Research article

Take Action Protocol: A radiation therapist led approach to act on anatomical changes seen on CBCT

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A B S T R A C T

Until recently Traffic Light Protocols (TLP) have been developed to recognize and react to Anatomical Changes (ACs) seen on Cone Beam Computer Tomography (CBCT) scans for the most common treatment sites. This involves alerting the Radiation Oncologist (RO), handing over findings, and RO providing the final decision, making it quite labour-intensive for the ROs as well as the Radiation Therapists (RTTs). A new approach was developed to act on ACs: the Take Action Protocol (TAP). In this protocol the RTTs do not only have a role in detecting ACs, but also decide on the appropriate action and follow up, resulting in a significant shift in responsibility. In this study we present the TAP and evaluated the benefit and outcomes of the implementation of TAP compared to the TLP. During a pilot period of six months the TAP was applied for 34 bladder and prostate patients. In 2 bladder and 6 prostate patients further decision making by an RO was required (compared to all 34 in the TLP), showing a large reduction in workload. ACs were accurately assessed by RTTs in >99% of the cases. In 5/34 patients RTTs specialized in Image Guided Radiotherapy provided additional instructions to improve accurate use of the TAP. Two surveys conducted by both ROs and RTTs on the TLP and TAP showed that the perceived involvement of the ROs and burden of responsibility for RTTs was comparable between the two protocols. The identification of patients with truly clinical relevant ACs and the adaptation of treatment for the remaining fractions improved according to ROs and RTTs responses. The TAP provides a better balance between workload and efficiency in relation to the clinical relevance of acting on ACs.

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Introduction

Since 2005 Cone Beam Computer Tomography (CBCT) image guidance is routinely used in our department for Image guided radiotherapy (IGRT) [1]. The appearance of Anatomical Changes (ACs) has become an important aspect of our IGRT workflow. Several studies report ACs for different treatment sites during the course of radiotherapy, which may affect the dose distribution or the outcome [2–6]. For predictable ACs, adaptive strategies can be very helpful to reduce the impact of ACs, e.g. prostate adaptive radiotherapy (ART) and Library of Plan (LoP) strategies for cervix and bladder cancer patients [7–11]. But for unexpected ACs a decision support protocol could help to determine whether for example unscheduled plan adaptation is required.

In our institute a decision support protocol was developed to guide the radiation therapists (RTTs) in prioritizing and reporting

ACs. This so called Traffic Light Protocol (TLP), initially developed for lung cancer treatment, is currently used for several treatment sites [2–6,12]. All CBCTs are screened for ACs by RTTs after performing image registration for set-up verification. According to this protocol, if AC's occur, the Radiation Oncologist or Physician Assistant (referred further to as RO) is alerted. RTTs report the information to the RO, and the RO follows up and reports the decision to RTTs.

For both ROs and RTTs the TLP proved to be quite labour-intensive due to the many steps described in the protocol. The decision for many cases could be left to RTTs. This would potentially reduce the workload for ROs and RTTs and allow a quick, smooth and adequate response for the most clinically relevant ACs leading to a new approach to act on ACs: the Take Action Protocol (TAP). In this protocol RTTs do not only have a role in detecting ACs, but also have an advanced role as they are deciding on the appropriate action and follow up in a standardized way, resulting in a significant shift in RTT responsibility.

In this study we present the TAP and evaluated the benefit and outcomes of its implementation compared to the TLP. The topics

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evaluated are: the accuracy of the reviewing and decision making by RTTs and the perceived burden of this increased responsibility for RTTs. Furthermore the impact of applying the TAP on workload (in relation to the clinical relevance), logistics, involvement of the ROs, and adequate responses to ACs were evaluated.

Methods and materials

Patient selection

During a pilot period from September 2017 to February 2018 the TAP was applied to patients with prostate (bed) radiotherapy (with/without elective lymph nodes) and entire/partial bladder radiotherapy. All patients were treated with Volumetric Arc Therapy. Several treatment regimens with/without chemotherapy were included. Dose schemes applied for prostate/prostate bed were typically 35 or 19 fractions and for the bladder 20 or 25 fractions. Patients with a palliative regimen or stereotactic radiotherapy were excluded from this study. Institute protocols prescribe using online (bladder and prostate patients) or offline (prostate (bed) and lymph node) 3D CBCT imaging. For the bladder patients a LoP strategy was used. A shrinking action level protocol was applied for offline imaging ($\alpha = 6$, N = 2) [13]. Data collection was approved by our Institutional Review Board.

Take Action Protocol (TAP)

In collaboration with ROs, physicists and a specialized IGRT RTT a TAP was designed for ACs frequently seen in the already clinically applied TLP for urological tumors. For prostate cancer patients frequently seen changes are: CTV outside PTV (due to varying bladder and rectal filing), lymph node progression and pelvic contour changes [14–16]. For bladder cancer patients commonly seen changes are: CTV outside PTV (due to varying bladder filling), pelvic contour changes and rapid increasing bladder filling during treatment [17–19]. The latter is important, as it should be taken into account when choosing a treatment plan from a LoP.

The Take action protocol consists of two elements (Fig. 1):

(1) A primary guideline describes how to act on the AC for online CBCT. Prior to the actual treatment a decision is made, whether an intervention is necessary to reduce the dosimetrical impact of the AC or if the appearance of the AC needs to be reviewed on the CBCT in the next fraction.
(2) When the AC appears to be systematic (e.g. CTV is out of PTV > 3 fractions), a flow chart guides the decision regarding the following fractions. This decision can be made after the actual treatment, unless the ACs have a large impact on the treatment, then the RO, physicist, dosimetrist or IGRT RTT will be consulted.

Fig. 2 demonstrates the steps taken to reach a decision in both the TLP and the TAP in a clinical example of the prostate being 3 fractions outside of the PTV caused by less rectal fill.

In preparation for the pilot a group of RTTs, already trained in performing IGRT of pelvic treatment sites, using the TLP and subsequently in recognizing ACs in this group of patients, was additionally instructed on the TAP and specifically on the use of the flow chart by the IGRT RTT involved in the design of the TAP.

Evaluation of the pilot

To evaluate the pilot patient scans were analyzed to assess the quality of applying the TAP and a survey was conducted among the ROs and RTTs to assess the use of the TAP.

To assess the accuracy of the reviewing and decision making by RTTs using the TAP, all CBCT images of all patients treated during the pilot were retrospectively reviewed daily by a group of IGRT RTTs, with the observations of the IGRT RTTs being the ground truth. The fractions, where ACs were incorrectly found (false positive) and missed ACs (false negative), were scored. The correct use of the TAP was evaluated, when ACs were present and required an action. If necessary additional instructions were provided by the IGRT RTT to improve the accurate use of the TAP before the next fraction. The number of additional instructions was scored to assess the accuracy of the decision making by RTTs.

An open survey was designed and sent to the RO urology team with questions how workload (in relation to the clinical relevance), logistics, involvement and improvement of the treatment was experienced. The open survey was also sent to the group of trained RTTs, who worked with the TAP during the pilot (suppl. Tables 1 and 2). The survey was performed before the pilot as a baseline measurement regarding the TLP and was repeated for the TAP after finishing the pilot in the same group of ROs and RTTs.

In order to investigate the use of the TAP on the workload, the amount and type of ACs, the number of interventions prior to treatment and the number of actions to improve the remaining fractions of the treatment were quantified.

Results

The patient and treatment characteristics for 22 bladder and 56 prostate (bed) patients included in the pilot study are shown in Table 1. In 16/22 (73%) bladder and 18/56 (32%) prostate patients relevant ACs requiring RTT attention were seen on CBCT (Table 2). For 21/501 (4%) fractions in bladder patients an online intervention was required. This consisted of re-setup of the patient following additional bladder instructions (wait for filling or voidance of the bladder) and acquisition of additional post radiotherapy scans to validate bladder inflow during treatment. Online interventions were performed in 13/1844 (1%) fractions for prostate patients, mainly due to air in the rectum requiring a flatulation tube to remove the air.

In 6/16 (38%) bladder patients with ACs a decision was made by an RTT to provide a solution to reduce the impact of the ACs for the remaining fractions. In 3 patients a treatment plan was added to the library to adapt for the decrease in bladder filling during treatment. In the other 3 cases instructions to choose a plan from the LoP was adapted to account for the rapid increase of bladder filling during the treatment. In 8/18 (44%) prostate patients with ACs treatment adaptation was required consisting of: repeating, postponing or proceeding the ART procedure, or the prescription of laxatives. In the 20 remaining patients the ACs had a random character and did not require a decision. In only 2 bladder (6%) and 6 prostate (18%) patients further consultation with an RO was required (Table 2), while according to the TLP this would have been all 34 patients (100%), showing a large reduction in workload for ROs.

Of the total amount of 1266 CBCTs, 1254 CBCTs (99.1%) were reviewed accurately by RTTs (Table 3). In 5 CBCTs (0.39%) an AC was incorrectly scored (false positive) and in 7 CBCTs (0.55%) an AC was present but not scored (false negative). In 5/34 patients it was necessary for the IGRT RTT to provide additional instructions to improve the accurate use of the TAP; which was in most patients advice or instructions on applying the flow chart to proceed with the decisions made described in the previous paragraph.

A summary of the results of the surveys using the TLP and the TAP are shown in Fig. 3. All results can be found in supplementary Table 1. The survey concerning the TLP was completed by 4 ROs and the TAP by 2 ROs. There were 32 RTT respondents for the
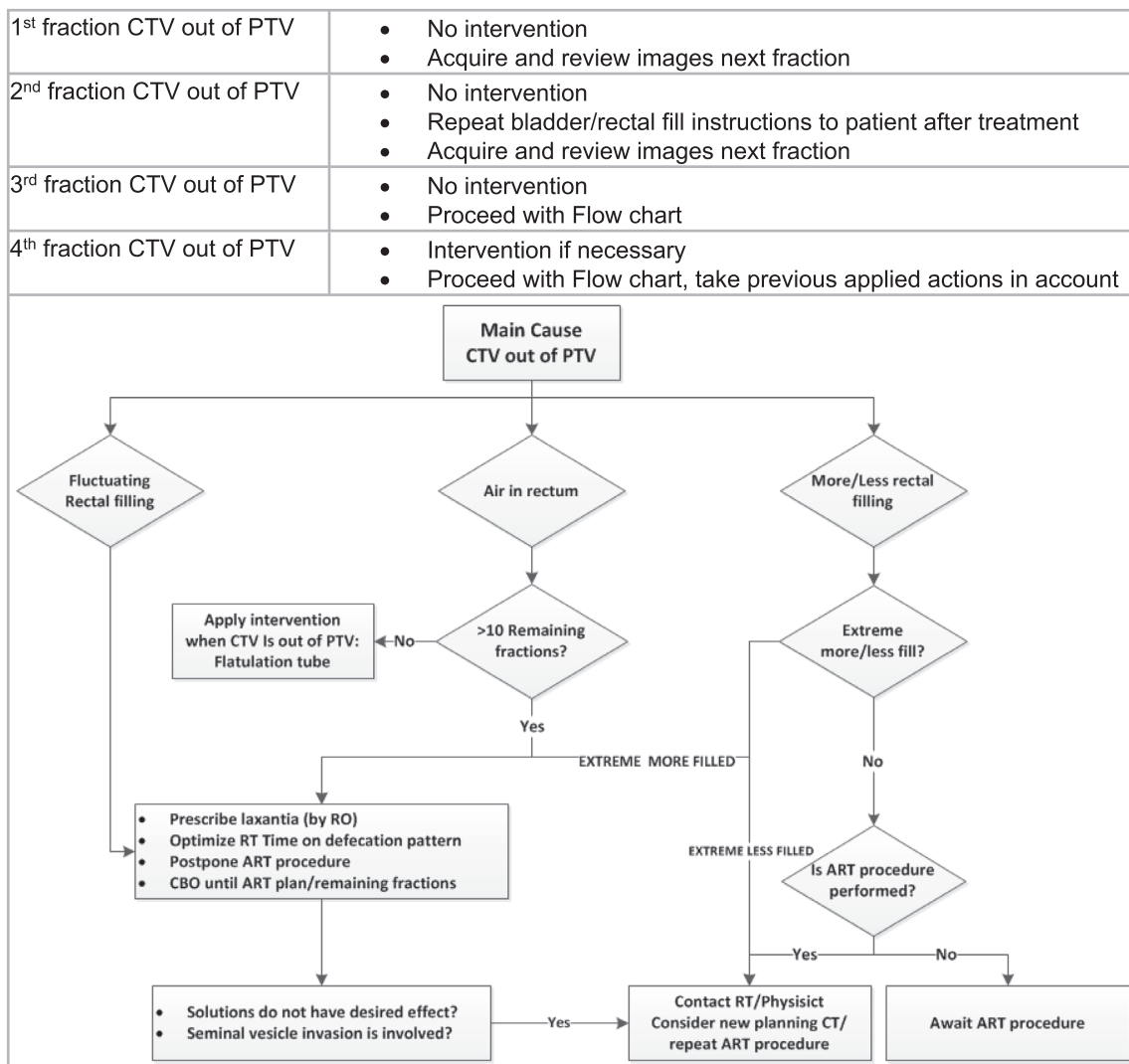
1st fraction CTV out of PTV	• No intervention • Acquire and review images next fraction
2nd fraction CTV out of PTV	• No intervention • Repeat bladder/rectal fill instructions to patient after treatment • Acquire and review images next fraction
3rd fraction CTV out of PTV	• No intervention • Proceed with Flow chart
4th fraction CTV out of PTV	• Intervention if necessary • Proceed with Flow chart, take previous applied actions in account

Fig. 1. Example of a Take Action Protocol for the prostate. Abbreviations: CTV = Clinical Target Volume, PTV = Planning Target Volume, ART = Adaptive radiotherapy, CBO = Cone Beam Online.

TLP and 18 for the TAP. The group of RTTs, who found the increased responsibility of handling ACs sometimes burdening, increased somewhat from 26% to 47% (Fig. 3d). For both protocols >50% of the responding RTTs reported that bearing the increased responsibility was acceptable.

The results of the surveys show that both RTTs and ROs found the workload and efficiency of the TAP more in balance in relation to the clinical relevance of acting on ACs compared to TLP (Fig. 3e). The logistics around the TAP were found to be more efficient by the ROs (Fig. 3a). For RTTs the change in efficiency was less well-defined. The identification of patients with truly clinical relevant ACs and the adaptation of treatment for the remaining fractions improved using the TAP for both ROs and RTTs (Fig. 3b and c).

Discussion

In this study the TAP is presented as a new method to act on ACs. ACs are often seen on CBCT scans during treatment. This study and several other studies report (high) prevalence of ACs in case of bladder, prostate, lung, esophageal, head&neck cancer and extremity soft tissue carcinomas [2–6,12]. In 25–59% of these ACs further decision making by the treating RO was required [3,12]. The Traffic

Light Protocol (TLP) was introduced into the clinic as a decision support for ACs in lung cancer treatments [2]. This has rapidly expanded to other treatment sites and to other institutes [4,6,12].

The TLP has proven to be a clear decision protocol to inform the RO of findings seen on the CBCT, to evaluate the visible ACs on CBCT and assess the impact of these on the treatment. But TLP was also found to be quite labour intensive by the ROs and RTTs. This was confirmed by the results of the survey, performed as part of this study. 50% of the responding ROs and 47% of RTTs found the workload of applying TLP (much) more than was justified by the clinical relevance of the observed changes (Fig. 3e).

The amount of plan adaptations was quite low relative to the amount of scored ACs. Belderbos et al reported 13% of patients in their study received an unscheduled adaptive treatment [3]. Other studies showed that in only 6% of the head and neck patients, in 8% of the extremity soft tissue carcinoma patients and in no esophageal cancer patients were plan adaptations required. [4,6,12]. The TAP was developed in a multidisciplinary setting using the large amount of experience and knowledge gained in recognizing and acting on ACs to improve the balance between the workload in performing interventions, alerting ROs and plan adaptations in relation to the clinical relevance. The flow
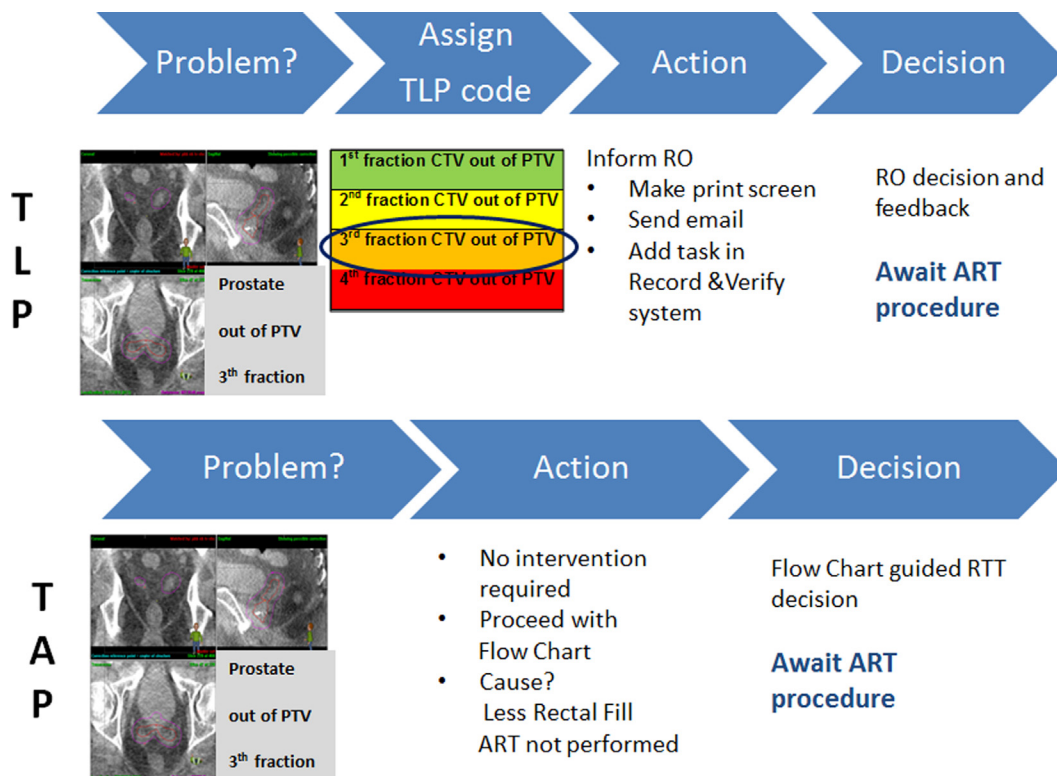
Fig. 2. Comparison steps TLP and TAP. Abbreviations: CTV = Clinical Target Volume, PTV = Planning Target volume, TLP = traffic light protocol, TAP = Take Action Protocol, ROs = Radiation Oncologist, RTT = Radiation technologist, ART = Adaptive radiotherapy.

chart in the TAP guides the RTT to make a decision for the following fractions resulting in a more standardized approach and uniformity in acting on ACs. When using the TLP, this solution was very RO dependent.

In this study the TAP was evaluated after applying this new approach in a pilot setting during a 6 months period. The results showed a large improvement in the workload in alerting and acting on ACs compared to the TLP. An RO was alerted to decide on plan adaptations in only 19% of bladder and 22% of prostate patients with ACs, whilst according to the TLP an RO would have been alerted for all patients. The workload was reduced for RTTs, as in the other 81% and 78% of patients the findings did not require consultation with an RO. However, the amount of interventions on the linac increased due to the TAP. In 8 (50%) bladder and in 3 (17%) prostate patients an online intervention was required to reduce the impact of the AC on the dose distribution (e.g. voidance of bladder, placing a flatulation tube). The amount of fractions, in which the interventions needed to be performed, was quite limited (for bladder in 4% and prostate in 1%), but still clinically relevant to improve the coverage of the target.

According to the results of the survey the RO's and RTTs found that the TAP improves the balance between workload and clinical relevance of interventions. Moreover, the use of the TAP also leads to improved identification of patients with truly clinical relevant ACs and consecutively to an improvement in adapting the treatment for the remaining fractions.

In the previously mentioned studies the ACs were reviewed by an RO often in consultation with a physicist. In the TAP RTTs do not only have a role in detecting ACs, but they also make the decisions on the appropriate action and follow these through. This provides a more advanced role and significant increased responsibility for

RTTs. The success rate of recognizing ACs by RTTs was >99% (Table 2), which is due to the >10 years' experience in using the TLP in our department. In 5/35 patients it was necessary for the IGRT RTT to provide additional instructions to improve the accurate use of the TAP. These were in most patients advices or instructions on applying the flow chart and proceeding with decisions given prior to the next fraction, resulting in an adequate response for these patients. Applying the flow chart is a new element for the RTTs and therefore additional instructions were mostly necessary during the first weeks of the pilot period, demonstrating a learning curve for RTTs on interpreting the TAP. We are highly confident in the accuracy of reviewing and decision making by RTTs.

Several studies have shown RTTs work as accurately as ROs in other fields within the scope of radiotherapy, for example: delineation of CTV or seroma in breast irradiation, RTT led pathway for palliative radiotherapy, patient assessments, and triaging of skin cancer patients [20–24]. In these studies the roles were specifically performed by a clinical specialist RTT, who had received site specific education and clinical training from an RO. This was not the case in this study, as image verification and screening for ACs was already a responsibility of the RTT in our department. A more comparable study was done by Alexander et al, in which the concordance between ROs and RTTs for CBCT image reviewing in IGRT of cervix cancer was examined. The image reviewing focused on offline verification and decision making. RTTs and ROs agreed in 96% of the reviewed images [25].

The shift in responsibility in deciding how to act on ACs from RO to RTT is an important issue. A small group of RTTs found the responsibility somewhat more taxing, but the majority of RTTs found working with the TAP satisfactory. During a team meeting the results of this study were discussed with the RTT's participat-

Table 1
Patient and Tumor characteristics.

Characteristic	Number (%) of patients	Characteristic	Number (%) of patients
Primary Diagnosis		*Primary Diagnosis*	
Bladder	22 (100%)	Prostate	56 (100%)
Gender		*Age (y)*	
Male	14 (64%)	≤50	1 (2%)
Female	8 (36%)	51–60	1 (2%)
		61–70	28 (50%)
Age (y)		71–80	22 (39%)
≤50	5 (23%)	≥80	2 (4%)
51–60	1 (5%)	NA	2 (4%)
61–70	4 (18%)		
71–80	4 (18%)	*TNM staging*	1 (2%)
≥80	8 (36%)	1c	6 (11%)
		2a	2 (4%)
TNM staging		2b	9 (16%)
T1	1 (4%)	2c	2 (4%)
T2	9 (41%)	2cN1-2	8 (14%)
T2Nx-1	3 (14%)	3a	2 (4%)
T3	5 (23%)	3b	10 (18%)
T3N2	1 (4%)	3c	12 (21%)
T4	3 (14%)	3cN1-2	1 (2%)
Combined with chemotherapy		4	1 (2%)
No	14 (64%)	M1	2 (4%)
Yes	8 (36%)	NA	2 (4%)
Radiation Scheme		*PSA*	26.7
25 × 2.0 Gy	11 (50%)	AVG	49.7
20 × 2.0 Gy	10 (45%)	SD	0.23–340.8
13 × 3.0 Gy	2 (5%)	Min-max	
		Gleason Score	
		<7	8 (14%)
		7	29 (52%)
		>7	16 (29%)
		NA	3 (5%)
		Radiation Scheme	
		35 × 2.0 Gy	49 (88%)
		19 × 3.4 Gy	6 (11%)
		15 × 3.4 Gy	1 (1%)

ing in the pilot. The RTT's mentioned that they felt more comfortable in the decision making as they gained more experience. This resulted in less burden of responsibility. Also having to contact the ROs less often, but taking action themselves, reduced the amount of workload in handling AC's and resulted in a more satisfactory balance of workload and clinical relevance. The responsibility remains within the limits of what RTTs consider to be their area of competence. The TAP is set up in such a way that in more challenging situations the final decision still remains with the RO.

The number of RO respondents in the TAP survey was unfortunately much lower than in the TLP survey. The results were discussed in a multidisciplinary meeting with the non-responding ROs and in a team meeting with the RTTs participating in the pilot where the results of the respondents were confirmed. The surveys provide more qualitative information and were therefore not powered and not performed with the aim of performing statistical analysis.

Based on the positive results of this study the TAP has been further developed and implemented for other urological tumors and other treatment sites. The advanced role of RTTs in detecting and acting on observed ACs plays a key role in our clinic, and should be validated in other clinics. The training program during the implementation of the TAP for the new treatment sites was expanded with interactive sessions to further train the RTTs on the use of the TAP using clinical examples.

Conclusion

The Take Action Protocol provides an accurate method to act on ACs in prostate and bladder cancer patients. Working with the TAP gives RTTs more responsibility than the TLP and provides an accurate IGRT evaluation and treatment delivery. Most RTTs find the increased responsibility of decision making regarding ACs satisfactory. The TAP also improves the balance of workload in relation to the clinical relevance of adapting to these ACs and is more efficient compared to TLP.
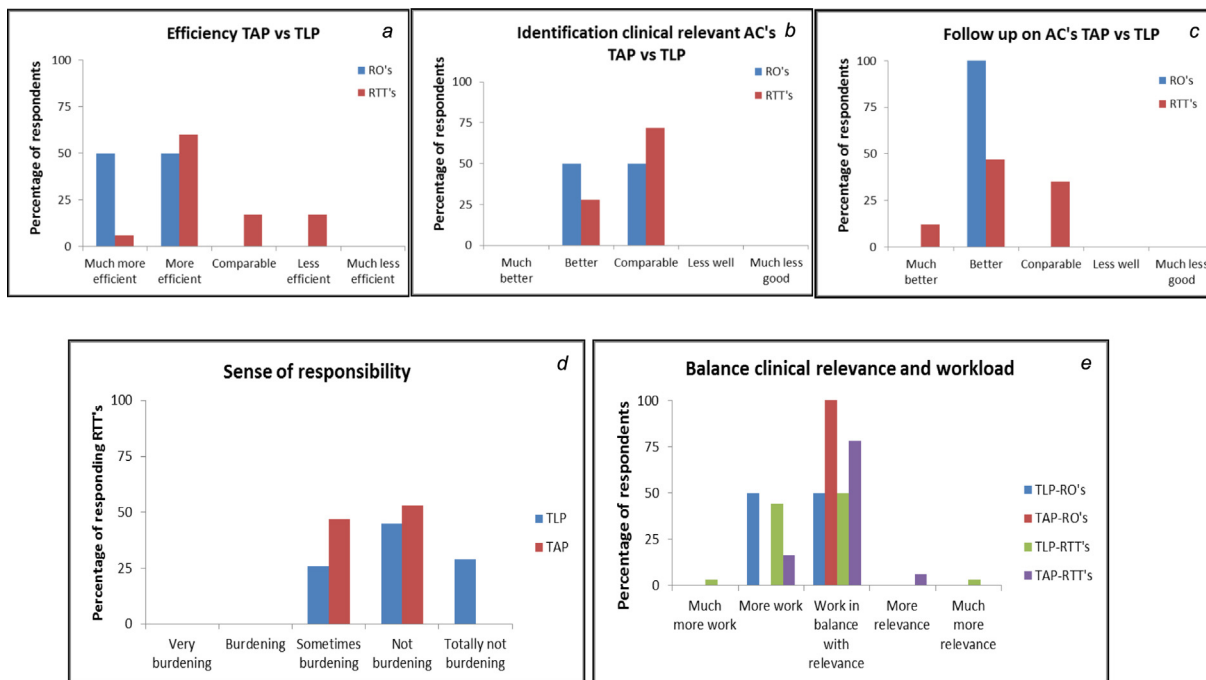
Table 2
Overview of visible Anatomical Changes, causes of these changes and undertaken actions.

	ACs on CBCT		Online interventions		N_{pat} Flow Chart actions	
	N_{pat}	N_F	N_{pat}	N_F	RTT	RO
Bladder	16	45	8	21	6	3
More filling(>1 cm min Diff)	4	6	1	1	–	–
Less filling(<1 cm min Diff)	7	28	3	10	3	3
Increased filling during RT	4	10	4	10	3	–
Contour changes	1	1	–	–	–	–
Prostate	18	44	3	13	8	4
CTV out of PTV: ↑Rectum	2	6	–	–	1	–
CTV out of PTV: ↓Rectum	7	11	–	–	2	1
CTV out of PTV: ↕Rectum	1	3	–	–	1	–
CTV out of PTV: Air in Rect	4	19	3	13	3	2
Increased/shifted LN	4	5	–	–	1	2

Abbreviations: N_{pat} = number of patients, N_F = number of fractions, Min Diff = minimal difference measured on CBCT images.

Table 3
Success rates in scoring of Anatomical Changes.

	Reviewed CBCTs	Accuracy in Scoring of ACs			
		False positive		False negative	
	N	N	%	N	%
Bladder	441	0	*0*	1	*0.23*
Prostate	825	5	*0.61*	6	*0.72*
Total	1266	5	*0.39*	7	*0.55*

Fig. 3. Results surveys on the Traffic Light Protocol and the Take Action Protocol. Results surveys on TLP and TAP about (a) Efficiency, (b) the identification of real clinical relevant ACs, (c) the follow up on ACs, (d) the sense of responsibility for RTTs and the balance of clinical relevance and workload. Abbreviations: AC = ACs, TLP = Traffic Light Protocol, TAP = Take Action Protocol, ROs = Radiation Oncologists, RTTs = Radiation technologists.

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.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tipsro.2020.12.001.

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