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Radiation dermatitis caused by a bolus effect from an abdominal compression device

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ABSTRACT

American Association of Physicists in Medicine (AAPM) Task Group 176 evaluated the dosimetric effects caused by couch tops and immobilization devices. The report analyzed the extensive physics-based literature on couch tops, stereotactic body radiation therapy (SBRT) frames, and body immobilization bags, while noting the scarcity of clinical reports of skin toxicity because of external devices. Here, we present a clinical case report of grade 1 abdominal skin toxicity owing to an abdominal compression device. We discuss the dosimetric implications of the utilized treatment plan as well as *post hoc* alternative plans and quantify differences in attenuation and skin dose/build-up between the device, a lower-density alternative device, and an open field. The description of the case includes a 66-year-old male with HER2 amplified poorly differentiated distal esophageal adenocarcinoma treated with neoadjuvant chemo-radiation and the use of an abdominal compression device. Radiation was delivered using volumetric modulated arc therapy (VMAT) with 2 arcs using abdominal compression and image guidance. The total dose was 50.4 Gy delivered over 40 elapsed days. With 2 fractions remaining, the patient developed dermatitis in the area of the compression device. The original treatment plan did not include a contour of the device. Alternative *post hoc* treatment plans were generated, one to contour the device and a second with anterior avoidance. In conclusion, replanning with the device contoured revealed the bolus effect. The skin dose increased from 27 to 36 Gy. planned target volume (PTV) coverage at 45 Gy was reduced to 76.5% from 95.8%. The second VMAT treatment plan with an anterior avoidance sector and more oblique beam angles maintained PTV coverage and spared the anterior wall, however at the expense of substantially increased dose to lung. This case report provides an important reminder of the bolus effect from external devices such as abdominal compression. Special consideration must be given to contour and/or avoiding beam entrance to the device, and to the use of such devices in patients who may have heightened radiosensitivity, such as those who are human immunodeficiency virus (HIV)–positive.

Introduction

The planning and delivery of radiation therapy for patients with thoracic, abdominal, and pelvic tumors is often complicated by respiratory motion. Several techniques exist for managing motion, including forced shallow breathing with abdominal compression.[1] Originally developed in Sweden in 1994,[2] most abdominal compression devices consist of a rigid arch positioned over the patient's abdomen, with a pressure plate attached to the arch with a screw to regulate the applied pressure and allow for reproducibility. Forced shallow breathing is most well studied and most commonly used for malignancies of the liver and lung, and it has been shown to reduce lung tumor motion in the cranio-caudal direction from a mean of 12.3 to a mean of 7.0 mm.[3]

The dosimetric effect of external devices such as abdominal compression plates is a complex issue requiring careful consideration. Such devices increase skin dose and attenuate photon beams. The beams eye view feature in treatment planning software can be used to avoid external attenuating devices if possible. In lieu of this, a recent American Association of Physicists in Medicine (AAPM) report recommended including immobilization devices in the planning computed tomography (CT) field of view,

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contouring the device as completely as possible, using CT values of the device rather than assigning a bulk density, and making measurements to verify planning system calculations for a certain device.[4]

There is extensive literature in recent years on the dosimetric effects of external devices; however, much of it centers on couch tops and immobilization devices such as stereotactic body radiation therapy frames and body immobilization bags.[4] The AAPM report also notes that there are very few clinical reports of skin toxicity because of external devices compared with the number of physics-based reports on potential toxicity,[4] despite their increasing use. One such physics-based report found significant 2D bolus effect on skin dose in the presence of immobilization devices, up to an increase by a factor of 4.3 in a 5 cm^2 area in an intensity modulated radiation therapy field with 15 MV beams.[5]

Here, we present the case of a 66-year-old man with distal esophageal adenocarcinoma treated with the use of an abdominal compression device who developed a grade 1 abdominal skin toxicity. We discuss the dosimetric implications of the utilized treatment plan as well as *post hoc* alternative plans and quantify differences in attenuation and skin dose/build-up between the device, a lower-density alternative device, and an open field.

Case description

A 66-year-old male presented with a diagnosis of HER2 amplified poorly differentiated distal esophageal adenocarcinoma. After noting dysphagia to solids, the patient underwent an upper endoscopy revealing a large polypoid tumor in the distal one-third of the esophagus, which was biopsied and diagnosed as poorly differentiated adenocarcinoma. Positron emission tomography/CT showed mild distal esophageal thickening with SUV 7.7, as well as a mildly prominent left paraesophageal lymph node. Endoscopic ultrasound revealed 3 malignant appearing peritumoral lymph nodes in the mediastinum. The patient was staged clinical T3N2M0. The patient's medical history was remarkable for well-controlled human immunodeficiency virus (HIV), asthma, and hypertension. His social history included current smoking with a 40-pack-year history.

The patient was treated with neoadjuvant chemo-radiation. Weekly carboplatin 2 mg/AUC and paclitaxel 50 mg/m^2 were administered concurrent with radiation. The patient underwent a CT simulation scan with the use of an abdominal compression device (SBRT-B1, CDR Systems, Canada) (Fig. 1). The device consists of a large indexable carbon fiber abdominal compression bridge with a compression post assembly. The bridge consists of 2 load bearing carbon fiber spans attached by small nylon screws. The cylinders between the spans are 0.5 in solid plastic (Delrin, *i.e.*, polyoxymethylene) with a density of 1.41 g/cm^3 and are adjustable in location. The compression post is supported by a nylon post retainer with the post itself made of Delrin. The compression plate is made of nylon with a density of 1.16 g/cm^3 at a perpendicular cross sectional thickness of 0.25 in.

Clinical tumor volume included the gross disease, the proximal and distal esophagus, stomach, and celiac nodes. The planned target volume (PTV) was created from clinical tumor volume with appropriate margins, and PTV was planned to a dose of 45 Gy in 25 fractions. This was followed by a boost to the gross tumor of an additional 5.4 Gy in 3 fractions for a total dose of 50.4 Gy delivered over 40 elapsed days. Radiation was delivered using volumetric modulated arc therapy (VMAT) with 2 arcs using abdominal compression and image guidance.

With 2 fractions remaining, the patient developed dermatitis in the area of the compression device (Fig. 2). The physician was notified that the device may be acting as a bolus and tissue attenuator, and that the prescribed dose may not be accurate. With only 2 treatments left and no evidence of true underdosing, no changes were made to the plan. To minimize bolus effect, the compression device was loosened one notch as to not touch the skin. The dermatitis resolved with conservative management.

The original treatment plan did not include a contour of the compression device. The 27 Gy isodose line is seen at the skin (Fig. 3A). PTV coverage at 45 Gy is acceptable at $>$ 95%. Replanning with the device contoured reveals the bolus effect. The 31.5 Gy isodose line is now seen at the skin, with a hotspot at the lateral aspect of the device to 36 Gy (Fig. 3B). PTV coverage at 45 Gy is reduced to 76.5%.

To avoid the compression device and thus bolus effect, we created a new VMAT treatment plan with an anterior avoidance sector and more oblique beam angles (Fig. 3C). PTV coverage at 45 Gy is maintained at 96%. The anterior wall is spared, receiving approximately 13 Gy. However, this is at the expense of substantially increased dose to the lungs. Organ-at-risk volumes and doses for each plan are shown in the Table.

The attempt to avoid the compression device with sector avoidance resulted in increased V_5 and V_{10} lung dose (both lungs minus PTV), violating the RTOG 1010 constraints[7] of $V_5 < 50\%$ and $V_{10} < 40\%$ at 70.2%, 42.6%, respectively (Table). Another possibility would have been to attempt to move the compression device

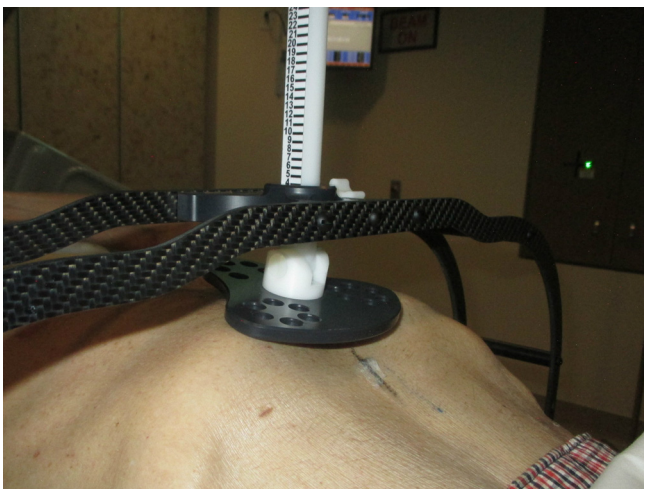

Fig. 1. CT simulation scan with abdominal compression device. (Color version of figure is available online.)

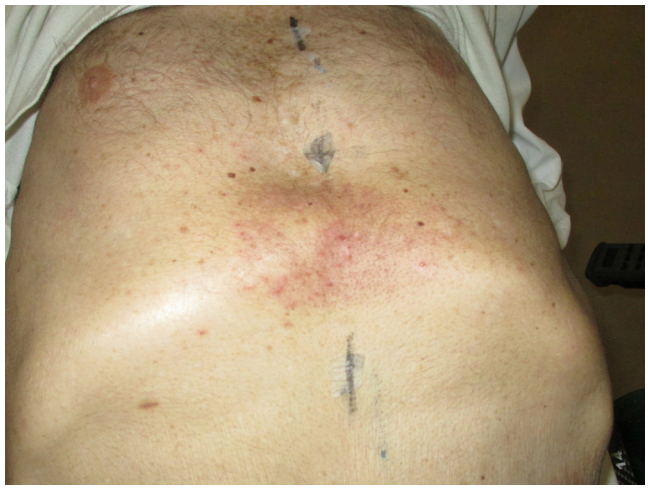

Fig. 2. Grade 1 skin toxicity at the site of the device, developed at the end of treatment. (Color version of figure is available online.)