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Whole breast nodal irradiation using supine VMAT and prone 3D planning: A case study

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The purpose of this study was to compare the variations in doses to the ipsilateral lung and heart between the supine whole breast and nodal volumetric-modulated arc therapy (VMAT) technique and the prone 3-dimensional conformal radiation therapy (3DCRT) technique. In this study, 3 patients who were simulated in the prone and supine positions were planned using supine VMAT and prone 3DCRT techniques to compare planning target volume (PTV) coverage as well as dose to organs at risk (ORs), including the heart and ipsilateral lung. Although all constraints were met, the ideal treatment technique depended on the patient's anatomy and lumpectomy location. Supine VMAT provided excellent coverage to the target structures but encountered difficulty in limiting dose to the ipsilateral lung and heart. When compared with the supine VMAT technique, the prone 3DCRT limited dose to the ipsilateral lung and heart but provided less dose coverage to the target volumes.

Introduction

In the United States, the cumulative lifetime incidence of breast cancer is 1 in 8 women.[1] In fact, breast cancer is so common that it has been ranked the second most common malignancy affecting women living in the United States after skin cancer. Although breast cancer is prevalent, the survival rates have been steadily increasing since 1989 as a result of earlier diagnosis and the development of more effective treatments, such as chemotherapy, hormone-targeting drugs, and radiation therapy. The increase in survival necessitates a greater need for therapies with decreased toxicity to normal tissues, providing better cosmetic outcomes and decreasing the risk of radiation-induced secondary malignancies.[2]

Supine 3-dimensional conformal radiation therapy (3DCRT), often treated with 3 fields monoisocentrically, was the gold standard for many years. However, the monoisocentric technique had limitations that included less than optimal planning target volume (PTV) coverage, problematic junctions between the breast and the nodal fields, and increased radiation dose to surrounding healthy tissues.[2] Nearly a decade ago, advances in technology paved the way for intensity-modulated radiation therapy (IMRT) techniques that increased PTV coverage, made better dose homogeneity possible, and decreased dose to surrounding structures.[3] In 2007, volumetric-modulated arc therapy (VMAT) was introduced clinically for breast cancer treatment and has since become a widely accepted method for treating left-sided breast cancer patients with nodal involvement. Although VMAT and IMRT are similar in PTV coverage, VMAT has better dose conformity, decreased maximum dose to surrounding tissues, less monitor units (MUs), and decreased treatment time.[2]

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Recently, 3DCRT prone breast techniques have garnered interest in the radiation oncology community. The prone position naturally pulls the breast away from the chest wall, allowing for the possibility of greater dose sparing to organs at risk (ORs). Currently, there is a lack of data comparing supine VMAT with prone nodal breast treatments. In this study, 3 patients who were simulated in the prone and supine positions were planned using supine VMAT and prone 3DCRT techniques to compare PTV coverage as well as dose to ORs, including the heart and ipsilateral lung.

Case Description

Patient selection and setup

Women with breast cancer and nodal involvement comprised the patient sample for this study. All patients in this study were diagnosed with grade 2 or 3 invasive ductal carcinoma and an intact breast. Patients were simulated in both prone and supine positions to attempt to reduce organ dose and deliver adequate dose to the breast and nodes. All patients were scanned head first using a computed tomography (CT) large bore scanner (General Electric Healthcare [GEHC], Milwaukee, WI). For the supine scan, the patient was placed on a 15° tilt breast board with the ipsilateral arm up and the head turned in the opposite direction. In the prone scan, the patient was placed on the abdomen on top of a prone breast board that measured 24.5 cm off the CT table. There was an opening on the affected side that allowed for the breast to fall forward and the supraclavicular (SCL) area to be exposed so that nodes can be treated without obstruction. The head was also turned away from the affected side, and a Civco (Kalona, IA) Vac-Lok bag was used to support the arms. Radiopaque CT wires were placed on the skin to delineate the edges of the breast tissue and tattoos were placed on the patient to reproduce daily setup. On-board imaging was used daily for each patient.

Target delineation

Target delineation was performed by the physician and medical dosimetrist on a Philips Pinnacle v9.8 treatment planning system (Fitchburg, WI). Contours were created on the planning CT and expanded following the Radiation Therapy Oncology Group (RTOG) 1304 protocol.[4] The protocol provided guidelines for contouring all target volumes and structures that included lumpectomy, breast, SCL nodes, axillary nodes, and internal mammary nodes (IMNs). All clinical target volume (CTV) contours were delineated based on the RTOG anatomy atlas.[5] Critical organs contoured included the ipsilateral and contralateral lung, contralateral breast, heart, and thyroid.

The lumpectomy gross tumor volume was contoured with available imaging and included the lumpectomy cavity, lumpectomy scar, seroma, and surgical clips. Lumpectomy CTV was created from a 1-cm expansion of the lumpectomy gross tumor volume that avoided the pectoralis muscles, was cropped 5 mm from the skin, and did not cross the midline. Lumpectomy PTV was created by expanding the CTV by 7 mm in all directions excluding the heart.

Breast CTV was classified as all palpable breast tissue that was delineated at the time of simulation with radiopaque wires. The lumpectomy CTV was included in this contour and excluded 5 mm of skin on the surface, the pectoralis, chest wall, ribs, and lung. The breast PTV was the breast CTV with 7-mm expansions that avoided the heart and did not cross the midline. Breast PTV Eval was created by copying the breast PTV and edited to exclude air outside the patient, 5-mm skin, and anything deeper than the anterior surface of the ribs. Breast PTV Eval was used for constraints in planning and dose-volume histogram analysis.

SCL CTV was contoured using the RTOG Breast Cancer Atlas.[5]

SCL PTV was created by expanding the supraclavicular CTV by 5 mm in all directions. The SCL PTV did not include the thyroid, trachea, esophagus, and lung, and was retracted 5 mm from the skin surface.

Axillary CTV was contoured from the remaining, undissected axillary nodes. The physician used the operative reports and other diagnostic imaging to determine what axillary nodes were to be included in planning. Typically, level I and II axillary nodes are removed so the level III nodes and any other remaining nodal levels must be included in the axillary CTV. Axillary levels can be found on the RTOG Breast Cancer Atlas.[5] Axillary PTV included a 5-mm expansion of the CTV excluding the lung. IMN CTV included the IMN and thoracic vessels in the first 3 intercostal spaces. The IMN PTV was a 5-mm expansion from the IMN CTV medially, laterally, superiorly, and inferiorly. The IMN PTV excluded the sternum, lung, and heart.

Treatment planning

Each patient used for planning had scans performed on the same day in both prone and supine positions. A total of 3 patients were planned with 3DCRT in the prone position and with VMAT in the supine position. Each patient was prescribed a dose of 50 Gy in 25 fractions to the whole breast and nodal regions. The lumpectomy was to receive a boost of 10 Gy in 5 fractions. The 3DCRT prone plans for all patients used single isocenter tangents for the whole breast along with an anterior and posterior SCL field.

Patient no. 1 was planned supine using a VMAT technique that used four 249° partial arcs with split beams to allow more adequate multileaf collimator (MLC) range. The