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Temporary Organ Displacement to Escalate Radiation Dose to Retroperitoneal Tumors and Decrease Toxicity to Organ at Risk

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Abstract

Purpose—To demonstrate that temporary organ displacement (TOD) by drainage catheter placement and hydrodissection, is feasible and reproducible for simulation (SIM) and stereotactic body radiation treatment (SBRT).

Methods—Between 2/2010 and 12/2018, 31 consecutive patients (20 men, 11 women; median age, 59 years) received both SIM and SBRT with TOD. The minimum required displacement was

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10 mm between gross tumor volume (GTV) and organ at risk (OAR). Complete displacement was defined as the ability to displace OAR from GTV a minimum of 10 mm across their entire boundary. Simulation was performed with hydrodissection on the same day. On the day of SBRT, displacement was reproduced by hydrodissection. Displacement was measured on CT images of TOD, SIM and SBRT. The drain was removed after SBRT.

Results—TOD (hydrodissection) was significantly associated with successful displacement of OAR from GTV greater than 10mm (median 20mm vs. 4.1 mm, $p<.001$) and maintained displacement at SIM and SBRT (SIM: 29.4 vs. 4.1, $p<.001$; SBRT: 32.4 vs. 4.1, $p<.001$). The OAR-GTV boundary showed median reduction of 35 mm (95% C.I. 27.5–37.5) following TOD. TOD achieved complete displacement in 22/31 (71%) of patients and 25/31 (81%) were able to undergo single fraction ablative SBRT. No patients developed procedure-related complications within 30 days. SIM and SBRT were successful without OAR toxicities within a median of 33 months (range 3–92 months).

Conclusions—TOD with placement of drain and hydrodissection is technically feasible, safe, and maintains displacement for SIM and SBRT.

Introduction

As radiation treatment becomes more conformal, higher doses are delivered to targets with an increasing need to protect organs at risk. Several techniques, such as reproducible patient immobilization, image guidance, and inverse treatment planning, have increasingly improved safe delivery of high dose stereotactic body radiation treatment (SBRT) (1, 2), which has been shown to have ablative effects (3). Allowing for uncertainties in planning or delivery, and to cover potential nonvisible microscopic satellite lesions, the volume of tissue receiving high dose radiation is required to extend at least 5–10 mm outside of a radiographically apparent tumor for clinical success. The volume of the tumor that is visible on imaging studies is called gross tumor volume (GTV) and the extended volume that requires full dose radiation is called planning tumor volume (PTV).

In cases where an organ at risk (OAR) abuts parts of GTV, this anatomic proximity poses a serious challenge to effective delivery of high dose radiation to PTV and increases the likelihood of injury to the OAR.

In image-guided percutaneous thermal ablation studies, several techniques such as injection of buffers like CO₂, air, saline, 5% dextrose in water (D5W) or placement of devices such as drainage catheters and balloons between tumor and critical organs have been successfully used in order to prevent nontarget ablation (4–8). Organ displacement techniques described in image-guided tumor ablation studies are one-time maneuvers performed during an ablation intervention and do not satisfy the main challenge of a radiation oncology scenario, where the displacement is required to be reproduced for both simulation (SIM) and SBRT which are a few days apart. The ideal solution is to perform both displacements with one intervention using a device that can stay in place in the patient for a few days between SIM and SBRT. Among devices that could potentially be used for TOD, all-purpose drainage catheter (drain) is the only one that is commonly carried by patients for prolonged periods. The experience in managing patients with fluid collections who required drainage catheter

with prolonged dwell times was used to achieve TOD in a radiation oncology scenario. The purpose of the study was to demonstrate feasibility of TOD and reproducibility of displacement at SIM and SBRT.

Materials and Methods

Patient Selection

Institutional Review Board waiver of consent was obtained for this retrospective study. Between February 2010 and December 2018, 31 consecutive patients who were deemed at risk for radiation toxicity to OAR based on desired radiation treatment planning, underwent TOD in anticipation of single fraction curative intent SBRT. The desired radiation treatment was dose escalation for single fraction ablative treatment. Radiation treatment was chosen based on multidisciplinary discussions among radiation oncologist, spine surgeon, medical oncologist and interventional radiologist including patient's preference as well (Figure 1). Data was compiled in a database compliant with Health Insurance Portability and Accountability Act. Quantification of radiation dosimetric benefits of this technique has been reported (9). This study reports on technical aspects, safety, reproducibility and efficacy of TOD intervention.

In all patients, the presence of an OAR within a 10 mm distance from the GTV posed a serious challenge to effective and safe delivery of single fraction curative intent SBRT and initiated an interventional radiology consultation by the radiation oncologist. The most recent cross-sectional imaging studies of potential cases were reviewed by the interventional radiologist for feasibility approval. A safe approach between skin and the boundary between GTV and OAR and lack of imaging evidence of tumor invasion to OAR were considered adequate for approval. Prior local surgery or radiation treatments were not considered exclusion criteria. Except for one patient who had two OARs (descending colon and left kidney), all others had one OAR per TOD. Large (including rectum) and small bowel loops in pelvis were considered one OAR and were collectively called pelvic bowel. All patients were seen at IR outpatient clinic prior to the TOD procedure for consultation, examination, blood work and consenting. Patients were provided supplies such as saline syringes and dressing material with relevant teaching to care for the drain for the period between simulation and SBRT.

Patient demographics and baseline characteristics are recorded in table 1. A total of 31 consecutive patients (20 men, 11 women; age range 20–80, mean: 57.4, median: 59) who received both SIM and SBRT with TOD for retroperitoneal malignancies were included in the analysis. OARs included pelvic bowel (n=22), kidney (n=8) and abdominal colon (n=2). Target tumors (GTV) included chordoma (n=18), sarcoma (n=6), germ cell tumor (n=3), renal cell carcinoma (n=3) and ovarian cancer (n=1). Location of retroperitoneal GTV was pelvis (S1-Coccyx, n=22) and abdomen (T12-L5, n=9). Twenty-one tumors were primary (chordoma and sarcoma), while 10 were recurrent/metastases. All primary tumors were chordoma and sarcomas.

TOD technique

All cases were performed under computerized tomographic (CT) guidance, specifically CT fluoroscopy (INTERACT Discovery RT or ACT/LightSpeed system, GE Healthcare, Chalfont St Giles, UK) and for some in addition to CT, fluoroscopic guidance was also used (Innova, GE Healthcare, Waukesha, WI, USA). One interventional radiologist with 6 years of experience at the time of the first TOD performed 18 interventions and a group of 7 interventional radiologists with 3–7 years of experience at the time of the first TOD performed 13 interventions (range 1–3). Each case was started with CT guidance for assessment of baseline anatomy and initial percutaneous access to the GTV-OAR boundary. Fluoroscopy if available was used for guidewire and catheter manipulation. All cases were performed with moderate sedation using intravenous midazolam (Hospira Inc., Lake Forest, Ill, USA) and fentanyl (Baxter Healthcare Inc., Deerfield, Ill, USA). Patients received one dose of intravenous antibiotic (cefazolin, or ciprofloxacin if allergic to cefazolin) for skin flora prophylaxis. Sedation time was considered to represent total procedure time. The type and size of drainage catheters (Cook Medical Inc., Bloomington, IN, USA) used were chosen at the discretion of the interventional radiologist and ranged from 8.5 to 12 French. Patients did not undergo bowel preparation. Based on the location of GTV and OAR and planned path of access for drain placement, the interventional radiologist determined prone or supine patient positioning (Figure 2). Under CT guidance, a 19 or 21 gauge needle was used to access the potential space between OAR and GTV. Using Seldinger technique, the needle was exchanged with a drain. If the planned location of locking loop of the catheter could not be accessed directly under CT guidance alone, fluoroscopy was used for guidewire manipulation. In these cases, an accessible point near the potential space between OAR and GTV was accessed by needle under CT guidance. Using Seldinger technique, the needle was exchanged with an 8 French vascular sheath and the intended final catheter position was accessed under fluoroscopic guidance by a 5 French directional catheter and hydrophilic guidewire coaxially. After confirming proper positioning of the wire with CT imaging, the vascular sheath and wire were exchanged with the drain under fluoroscopy. After placement of the drain, displacement was verified with CT imaging with the patient in supine or prone position at the discretion of the interventional radiologist. Supine position was preferred as this is the most common position for SBRT. However, since displacement was verified with CT imaging in supine position before SIM and SBRT and the radiation oncologist could use additional saline necessary to achieve the desired displacement, it was not mandatory to perform verification imaging of TOD intervention in supine position. An approximately 1:20 dilute mixture of iohexol-140 (Omnipaque; GE Healthcare, Princeton, NJ, USA) in normal saline was injected in 20–50 mL aliquots via the drain and minimum displacement between OAR and GTV in axial plane was verified by CT imaging. This was repeated until the minimum displacement of more than 10 mm was achieved across the boundary of OAR and GTV or no further displacement was achieved. Manual aspiration was done to withdraw free injected fluid. No additional efforts were made to aspirate the remainder of fluid as it was expected to be absorbed shortly. The drain was capped. The volume of fluid for each case was communicated to the radiation oncologist to be used at the time of SIM and SBRT. After recovery in the post anesthesia care unit, patients were discharged to go to the radiation oncology department for SIM after which they were discharged home. Technical success was defined as the ability to displace OAR from GTV at TOD intervention and at

both SIM and SBRT. Complete displacement was defined as the ability to displace OAR from GTV a minimum of 10 mm across the entire boundary. Incomplete displacement was defined as residual areas with less than 10 mm distance across the OAR-GTV boundary. Patients were followed for up to 30 days after TOD intervention to assess procedure-related complications.

OAR-GTV Measurements

The OAR-GTV boundary was determined by the number of intraprocedural axial CT images (5 mm slice thickness) where the distance was less than 10 mm. The number of slices was multiplied by the slice thickness to determine the OAR-GTV contact length in the sagittal plane. The distance between OAR and GTV was the minimum distance within each slice, averaged across all slices within the OAR-GTV boundary. Displacement was defined as the difference between OAR-GTV distances before and after TOD. Location of the tip of the drainage catheter with regards to OAR-GTV boundary after hydrodissection was labeled, “center” if it was within the central region of the boundary (Figure 2d and 2e). It was labeled “side” if it was toward one side of the boundary and off-centered. This displacement was measured pre- and post-TOD and at the time of SIM and SBRT.

Simulation and SBRT

On the same day, at the radiation oncology department, a repeat cone beam CT scan was performed approximately 4 hours after TOD intervention to re-assess displacement (TrueBeam High Definition, Varian Medical Systems, Palo Alto, CA, USA) (Figure 2f). Additional fluid was added based on cone beam CT images on a case-by-case basis. Simulation was performed with the desired displacement. Patients with complete displacement of OAR-GTV boundary to 10 mm or more were calculated to receive a single fraction of treatment. Depending on the degree of displacement and anatomy and at the discretion of radiation oncologist, those with incomplete displacement were set to receive either single fraction SBRT or lower doses of treatments in multiple fractions. At the end of CT simulation, manual aspiration was done to withdraw saline. The fluid that could not be freely aspirated was left to be absorbed. During the few days between simulation and SBRT, the drain was kept capped with a daily flush of 10 mL normal saline to maintain patency. Patients were instructed not to aspirate the catheter after flushing. On the day of SBRT, displacement was repeated by administration of the predetermined amount of saline via drain (Figure 2g). Desired displacement was verified by cone beam CT images. At the end of SBRT, the drain was removed by IR staff.

Statistical analysis

Characteristics for the cohort were summarized as medians and ranges or frequencies and percentages. The distribution of characteristics was compared between patients with complete and incomplete displacement using the Wilcoxon rank sum test or Fisher’s exact test for continuous and categorical variables, respectively. The distance between OAR and GTV within the OAR-GTV boundary were summarized with medians and ranges for measurements taken pre- and post-TOD and at simulation and SBRT. To assess whether there was at least a 10 mm displacement post-TOD and maintenance of displacement at time of simulation and SBRT session(s), the post-TOD measurements were compared to pre-TOD

and assessed whether the paired differences were significantly different from 10 using the 2-sided Wilcoxon signed rank test. The median change in length of OAR-GTV contact surface pre- and post-TOD was estimated along with a 95% confidence interval based on normal approximation.

Results

TOD procedural details are recorded in table 2. The length of procedure ranged from 25 to 150 minutes (mean: 79.8 minutes, median: 75 minutes). In 14 cases the entire procedure was performed under CT guidance while both CT and fluoroscopy were required for 17 cases. A regular 25-mm diameter locking loop (n=20) or 10-mm diameter locking loop (Dawson-Mueller type) (n=11) drains were used. The size of drainage catheters placed included 8.5 French (n=23), 10 French (n=7) and 12 French (n=1). Except for one patient who received two drains for one GTV, all patients received one drain. Patient position for drain placement was prone (n=29) or supine (n=2; 1 pelvis and 1 abdominal retroperitoneum). Patient position for verification of displacement was supine (n=14) or prone (n=17). For the entire group, the median amount of fluid required to achieve minimum displacement was 130 mL (range: 50–1000 mL). Patients with prior local treatment at the site of TOD (n=8)(surgical resection alone (n=2), radiation therapy alone (n=4), combination of surgery and radiation therapy (n=2)) had a median fluid volume of 175 mL (range 100–1000 mL) while those with no prior treatment at site of TOD (n=23) had a median fluid volume of 120 mL (range 50–250 mL), $p=0.079$. Within this group only two patients with history of both surgery and radiation treatment were outliers, each requiring 1000 mL volume for minimum displacement and the other 6 patients with history of either surgery or radiation treatment required volumes (median: 140 mL, range: 100–250 mL) comparable to the rest of patients with no prior history of local treatment. In all 31 patients, an all-purpose drain could be successfully placed either centrally in the GTV and OAR boundary (“center”, 19 cases, 61.3%) or off-centered and toward one side of the boundary (“side”, 12 cases, 38.7%). Technical success was 100% (31/31), with complete displacement in 71% (22/31) of cases and incomplete displacement in 29% (9/31) of cases.

The median distances within the OAR-GTV boundary are recorded in (Table 3). TOD resulted in a significant increase in displacement between the OAR and GTV of more than 10 mm (median of 20 mm vs. 4.1 mm, $p<.001$). The post-TOD distance of at least 10 mm distance was maintained at both SIM and SBRT (SIM: 29.4 vs. 4.1, $p<.001$; SBRT: 32.4 vs. 4.1, $p<.001$). The estimated OAR-GTV contact length pre- and post-TOD showed a median reduction of 35 mm (95% C.I. 27.5–37.5). The minimum distance at SBRT was lower for patients who received multiple fractions (median 15 mm, range 8–47 mm) than for patients with only a single fraction (median 33 mm, range 7–76 mm). Eight patients had prior local treatment (surgery n=2, radiation n=4, both surgery and radiation n=2). The six patients who had undergone a single treatment type had complete displacement. Two patients with history of both surgery and radiation had incomplete displacement.

Although non-significant, patients with complete displacement had a higher percentage of center drain location than patients with incomplete displacement (center 73% (n=16) vs side 33% (n=3), $p=0.056$) and warrants further study in larger cohorts. There was no statistically

significant relationship between complete displacement and OAR-GTV boundary ($p=0.2$), tumor type ($p=0.99$) or location ($p=0.40$), history of prior local surgery or radiation treatment ($p=0.99$), drain type ($p=0.40$) or size ($p=0.30$) and age ($p=0.11$) or gender ($p=0.70$). In two patients, drains were occluded so they could not be injected on the day of SBRT. Both patients were referred to IR for catheter exchange and received radiation treatment on the same day.

SBRT details are reported in table 4. In one patient SBRT was performed on the day of TOD (0 days interval). In all other patients SBRT was performed a few days after simulation (1–20 days, mean 4.2, median 2). Single-fraction SBRT was provided to 25/31 (81%) patients, while five patients received 3 fractions and one patient was treated with 5 fractions. Total treatment dose was 2100 cGy ($n=1$), 2400 cGy ($n=23$), 2700 cGy ($n=2$), 2850 cGy (1) and 3000 cGy ($n=4$). Following SBRT, the patients were followed up for a median of 33 months (range: 3–92 months).

Complications

The Society of Interventional Radiology adverse event classification system was the basis for evaluating complications of TOD intervention (10). No patient developed hemorrhage, infection, or injury to the displaced OAR from TOD intervention. The National Cancer Institute Common Terminology Criteria for Adverse Events version 5.0 was the basis for evaluation of toxicities of radiation treatment. The main purpose of reviewing complications related to radiation treatment was to assess toxicity to organ at risk specific to each TOD intervention. No acute toxicities related to OAR injury (e.g. bowel perforation) occurred within the first month after SBRT. No delayed toxicity to OAR was noticed within a median of 33 months (range 3–92 months). Acute radiation treatment toxicities occurred in 13/31 (42%) patients, including grade 1 dermatitis ($n=7$), grade 2 dermatitis ($n=1$), grade 3 dermatitis ($n=1$), diarrhea ($n=2$) and grade 1 fatigue ($n=2$). One patient who underwent TOD for kidney protection developed a ureteral stricture distal to the displaced kidney and required a ureteral stent. The kidney (OAR) and adjacent ureter did not show any toxicities.

Discussion

With the improvement in radiation oncologic technology, three-dimensional target treatment delivery has become more precise. These techniques have facilitated tumor dose escalation resulting in improved outcomes. Dose escalation is particularly critical for ablative treatment of unfavorable tumor histologies such as sarcoma, renal cell carcinoma, chordoma and nonseminomatous germ cell carcinoma (11,12). The advent of image-guided intensity modulated radiation therapy (IG-IMRT) has allowed delivery of greater doses of radiation. However, this treatment is limited in cases where the tumor is immediately adjacent to a critical structure. Numerous techniques of separating adjacent organs from tumors in thermal ablation have been described in the radiology literature. Methods have included patient repositioning, percutaneous placement of angiographic balloons between the liver and stomach for radiofrequency ablation and injection of saline, air, CO₂ or D5W into both the retroperitoneal and peritoneal spaces (4–8). Techniques aimed at shifting critical organs away from the PTV have been used in traditional radiation therapy. To separate the prostate

and rectum for radiation treatment of the prostate, techniques have included collagen and hyaluronic injection, as well as biodegradable balloon implantation (13,14). These are designed for protecting a small area between prostate and anterior wall of rectum and are technically cumbersome to perform with trans-rectal ultrasound guidance and trans perineal access. Less invasive techniques such as moderate deep-inspiration breath hold maneuvers during radiation in the treatment of left-sided breast cancer have been used to reduce cardiac dose (4). In respect to the bowel, injury from radiation to adjacent organs can manifest as bleeding, ulceration, fistula, and perforation occurring weeks to months post radiation (16,17). Unlike thermal ablation, in which both organ displacement and ablation are performed in the same setting, radiation oncology faces the challenge of a multi-day time gap between simulation and SBRT. Moreover, the degree of displacement at the time of SBRT must be as reproducible as achieved and verified on the day of simulation.

The procedure length of TOD intervention is slightly longer than image guided drainage catheter placement for a routine indication such as retroperitoneal abscess. The mean procedure length was 79.8 minutes with a median of 75 minutes. Among the reasons for additional procedure length include: using two imaging modalities of CT and Fluoroscopy in some cases, challenges with placing a drain in a potential space and not an existing cavity, challenges in patients with prior history of surgery and or radiation treatment with adhesions and changing patients' position from prone to supine for verification purposes.

This case series assesses feasibility and outcomes of an image-guided displacement technique to facilitate radiation treatment.

There are several limitations to this study. This study is retrospective and vulnerable to introduction of biases and confounders. It may be underpowered to detect small differences due to small sample size from a single center. Lack of control group is a limitation to this study. It is likely that without organ displacement, SBRT would not be a treatment option for some patients, so a true control arm may be difficult to find; however, historical controls could be performed in future studies. The linear method of measurement of distances between OAR and GTV on axial plane as opposed to volumetric measurement is another limitation. The most common organ at risk in this study was pelvic bowel which can be highly mobile making displacement measurements challenging. Given the known benefit of TOD in significantly reducing the dose to OAR ($p=0.008$) (9), and lack of any late toxicities in this patient cohort for a median of 33 months (range 3–92 months), very long sequelae of radiation toxicity to OAR still cannot be confidently ruled out. The prolonged study enrollment period is multifactorial and inherently a limitation to this study. It is because the main disease entity in the study (chordoma, $n=18$) is a rare disease with a 1 in one million per year incidence. There are other treatment options available for this disease and not all cases require TOD for SBRT. The evolution of radiation oncologic technology may affect applicability of this technique to future patients.

This study demonstrates technical feasibility and safety of TOD that reproducibly displaces OAR from GTV for both simulation and SBRT, allowing for higher doses of radiation to be delivered to GTV while reducing unwanted toxicity to OAR. TOD should be considered for

select patients with retroperitoneal tumors too close to an organ at risk who are scheduled to undergo SBRT.

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Figure 1.

Study flow chart. Numbers in parentheses only refer to study patients and not the overall volumes. IR: Interventional Radiology, SBRT: Stereotactic Body Radiation Treatment, OAR: Organ-at-Risk, TOD: Temporary Organ Displacement

Figure 2.

69-year-old male with a sacral chordoma. Planned to undergo stereotactic body radiation therapy (SBRT).

(2a) Pre-procedural Axial T1-weighted post-contrast MRI in supine position demonstrate the tumor (T) abutting the rectum (*).

(2b) Intraprocedural CT with the patient in prone position prior to TOD. The rectum (*) abuts the tumor (T).

(2c) The needle (arrow) was advanced through a right trans gluteal approach to access the potential space between tumor (T) and rectum (*).

(2d) The needle was exchanged over a wire for 8.5 French Dawson-Mueller drainage catheter (arrows). The gross tumor volume (GTV) is outlined by the dark red line (T). The organ-at-risk (rectum) is outlined by the dark orange line (*). The catheter tip is seen in the presacral space between OAR and GTV in a “center” location (central arrow).

(2e) A total of 120 mL of saline: Omnipaque 140 mixture (ratio 10:1) was injected through the catheter to induce hydrodissection. The fluid is seen (arrowheads) separating the GTV

(dark red line) (T) from the displaced OAR (light purple line) (*) by at least 15 mm in the shortest axial dimension (double arrows between dotted straight lines).

(2f) Simulation Cone-Beam CT (CBCT) performed with the catheter in place (arrow) and hydrodissection (arrowheads) demonstrates reproduced displacement between GTV (dark red line) (T) and OAR (light purple line) (*). The minimum axial OAR-GTV distance was 22 mm (double arrows between dotted straight lines).

(2g) Single-fraction 2400 Gy SBRT was successfully administered two days later. The GTV (dark red line) (T) and the OAR (light purple line) (*) were reproducibly displaced (double arrows between dotted straight lines) prior to SBRT by hydrodissection (arrowheads) through the catheter (arrow), permitting safe delivery of high-dose RT. The catheter was removed by IR staff after SBRT.

Table 1.

Baseline demographics of patients undergoing temporary organ displacement (TOD) prior to stereotactic body radiation therapy (SBRT) of retroperitoneal tumors.

<i>Age (Years)</i>	<i>Average</i>	<i>Range</i>
	57.5	20 – 82
<i>Gender</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Male</i>	20	64.5
<i>Female</i>	11	35.5
<i>Tumor Histology</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Chordoma</i>	18	58.1
<i>Sarcoma</i>	6	19.4
<i>RCC</i>	3	9.7
<i>GCT</i>	3	9.7
<i>Ovary</i>	1	3.2
<i>Location of Tumor</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>T12-L5</i>	9	29.3
<i>SI-Coccyx</i>	22	70.7
<i>Organ at Risk (OAR) Type (n=32)</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Pelvic Bowel</i>	22	71.0
<i>Kidney</i>	8	29.0
<i>Colon</i>	2	3.2
<i>Prior Local Therapy?</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>None</i>	23	74.2
<i>RT only</i>	4	12.9
<i>RT + Sx</i>	2	6.5
<i>Sx only</i>	2	6.5

RCC: Renal Cell Carcinoma; GCT: Germ Cell Tumor; RT=Radiation Therapy; Sx: Surgery

Table 2.

TOD procedural details.

<i>Placement Position</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Supine</i>	2	6.5
<i>Prone</i>	29	93.5
<i>Imaging Modality During TOD placement</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>CT Only</i>	14	45.2
<i>CT + Fluoro</i>	17	54.8
<i>Length of Procedure (min)</i>	<i>Average</i>	<i>Range</i>
	79.8	25 – 150
<i>Type of Drainage Catheter Placed</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>25 mm diameter locking loop</i>	20	64.5
<i>10 mm diameter locking loop</i>	11	35.5
<i>Number of Drainage Catheters Placed</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>One</i>	30	97
<i>Two</i>	1	3
<i>Drainage Catheter size (French)</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
8.5	23	74.2
10	7	22.6
12	1	3.2
<i>Location of Drainage Catheter Placement</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Central</i>	19	61.3
<i>Side</i>	12	38.7
<i>Pre-TOD OAR-GTV Boundary (mm)</i>	<i>Average</i>	<i>95% C.I.</i>
	39	(34.2 – 43.8)
<i>Post-TOD OAR-GTV Boundary (mm)</i>	<i>Average</i>	<i>95% C.I.</i>
	6	(2.1 – 9.8)
<i>Extent of Displacement</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Complete</i>	22	71.0
<i>Incomplete</i>	9	29.0
<i>Volume of Saline injected during TOD (mL)</i>	<i>Average</i>	<i>Range</i>
	195.8	50 – 1000

<i>TOD Success</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Yes</i>	31	100

<i>Verification Position</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Supine</i>	14	45.2
<i>Prone</i>	17	54.8

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Table 3.

Median displacement of organ-at-risk from the gross tumor volume across the sample prior to TOD, following TOD, at SIM and SBRT.

Variable	Median (Range) mm
<i>Pre-TOD</i>	4.1 (0.5–8.7)
<i>Post-TOD</i>	20.0 (6.7–39.3)
<i>SIM</i>	29.4 (6.9–55.6)
<i>SBRT</i>	32.4 (7.2–75.9)

TOD: Temporary Organ Displacement; SIM: Simulation; SBRT: Stereotactic body radiation therapy

Table 4.

SBRT treatment details.

<i>Interval Between TOD and SBRT (days)</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>1 to 3</i>	20	64.5
<i>4 to 7</i>	5	16.1
<i>8 to 14</i>	5	16.1
<i>>14</i>	1	3.2
<i>Total number of RT Fractions</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>One</i>	25	80.6
<i>Three</i>	5	16.1
<i>Five</i>	1	3.2
<i>SBRT Dose (cGy)</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>2100</i>	1	3.2
<i>2400</i>	23	74.2
<i>2700</i>	2	6.5
<i>2850</i>	1	3.2
<i>3000</i>	4	12.9
<i>RT Success</i>	<i>Frequency (n)</i>	<i>Percent (%)</i>
<i>Yes</i>	31	100

cGy: Centigray (unit)