whereas 25% said no and another 25% did not know. Similarly 50% of the respondents did not find SGRT based real time tracking accurate.

In the present study respondents found lack of compatibility of SGRT with proton therapy system components, camera collision and recalibration issues and slower reaction times in gating were some of the problems experienced by the respondents when using SGRT.

Translational errors can be rectified by moving treatment couch in Right and Left direction (i.e. laterally), in Superior and Inferior direction (i.e. longitudinally) and in up and down direction (i.e. vertically) in most Radiotherapy treatment machines [19] where as rotational setup errors can be fixed by moving gantry and collimator to correct for target movements [20] or by using 6D reposition device such as 6D couch.

In this study translational setup uncertainty was 3mm (25%) with AlignRT®, 5mm or less (25%) with AlignRT® and 8mm (25%) with C-Rad Catalyst in breast cancer patients in 3 proton therapy Radiation centres in USA i.e. in hospital in Cleveland, cancer institute in Miami and Academic institute in Iowa, USA respectively whereas Translational setup uncertainty was 3mm and 5mm or less in lung cancer patients in hospital in Cleveland, Ohio and Academic institute in Iowa, USA. A study found that smaller CBCT based 3D positional corrections are required for breast, Pelvis, abdominal and chest cancer patients when initially aligned with C-RAD Catalyst HD than those aligned with subcutaneous tattoos [21]. The results were statistically significant (p< 0.001). Breast cancer patients were found to have an average of post-CBCT 3D corrections of 1.4 cm and **0.6 cm** and standard deviation of 0.7 and 0.2 cm in three point localization and Surface imaging respectively. Chest and upper extremities patients were found to have an average of post-CBCT 3D corrections of 0.9 and 0.5 cm and Standard deviation of 0.6 cm and 0.3cm for three point localization and C-RAD Catalyst imaging techniques respectively. In the present study C-RAD based patient positioning in breast cancer patients reported 8mm translational setup uncertainty which is slightly higher correction reported by [21]. This could be due to the difference in registration technique and IGRT technique e.g. RIUS in Miami Cancer institute used deformable registration technique in SGRT and C-RAD positioning was confirmed using KV orthogonal and CBCT later.

In this study residual setup error (RSE) was found to be 3mm when using AlignRT® and C-Rad SGRT systems in breast cancer patients. A study by Laaksomaa et al. [11] found the systematic residual errors of the bony structures 3mm or less with SGRT-only in AlignRT® and Catalyst groups in DIBH

treatment of breast cancer patients. The study also found reduction in systematic error of 2mm or less (except for shoulder joint) in both groups when SGRT was used with daily IGRT. The same study concluded that a heart planning margin of 3-7mm may be required due to errors in Pitch and superior/inferior direction.

A study by Jimenez *et al*. [22] compared the accuracy of tattoo based setup to a tattoo free patient setup using AlignRT® in 20 APBI patients. They found statistically significant mean 3D vector shifts for initial setup for patients in the no tattoo compared to tattoo group whereas individual vector directions were not different between the two groups (shifts for Initial setup). Random and systematic errors were larger in the no tattoo group especially in superior/inferior direction due to absence of tattoos to lead patient alignment. However these errors were compensated by surface imaging prior to IGRT. Mean 3D vector shifts detected after Xray imaging data for patients in the No tattoo group compared to tattoo group were not statistically significant i.e. 4.6mm vs. 5.9mm respectively. Similarly Random and systematic errors were also not statistically significant.

A word of caution: Author of the present study did not find LinkedIn platform very reliable and it resulted in lose of some data due to unreasonable behaviour of LinkedIn team. For future studies Author recommend that if anyone wants to use LinkedIn platform to distribute E- questionnaire or to communicate with or recruit the participants of a study, make copies of all the correspondence in some other media as data can be lost at any time. Secondly Author of the present study recommend that other professional bodies (e.g. American Association of Medical Physicists and American society of Radiation Oncology and ASTRO) in USA and other professional bodies in rest of the world, must develop social media platforms with equal and /or better capabilities than current social media platforms so that there is no need to rely on a handful of social media as there is a tendency for current social media platforms to exercise undue power and authority over accounts of professionals.

Limitation of the study and Future Directions
The present study involved only 4 case studies which is a limitation of the present study. Although the study has shown the current status of SGRT in 4 Proton therapy institutes and have provided valuable information, these views and opinions are not representative of entire radiation oncology world. Studies involving more Proton therapy institutes and Radiation oncology professionals working there are needed. Studies involving Quality of life of patients undergoing SGRT treatment are needed to see psycho-social effects of this technology on the patient.

Conclusion
The current status of AlignRT® and Catalyst as shown by four case studies is that it is used to complement IGRT and at present professionals do not think it can entirely replace IGRT such as KV orthogonal imaging or CBCT. A number of improvements in AlignRT® are suggested by the respondents such as fast reaction times. A number of challenges were identified by the respondents in the present study such as lack of compatibility of SGRT with proton therapy system components, camera collision and recalibration issues and slower reaction times in gating.

Majority of respondents found implementation of AlignRT® in the department complicated and there seems to be need for well-defined SGRT implementation and usage guidelines and perhaps standardization of SGRT usage and implementation protocols. All of the respondents found that SGRT resulted in reduced setup margins for breast cancer patients. Two of the most common reasons for SGRT adoption were to reduce treatment times and to achieve more precise treatment. Couch errors and deviations were found with AlignRT® when used with proton therapy. AlignRT® and catalyst are found to be useful in breast and lung cancer patients as well as in liver, mediastinum and pancreatic cancer treatment. 50% of the respondents reported 3mm residual setup error for breast cancer patients using both AlignRT® and Sentinel / Catalyst C-Rad SGRT systems. SGRT based training and educational modules should be introduced in the curriculum and training of Medical Physicist and Radiation oncologists.

Supplementary Data: Supplementary data related to this article can be found below:

Appendix A: A sample Questionnaire

SGRT: Survey

This survey is conducted to determine the current status of Surface guided Radiotherapy (SGRT) technology in Proton therapy Radiation oncology. The survey is mainly a multiple choice questionnaire and I would greatly appreciate if you could take some time to complete it.

It consists of 30 questions. It will take 10-15mins of your time to fill it in depending on your experience. For open ended questions please write your answer in the space provided after each question. For multiple choice questions simple either circle or tick mark or high light the option or options that best applies to you or just type your answer (e.g. to answer Q1 you can write/type B). The survey is anonymous so no personal information is collected. However demographic information is collected.

The survey has following sections:

1.   Demographic

2.   Institutional background/ organizational/ clinical resources

3.   SGRT technical info

4.   Proton therapy system info

The survey is designed in MS word so you can type your answers in the doc or docx file and save your responses before returning the completed survey. Participation in this study is entirely on voluntary basis. If you need assistance in understanding survey questions please do not hesitate to contact principal investigator. The principal investigator is Medical physicist, therapy radiographer and radiation protection supervisor. Please submit your responses as soon as possible or by **20th June 2020. By filling this survey you give your informed consent to use your views anonymously for research and academic purposes.** The results of survey will be shared with you if you wish to know them. Please return the completed survey to: Principal investigator by email taqaddas2018@gmail.com

Demographic Information

Q.1 Gender of the Respondent

A.   Male

B.   Female

Q.2 Age

A.   Less than 30 years

B.   30-40 years

C.   40-50 years

D.   50-60 years

E.   Above 70 years

Q.3 Marital status

A.   Single

B.   Married

C.   Divorced

D.   4. Separated

Q.4 Occupation (Please state your occupation):

A.   Radiation oncologist
B.   Medical Physicist

C.   Radiation/ Radiotherapy Dosimetrist

D.   Research medical physicist

E.   Director

F.   Other (Please specify):

SGRT institutional background & organizational resources:

Q. 5. Location: city, country of your institution?

- City

- Country

Q.6. Type of Practice

A.   Academic practice/ centre
B.   Private practice/ centre
C.   Public
D.   Not for profit
E.   Other: please specify
F.   Do not know

Q.7. Do you use SGRT in RT delivery?

- Yes

- No

Q.8. What type of SGRT technology you employ in your department e.g. Vision RT/ Align RT?

A.   Vision RT/ Align RT

B.   Other (Please Specify):

Q.9. Do you think SGRT usage has resulted in needing more staff?

- Yes

- No

- Do not Know

Q.10. How many professionals are involved in SGRT treatment delivery (e.g. Radiation oncologist : 1)?

A.   Medical physicists
B.   Radiographers
C.   Radiation technologists
D.   Dosimetrists
E.   Radiation oncologists
F.   Other (Please specify)

Q.11. How would you like to describe implementation and integration of SGRT in treatment delivery:

A.   Easy
B.   Complicated
C.   Time consuming
D.   Do not Know
E.   Other (Please specify):

Q.12. What challenges did you or your institution faced when implementing SGRT for PT? Please select all options that apply to you.

A.   Lack of knowledge/ Difficulty acquiring required SGRT knowledge
B.   Lack of training
C.   Shortage of guidelines for cyber knife treatment planning for various cancers
D.   Shortage of QA guidelines for cyber knife setup and implementation.
E.   Financial
F.   Lack of personnel
G.   Complex QA/Commissioning programme
H.   Others (please specify):

Information about SGRT

Q.13. How long you have been using SGRT to give treatment?

A.   Less than 6 months
B.   1 year
C.   5 years
D.   10 years
E.   Others (please specify)

Q.14. Do you use rigid or deformable registration in SGRT?

Q. 23. Do you think SGRT has resulted in better inter or intra fraction motion?

- Yes
- No
- Do not Know

Q.24. Do you think SGRT can replace entirely KV or MV imaging in accurate patient setup?

- Yes
- No
- Do not Know

Proton therapy system info

Q.25. For which Proton therapy system you use SGRT e.g. IBA, Hitachi or other?

Q.26. Do you find real time tracking provided with SGRT accurate, useful and easy to use?

- Yes
- No
- Do not Know

Q.27. What problems you experience with Align RT/ SGRT?

Q.28. Do you find any couch error/ deviations when using Align RT?

Q.29. Do you think Arm positioning and surface alignment using align RT in Breast cancer patients is perfect or do you experience any problems e.g. moving or repositioning patient arm in breast cancer patients ?

Q.30. Do you think OSMS / tracking system captures smaller patient movements very well in breast cancer, lung cancer and sarcomas?

Thank you for your time.

Q.15. How much translation setup uncertainty you have found with use of SGRT for following cancers:

	AP	RT/LT	SUP/INF
Ca Lung			
Ca Breast			
Brain Cancer			
Other (Please Specify)			

Q.16. How much residual setup error (RSE) you find with SGRT e.g. 4mm?

	RSE
Ca Lung	
Ca Breast	
Brain Cancer	
Other (Please Specify)	

Q.17. For what cancers you find SGRT useful and accurate in treatment?

A. Breast cancer
B. Lung
C. Brain
D. Other: please specify

Q.18. Why did you adopt SGRT?

A. To achieve dose escalation
B. To reduce set up margins (CTV, PTV, TV)
C. To achieve more precise treatment delivery
D. To get better local control rates
E. To reduce treatment time
F. For retreatment
G. Clinical research
H. To gain a competitive edge
I. Others (Please specify)

Q. 19. What SGRT system consists of?

Q.20. Do you use SGRT in combination with other IGRT techniques e.g. CBCT, KV orthogonal imaging?

Q.21. What improvements you want to see in SGRT system?

Q.22. Do you think SGRT use has resulted in reduced setup margins (CTV, PTV) in any of the following cancers:

A. Ca breast
B. Ca lung
C. Ca brain
D. Others (please specify):

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