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Feasibility and full-course dosimetry of an intraoperatively placed multichannel brachytherapy catheter for accelerated partial breast irradiation

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ABSTRACT

PURPOSE: Determine feasibility and resultant dosimetry of an intraoperatively placed multichannel intracavitary brachytherapy catheter for accelerated partial breast irradiation (APBI).
METHODS: Patients with breast cancer underwent intraoperative brachytherapy catheter placement based on frozen section analysis with immediate postoperative APBI. The planning target volume evaluation (PTVEval) and organs at risk were contoured on daily pretreatment CT scans for each patient, and the original treatment plan was applied to assess full-course dosimetry.
RESULTS: Of the first 21 patients consented for intraoperative catheter placement, 20 (95%) were able to proceed with treatment as planned. The mean volume of PTVEval receiving 90% of prescription dose ($V_{90\%}$) and mean percentage of prescription dose to 90% of the PTVEval ($D_{90\%}$) on initial planning were 96.7 (±1.1%) and 100.2 (±2.1%), respectively. Full-course dose coverage remained excellent with a mean PTVEval $V_{90\%}$ and $D_{90\%}$ of 95.0 (±4.4%) and 100.2 (±9.6%), respectively. Mean full-course maximum dose constraints for chest wall and skin were met by 70% and 95% of patients, respectively. Air accumulation >1 cc during treatment increased the risk of a daily fraction with PTVEval coverage below goal (odds ratio, 9.8; $p = 0.05$), whereas those with applicators <0.5 cm from the chest wall at planning were at risk of exceeding that organ's maximum dose constraint on a daily fraction (odds ratio, 45; $p = 0.02$).
CONCLUSIONS: Intraoperative catheter placement and early initiation of APBI based on frozen section pathology is feasible, yields acceptable dosimetry, and is an option for completing breast conserving therapy in less than 10 days.

Keywords: Breast cancer; Accelerated partial breast irradiation; Dosimetry; Brachytherapy; Frozen section pathology; Adaptive replanning

Introduction

Breast conserving therapy (BCT), defined as breast conserving surgery (BCS) followed by adjuvant radiation therapy, is the preferred treatment for many women with early stage breast cancer and provides equivalent survival outcomes relative to mastectomy (1, 2). Although conventional and hypofractionated whole breast irradiation have been used as adjuvant treatment, recent data have emerged that support the use of accelerated partial breast irradiation (APBI) as an effective and convenient alternative (3, 4). APBI allows delivery of a short course of radiation therapy to the highest risk breast tissue surrounding the surgical resection cavity and can be performed using a variety of techniques, including external beam radiation therapy, interstitial or intracavitary brachytherapy, or intraoperative radiotherapy (5–8).

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Delivery of intracavitary APBI with a multichannel catheter allows the ability to optimize dose delivery to the target volume, while potentially sparing dose to nearby organs at risk (OAR). Placement of the catheter has typically required a second procedure 3−6 weeks after surgery, prolonging the time required for completion of locoregional therapy. There have been two primary barriers to intraoperative catheter placement and more rapid initiation of APBI delivery. First, final surgical pathology is often reported days after surgery and may reveal adverse features that are felt to be a potential contraindication to ABPI. In addition, the impact of postoperative changes on target coverage and normal tissue dosimetry in the days immediately after lumpectomy are uncertain, and significant fluctuations during the treatment course could potentially compromise the quality of APBI. This study was undertaken to assess the feasibility of placing a multichannel brachytherapy catheter at the time of lumpectomy based on the frozen section specimen analysis and to analyze the impact of tissue and catheter dynamics on full-course dosimetry with early postoperative initiation of ABPI.

Methods and materials

Patients and outcomes

We analyzed 21 consecutive patients treated between October 2012 and June 2013 at Mayo Clinic Rochester with lumpectomy and planned for adjuvant APBI using an intraoperatively placed strut-adjusted volume implant (SAVI) catheter. All patients were prospectively enrolled in a registry that captured patient, tumor, and treatment characteristics. Further information on toxicity, cosmesis, and oncologic outcomes was obtained from medical record review. Followup evaluations were performed every 3−6 months after BCT. All study activities were approved by the Mayo Clinic Institutional Review Board.

Patient eligibility

Before surgery, all patients underwent a preoperative evaluation including diagnostic mammography and ultrasound of the breast and axilla. Preoperative percutaneous needle biopsy pathologic confirmation of breast cancer was obtained for all patients, and fine needle aspiration biopsy of sonographically suspicious axillary nodes was performed if indicated. Inclusion criteria for consideration of intraoperative placement of the brachytherapy catheter included age 50 years and older with a diagnosis of a unicentric estrogen receptor−positive invasive breast cancer with a negative preoperative axillary ultrasound or lymph node fine needle aspiration. Patients with ductal carcinoma in situ measuring ≤2 cm clinically were also eligible. Preoperative exclusion criteria included pathogenic BRCA 1/2 mutation, infiltrating lobular histology, receipt of neoadjuvant therapy, history of prior ipsilateral breast cancer or ipsilateral breast radiation, or active connective tissue disease.

Treatment

All patients had wide local excision of the breast tumor, and sentinel lymph node biopsy was performed with intraoperative frozen section pathology evaluation. If the initial frozen margins for the primary tumor were positive, additional tissue around the lumpectomy cavity was subsequently resected during the same procedure. After resection margins and sentinel lymph node(s) were confirmed negative on frozen section pathology, a SAVI device (Cianna Medical, Aliso Viejo, CA) was placed in the operating room via a counterincision into the lumpectomy cavity. Confirmation of final permanent section pathology was required before the initiation of brachytherapy treatments. If final pathology revealed characteristics that excluded use of APBI according to our protocol (i.e., persistent positive margins or lymph node metastases), the applicator was to either be removed or be used for a lumpectomy cavity boost before commencing appropriate external beam radiation for the clinical scenario. Oral antibiotics were given for the duration of catheter placement. Adjuvant endocrine therapy was used at the discretion of the treating oncologist and initiated after completion of radiotherapy.

Brachytherapy planning began on the first weekday after surgery. CT-based three-dimensional (3D) treatment planning was performed using Varian BrachyVision (Varian Medical Systems, Inc., Palo Alto, CA), and individualized treatment plans were created to maximize target coverage and spare adjacent OAR. The PTVEval was established as a 1 cm expansion from the applicator surface into breast tissue. The PTVEval included invaginated breast tissue and was limited to exclude pectoralis muscle, chest wall, and a 5-mm inner margin beneath the skin surface, as per Radiation Therapy Oncology Group 0413 guidelines. The inner rim of the PTVEval expansion was not standardly edited to account for periapplicator air or seroma but was altered based on final physician review to ensure all regions at risk, such as breast tissue with visible surgical clips, were appropriately included. Contoured OAR used for optimization included the breast tissue outside the lumpectomy cavity, the chest wall within 2 cm of the PTVEval, adjacent ribs, ipsilateral lung, heart (for left-sided cases), and the skin (defined as a 5-mm contraction beneath the external patient contour). All patients underwent case-specific dose optimization using unique dwell patterns to best meet the institutional dosimetric target values for PTVEval and OAR listed in Table 1. All dosimetric parameters are reported as percentage of prescription dose, unless otherwise indicated. The average time required for contouring and treatment planning was approximately 5−6 hours, depending on the position of the catheter and the proximity of OAR.

Radiation treatments commenced on the subsequent weekday after brachytherapy planning using a twice-daily schedule to deliver either 34 Gy in 10 fractions or 32 Gy in eight fractions to the PTVEval. The dose fractionation