Spatially Fractionated GRID Therapy: A Case Study

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Abstract:

Introduction: The GRID technique of spatial fractionation can be used with modern MV linear accelerators. This technique combines the advantages of skin sparing with partial tissue blocking, therefore speeding up the regrowth and recovery of normal tissue following high-dose radiation therapy. However, special planning methods and QA may be required. In this case study, the process of establishing the GRID technique for use in this clinic is outlined, as well as some clinical examples of successful treatment planning using the standard GRID technique parameters to different treatment sites.

Case Description: GRID treatment is indicated for palliative radiation treatment to bulky, radio-resistant tumors. Patients with tumors that classify as candidates for GRID treatment may present somewhat rarely in the clinic. Three patient case studies are presented here to illustrate the similarities and differences among GRID treatments to varying sites and histology in the pelvis, abdomen and upper lung.

Conclusion: GRID therapy is a novel yet simple technique used to successfully provide a palliative benefit in the radiation treatment of bulky, radio-resistant tumors.

Key Words: GRID, hypofractionated, radio-resistant, palliative.

Introduction

The GRID therapy technique is unique within the radiation therapy field. This technique involves administering a single, high-dose treatment through a GRID block rather than open fields.[1] The GRID block spatially fractionates the beam into many smaller "beamlets." The partial blocking protects portions of healthy skin and tissue therefore speeding the regrowth and recovery of normal tissue following high-dose radiation therapy, with little to no acute side effects.[2] GRID treatment is sometimes described as "virtual brachytherapy," as the resulting isodose patterns are similar to those of high-dose rate (HDR) brachytherapy.

Historically, GRID blocks were used with orthovoltage machines in order to provide the benefit of partial skin sparing, which is not inherent in low energy beams.[1] When MV linear accelerators were developed, GRID therapy use declined. This was due to the superior skin-sparing effects of the MV beam, removing one of the most obvious advantages of block-based spatial fractionation. However, in recent decades, the GRID technique has been used in conjunction with MV radiation therapy to combine the advantages of both modalities. This technique has been shown to be very effective in the palliative treatment of large, bulky tumors of radio-resistant histology, and in some cases, even curative treatment has been achieved.[1-3] Debulking GRID treatments followed by standard external beam radiation therapy (EBRT) have resulted in even better outcomes than GRID treatment alone.[2]

In this clinic, patients with bulky, radio-resistant tumors present rarely. Prior to the establishment of the GRID program, such patients would be treated with standard EBRT or perhaps an open-field hypofractionation scheme, if radiotherapy was indicated at all. The GRID technique was commissioned for use in this clinic in late 2014 with 7 patients treated to date. Treatment sites and tumor histology have varied but successful treatment plans have been achieved for all the patients using the standard GRID treatment parameters described here.

Typically GRID treatments are prescribed to the depth of maximum dose (D_{max}) at 100 cm source-to-skin distance (SSD) for a single, unopposed field to a dose of 1000-2000 cGy.[1,4] The beam angle is chosen to traverse the shortest distance to the gross tumor volume (GTV).[3] The GRID block is not currently modeled in all treatment planning systems (TPS); therefore, open-field configurations are used within the TPS to evaluate beam angles and target coverage. However, the resulting TPS-calculated monitor units (MUs) and dose-volume histograms (DVHs) cannot be trusted for dose determination.[3] Medical physicists must perform additional QA and dose calculations to ensure proper MU delivery.[4]

GRID blocks may be created from brass, cerrobend or multi-leaf collimators (MLCs); however, studies have shown little difference in the performance of plans using GRID blocks of different hole spacing or blocking pattern designs.[5] The GRID block used in this study was manufactured by .decimal (Figure 1). It is made of 7.62 cm thick brass with 149 divergent holes arranged in a hexagonal pattern that cover a maximum field size of 25 x 25 cm at treatment depth. An MLC grid block was modeled for commissioning purposes but slow treatment delivery and leakage concerns precluded use in this clinic.

Case Description

Patient Selection & Patient Set-up

GRID treatment is indicated for palliative radiation treatment to bulky, radio-resistant tumors. Rarely do patients with tumors qualifying for GRID treatment present at this clinic. Only 9 patients have been planned to date with 7 ultimately receiving treatment. Three patient case studies are presented to illustrate the similarities and differences among GRID treatments to varying sites and histologies.

Patient 1 had undergone colon resection for colon cancer in 2011, followed by chemotherapy. In 2013, the patient underwent a right nephrectomy for stage T3 transitional cell carcinoma of the renal pelvis. In 2015, the patient presented with metastatic transitional cell carcinoma in the retroperitoneum of size 15 cm x 8.2 cm x 19.5 cm (Figure 2). The radiation oncologist recommended palliative GRID radiation therapy for pain relief followed by a standard course of EBRT.

Patient 2 was diagnosed in 2011 with stage T2bN0M0 high-grade pleomorphic sarcoma of the right thigh adductor muscles which was treated with preoperative radiotherapy and surgery. In 2013, the patient was diagnosed with intermediate risk prostate adenocarcinoma. This disease was monitored with active surveillance due to the proximity to the previous treatment site. In 2014, the patient presented with metastasis from the thigh sarcoma to multiple bilateral pulmonary nodes, including a large 13 cm mass in the left upper lobe abutting the brachial plexus (Figure 3). Surgery was contraindicated due to multiple metastatic lesions. The radiation oncologist recommended palliative GRID radiation therapy for symptom relief from brachial plexopathy followed by a standard course of EBRT.

Patient 3 presented in 2012 with renal cell carcinoma with metastatic disease throughout the left pelvis. This was initially treated with left nephrectomy, palliative EBRT to the left pelvis, and chemotherapy. Follow-up imaging in November 2014 revealed metastatic disease to the brain, which was treated with stereotactic radiosurgery (SRS). Additional follow-up imaging in February 2015 showed progression of metastasis throughout the left pelvis. The patient also reported worsening pain symptoms. The radiation oncologist recommended palliative GRID radiation therapy with the clinical goals of pain relief and prevention of pathologic hip fracture (Figure 4).

Positioning and GRID treatment dose varied depending on the treatment site and clinical indication. Because of the high risk and lengthy delivery time of a single high-dose fraction, patient comfort, reproducible positioning, and immobilization were of the utmost importance during simulation and treatment. The 3 cases presented here were all positioned in the supine, head-first position. Patients 1 and 2 were positioned with arms raised above the head and immobilized with custom Vac-Lok molds. Patient 3 was positioned with hands on the chest and a sponge under the knees.

Target Delineation

The medical dosimetrist contoured all OR. For Patient 1, the OR included left kidney, right and left lungs, cauda equina, spinal cord, liver, heart, bowel, and stomach. For Patient 2, the OR included right and left lung, spinal cord, liver, heart, bowel cavity, stomach, esophagus, trachea, brachial plexus, and thyroid. For patient 3, the OR included bladder, bowel cavity, femoral heads, rectum, and sacral nerve root. Each patient was contoured and planned using the Varian Eclipse 11.0.47 TPS to be treated on a Varian Trilogy Linac iX.

Because of the large bulk of GTVs typically indicated for GRID treatment, the tumors tend to be fixed with negligible motion regardless of their location.[3] Adding a GTV expansion margin is not necessary when designing treatment fields. However, critical OR were blocked and/or avoided with careful beam angle choice, even if it required additional blocking of the GTV beyond the partial blocking provided by the GRID. The radiation oncologist adjusted the MLCs for each patient to compromise GTV coverage in order to minimize dose to the OR in closest proximity. For patient 1, the GTV coverage was compromised in favor of a 1 cm margin to the left kidney, with no further GTV expansion (Figure 2). For Patient 2, the brachial plexus, esophagus and spinal cord were blocked and a 7 mm GTV expansion added elsewhere (Figure 3). For Patient 3, portions of the GTV were blocked near the rectum, sacral nerve root and bowel cavity, with no further GTV expansion (Figure 4).

Treatment Planning

The palliative GRID treatment dose prescriptions, palliative EBRT prescriptions, and beam angle arrangements for each plan are shown in Table 1. In each patient’s case, the machine MU limits were exceeded by the large dose delivered in the single field. Therefore, each GRID beam was divided into 2-3 deliveries. Standard QUANTEC guidelines were used to evaluate OR doses for the EBRT plans.[7] For the GRID treatments, the highest priority was minimizing OR dose to a negligible amount.

Patient 1 was prescribed a GRID treatment dose of 2000 cGy in 1 fraction to be followed by a standard palliative EBRT treatment plan of 4000 cGy in 20 fractions. The GRID treatment was planned to one 65° LAO beam of 18 MV energy. The EBRT course used opposed 18 MV 25.5° LAO and 205.5° RPO beams weighted 60%-40%.

Patient 2 was prescribed a GRID treatment dose of 1800 cGy in 1 fraction to be followed by a standard palliative EBRT treatment plan of 3000 cGy in 10 fractions. The GRID treatment was planned with a 155° LPO beam of 18 MV energy. The EBRT course was delivered in an anterior-posterior (AP) beam and a 155° LPO field weighted 57% and 43%, respectively. Both EBRT beams were 18 MV energy.

Patient 3 was prescribed a GRID treatment dose of 2000 cGy in 1 fraction to be followed by a standard fractionated EBRT palliative treatment plan of 2500 cGy in 10 fractions. The plan consisted of a 200° RPO field of 18 MV energy. The EBRT course was delivered in opposed 18 MV AP and posterior-anterior (PA) fields.

Plan Analysis & Evaluation

The Varian Eclipse 11.0.47 TPS is not currently capable of modeling the reduction in treated volumes or output factor modification to beams with the GRID block in place. Therefore, the TPS-calculated isodose lines and DVH curves were not used for MU or dose calculations for the GRID fields. Open-field isodose lines were used to evaluate target coverage and OR sparing only (Figure 5-7) and MUs were calculated by medical physicists.[4] To this end, the medical physicists commissioned a GRID block output factor table by measuring beam outputs under the standard GRID treatment delivery setup conditions of 100 cm SSD with dose prescribed to the depth of D_{max} for each available beam energy (6X and 18X) at field sizes ranging from 2.5 cm to 22 cm (Figure 8). Measurements were made in water using a stereotactic diode on the central axis with the diode axis parallel to the beam direction to minimize any stem effect. Medical physicists performed final MU calculations for GRID fields independent of the TPS with a GRID-specific MU hand calculation based on these output factor measurements (Figure 9). Full percent-depth dose (PDD) measurements were also performed for both energies and compared against an MLC-modeled and delivered GRID block treatment to complete the commissioning exercise.

As a special safety note, neutron contamination is produced by photon beams above energy of approximately 10 MV.[6] If energies higher than 10 MV are used for a GRID treatment, the neutron contamination of the beam initiates radioactivity of the GRID block itself. Medical physicists performed post-18 MV treatment radiation survey measurements on the surface of and 1 meter away from the GRID block, which indicated an exposure rate of nearly 100 mRem/hr on the surface with exposures dropping to 16 mRem/hr from 1 meter away, and an effective half-life of approximately 10 minutes. Radiation therapists and medical physicists followed proper radiation safety ALARA measures to minimize occupational radiation dose, such as avoiding handling the GRID block immediately after treatment and storing the GRID block in a low-occupancy area of the treatment room. In this clinic, GRID treatments are now scheduled immediately prior to the lunch hour and at the end of the day to facilitate these radiation safety measures.

Conclusion

The GRID technique is not new to radiation therapy and has been successfully used with linear accelerators to improve clinical outcomes by combining the deep beam penetration and skin-sparing benefits of MV beams with the partial tissue blocking effects of spatial fractionation.[1-3] Medical dosimetrists can bypass the TPS modeling difficulties by planning open fields to evaluate beam angles and field sizes for optimal target coverage and OR sparing.[3] By using the standard treatment planning guidelines of prescribed dose to D_{max} with a 100 SSD setup, medical physicists can easily perform MU calculations for a commissioned GRID block.[4] The risk of high dose, single-fraction delivery should be mitigated by careful immobilization during simulation and treatment, with a special eye on patient comfort whenever possible. This technique is an excellent tool for medical dosimetrists in the cases of patients with large, bulky tumors, especially when followed by standard EBRT.[2]

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Figures

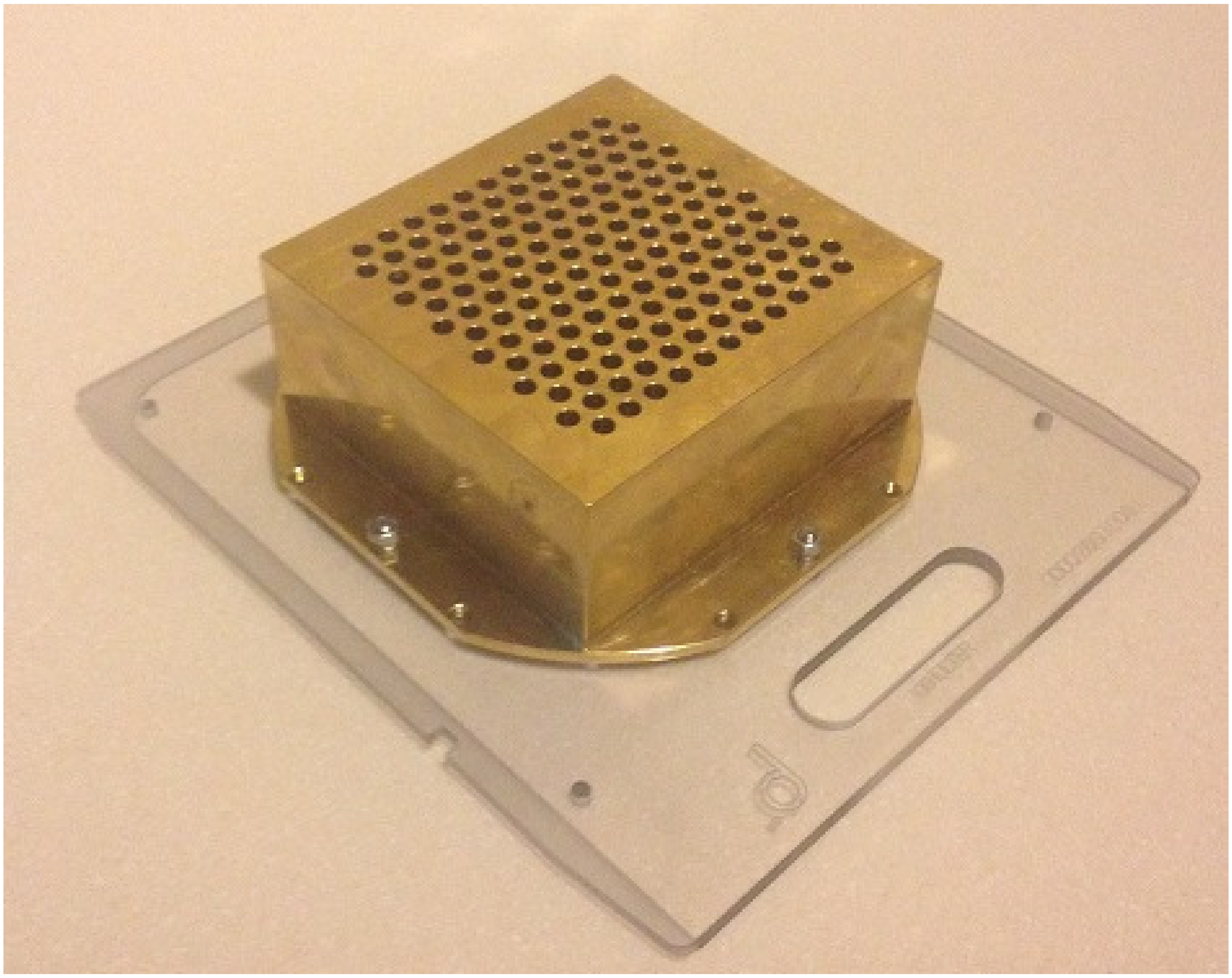


Figure 1. Photo of the brass GRID block manufactured by .decimal.

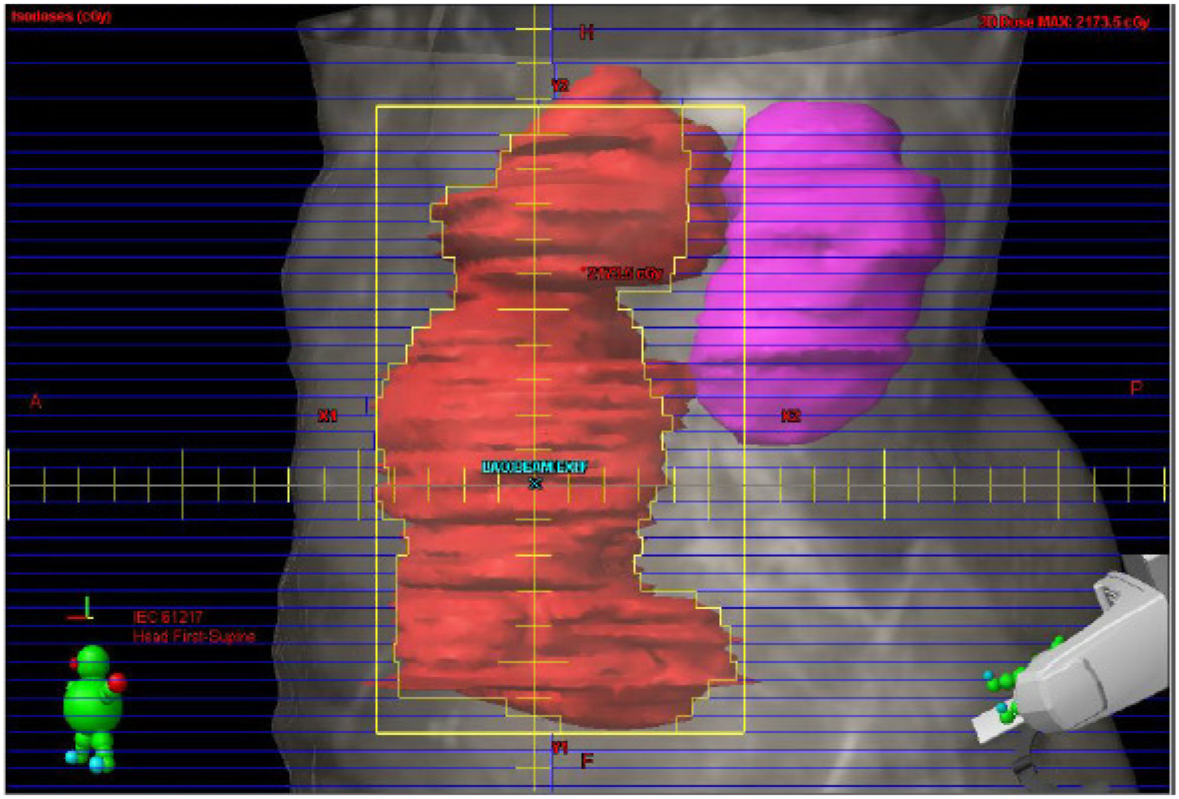


Figure 2. Patient 1: Beams-eye view (BEV) of left anterior oblique (LAO) GRID field with MLC block. Note the GTV (red) coverage was compromised to spare left kidney organ at risk (OR) (magenta).

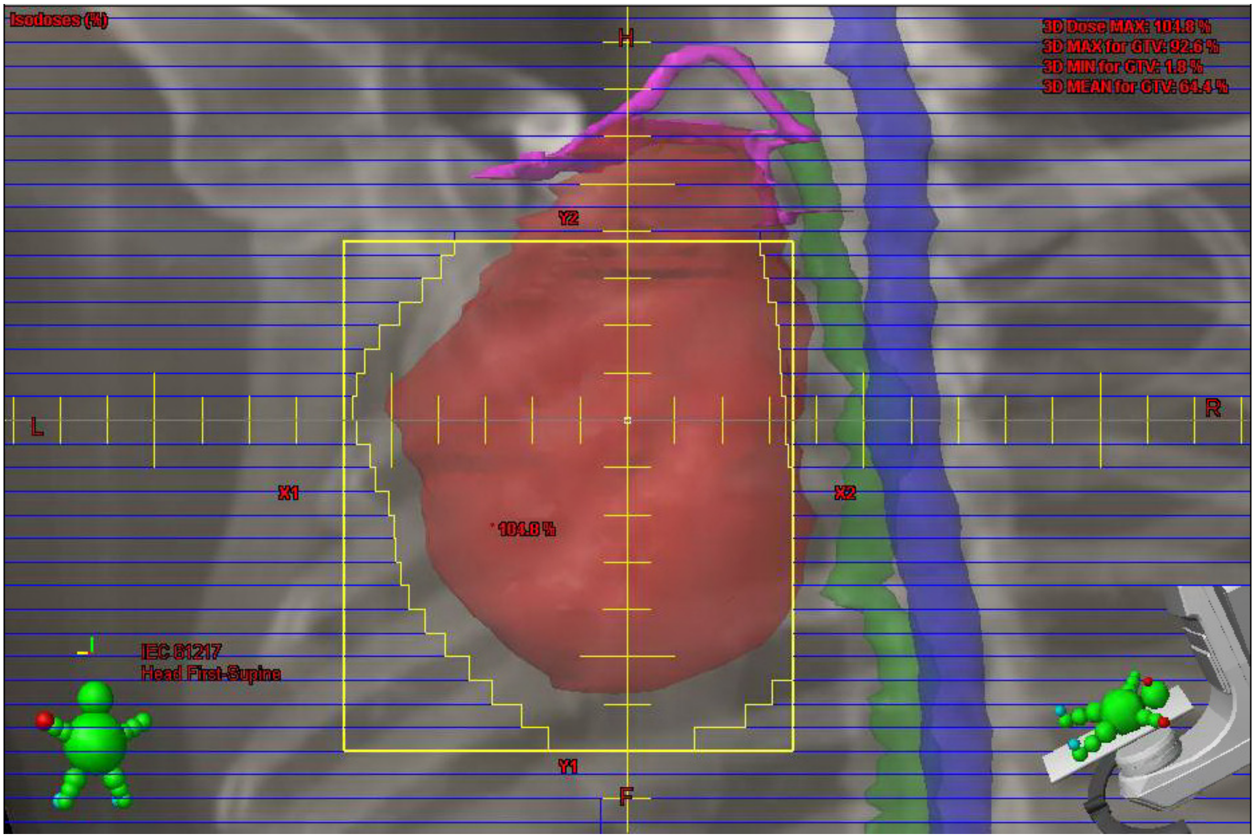


Figure 3. Patient 2: Beams-eye view of left posterior oblique (LPO) GRID field with MLC block. Note the GTV (red) coverage was compromised to spare brachial plexis (magenta), esophagus (green) and spinal cord (blue).

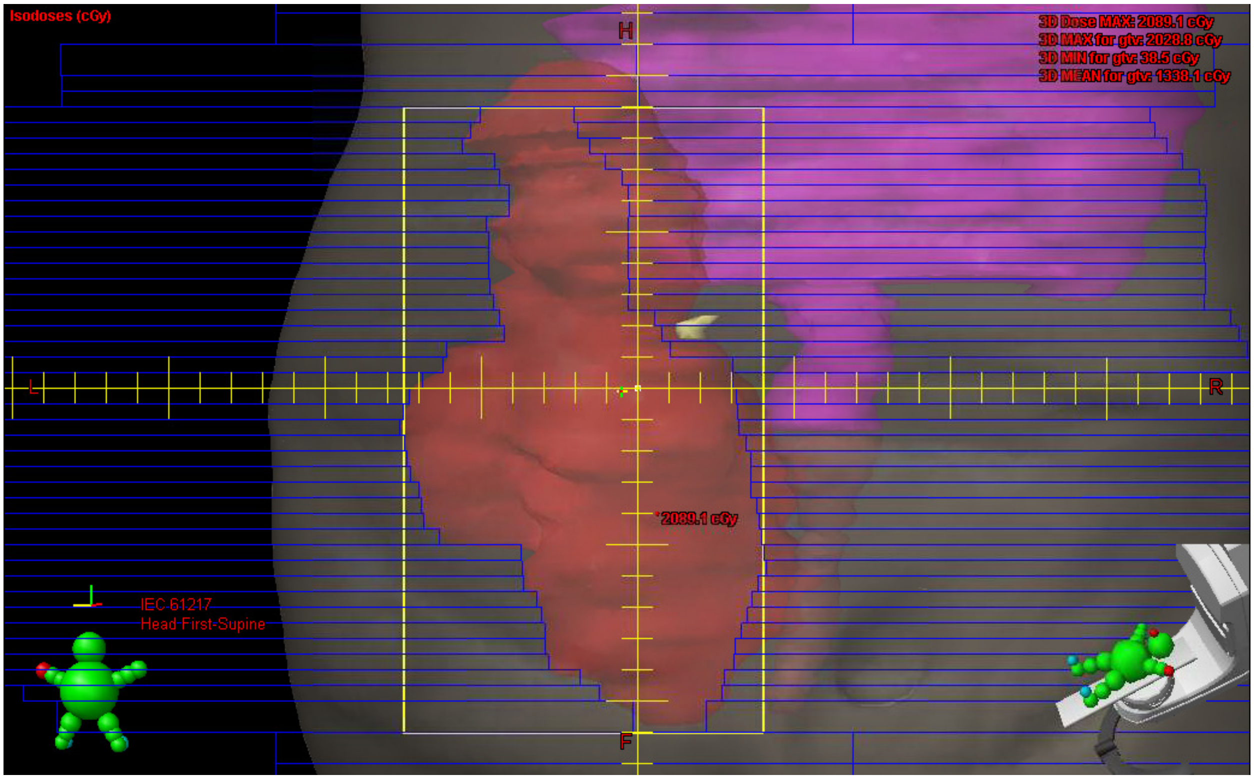


Figure 4. Patient 3: Beams-eye view of right posterior oblique (RPO) field with MLC block. Note the GTV (red) coverage was compromised to spare bowel cavity (magenta), rectum (brown) and sacral nerve root (yellow).

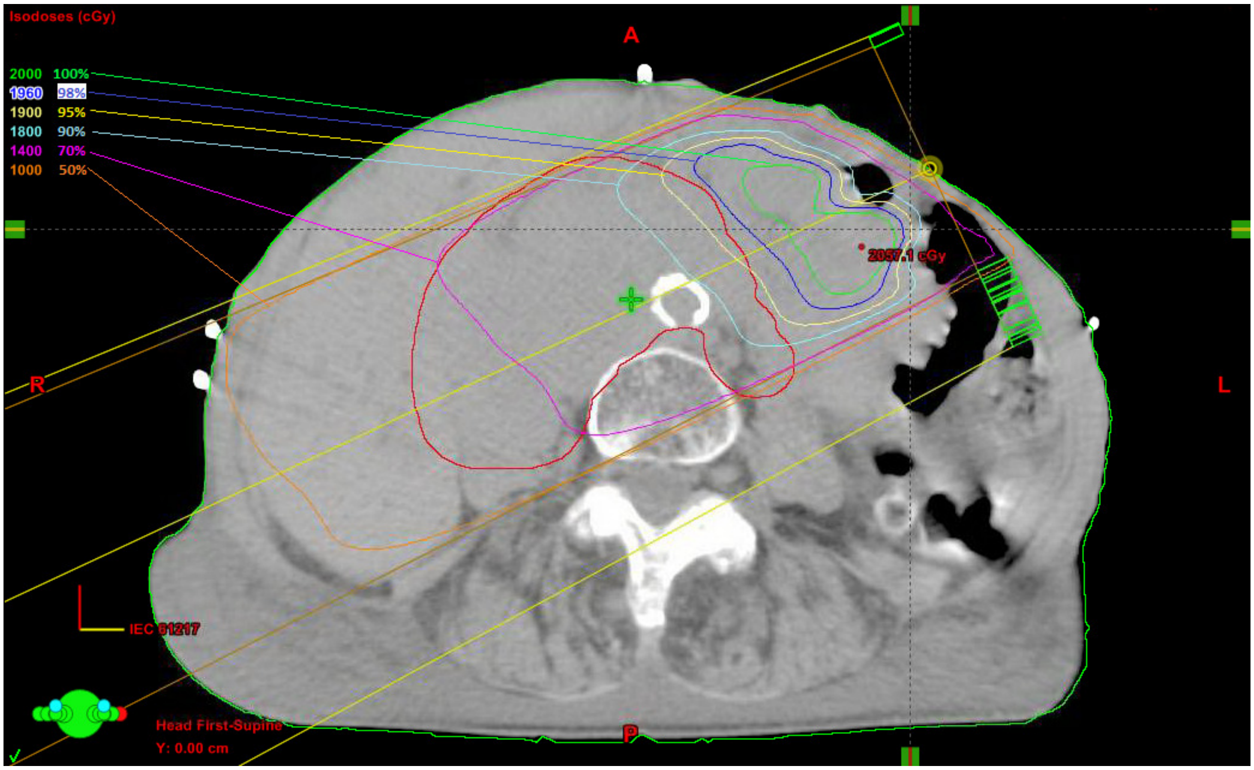


Figure 5. Patient 1: An axial view at isocenter of the open field isodose lines which were used to evaluate GTV (red) coverage and OR sparing only.

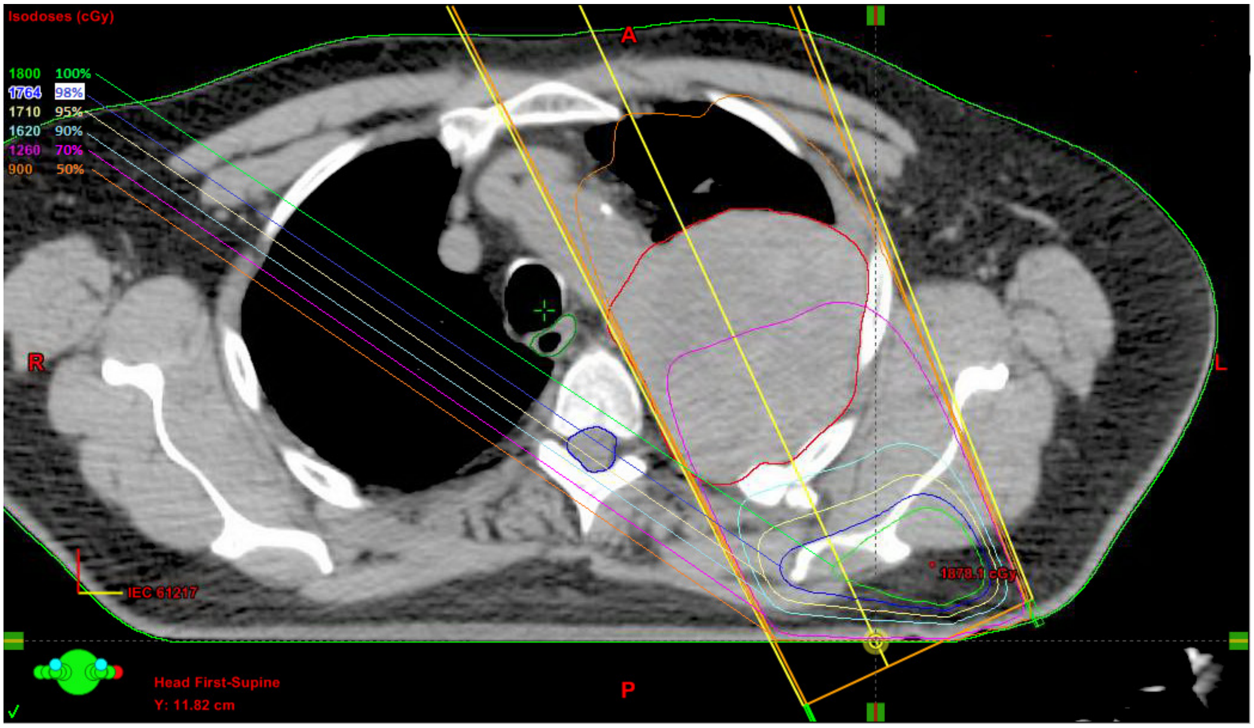


Figure 6. Patient 2: An axial view at isocenter of the open field isodose lines which were used to evaluate GTV (red) coverage and OR sparing only. The spinal cord contour is visible in blue and the esophagus contour is visible in green.

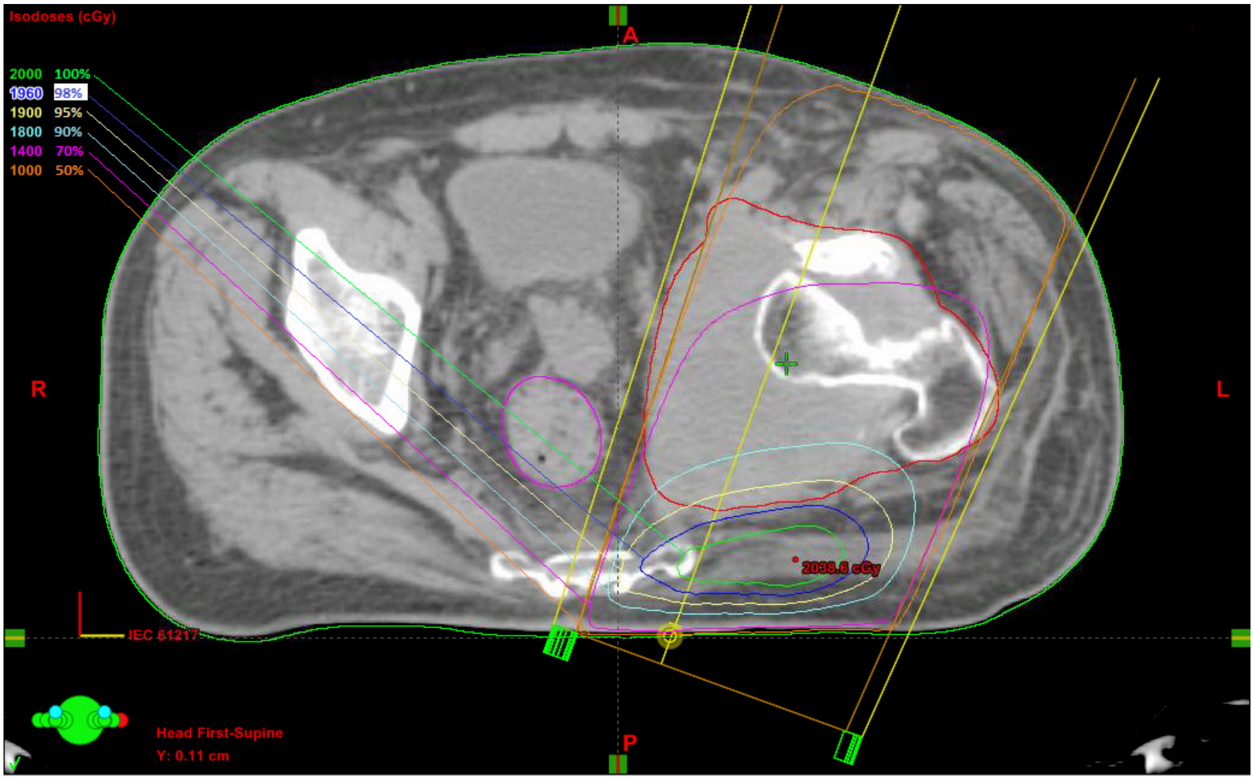


Figure 7. Patient 3: An axial view at isocenter of the open field isodose lines which were used to evaluate GTV (red) coverage and OR sparing only. The bowel cavity contour is visible in magenta.

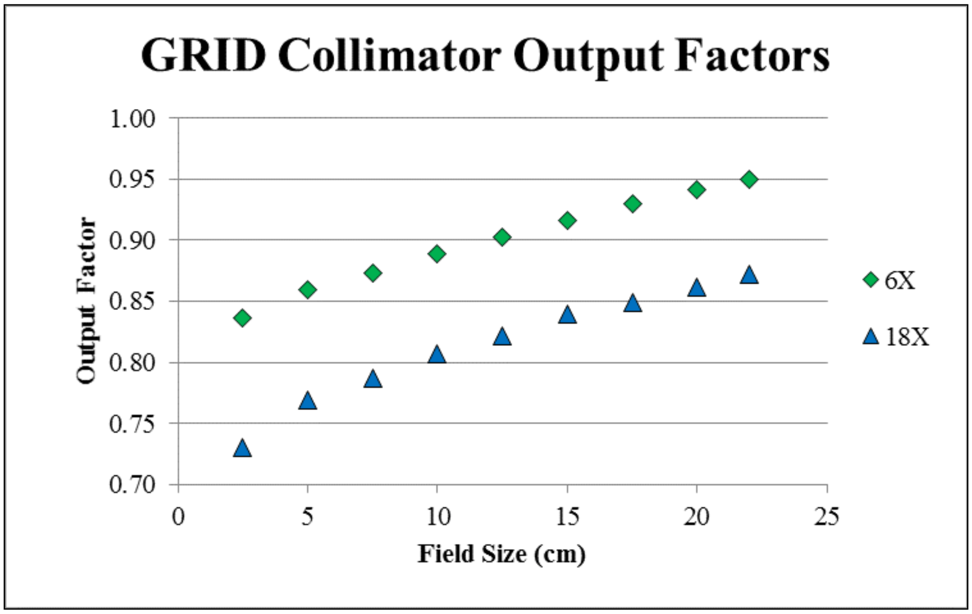
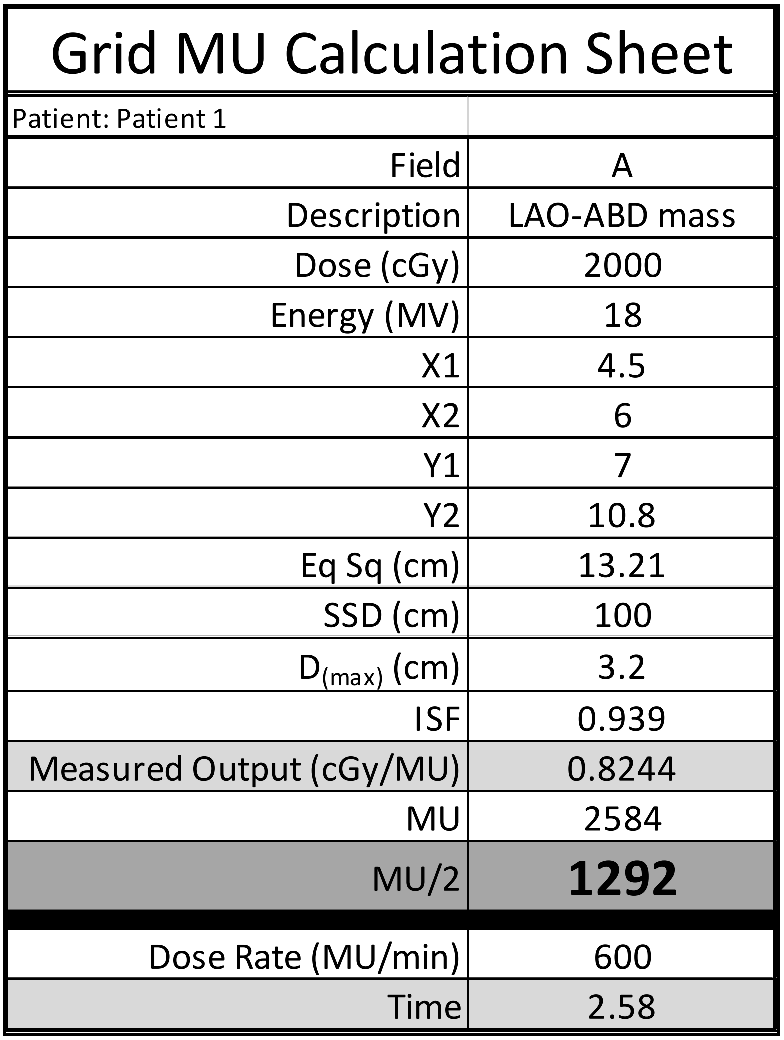


Figure 8. Output factor vs. field size for the GRID block in 6X (green) and 18X (blue) beams. This information was used in the MU hand calculation to determine MUs and dose.



Grid MU Calculation Sheet	
Patient: Patient 1	
Field	A
Description	LAO-ABD mass
Dose (cGy)	2000
Energy (MV)	18
X1	4.5
X2	6
Y1	7
Y2	10.8
Eq Sq (cm)	13.21
SSD (cm)	100
$D_{(max)}$ (cm)	3.2
ISF	0.939
Measured Output (cGy/MU)	0.8244
MU	2584
MU/2	**1292**
Dose Rate (MU/min)	600
Time	2.58

Figure 9. Sample MU hand calculation used by medical physicists to calculate MUs for GRID treatment delivery, using field size-based output factor measurements. Note that the total and split-field MUs are both included to accommodate the MU limit of the linear accelerator.

Tables

Table 1. Treatment planning details for Patients 1-3.

	Patient 1	**Patient 2**	**Patient 3**
Disease Site:	Renal Pelvis Cancer	Left Upper Lobe Lung	Left Hemipelvis
High Risk OR:	Left Kidney	Brachial Plexus Esophagus Spinal Cord	Sacral Nerve Root Bowel Space Rectum
GRID Treatment			
Prescription:	2000 cGy	1800 cGy	2000 cGy
Number of Fractions:	1	1	1
Beam Angle(s):	65°	155°	200°
Beam Energy:	18MV	18MV	18MV
Standard EBRT			
Prescription:	4000 cGy	3000 cGy	2500 cGy
Number of Fractions:	20	10	10
Beam Angles:	25.5°/205.5°	0°/155°	0°/180°
Energy:	18MV	18MV	18MV
Wedges:	10° (on 25.5° beam)	10°/15°	N/A