Advances in Radiation Oncology (2018) ■■, ■■–■■

advances
in radiation oncology

www.advancesradonc.org

Scientific Article

Local failure and vertebral body fracture risk using multifraction stereotactic body radiation therapy for spine metastases

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Received 9 February 2018; received in revised form 4 April 2018; accepted 4 April 2018

Abstract

Purpose: Single-fraction radiation surgery for spine metastases is highly effective. However, a high rate (20-39%) of vertebral body fracture (VBF) has been associated with large, single-fraction doses. We report our experience using multifraction stereotactic body radiation therapy (SBRT).

Methods and materials: All patients who were treated with multifraction SBRT for spine metastases at our institution between 2009 and 2017 were retrospectively analyzed. SBRT was delivered in 2 to 5 fractions using the Cyberknife System (Accuray, Sunnyvale, CA). Patients were followed clinically and with magnetic resonance imaging every 3 to 6 months. Local control, complications (including VBF), and overall survival were evaluated. Patient, disease, and treatment variables were analyzed for a statistical association with outcomes.

Results: A total of 83 patients were treated to 98 spine lesions with a median follow-up of 7.6 months. Histologies included non-small cell lung cancer (NSCLC; 24%), renal cell carcinoma (RCC; 18%), and breast cancer (12%). Surgery or vertebroplasty were performed before SBRT in 21% of cases. Patients received a median SBRT dose of 24 Gy in a median of 3 fractions. Local control was 93% at 6 months and 84% at 1 year. Higher prescribed dose, higher biologic effective dose, higher minimum dose to 90% of the planning target volume, tumor histology, and smaller tumor volume predicted improved local control. The cumulative dose was 23 Gy versus 26 Gy for patients with and without failure ($P = .02$), higher biologic effective dose 39 Gy versus 46 Gy, ($P = .01$), and higher minimum dose to 90% of the planning target volume 23 Gy versus 26 Gy ($P = .03$). VBF occurred in 4.2% of all cases and 5.3% of those without surgery or vertebroplasty prior to SBRT. Only preexisting VBF predicted risk of post-SBRT VBF ($P < .01$).

Meeting information: Presented at the 2018 American College of Radiation Oncology Annual Meeting, February 1-3, 2018 in Fort Lauderdale, Florida.
Sources of support: Supported by the Warren Alpert Medical School of Brown University Summer Research Assistantship grant (2016).
Conflicts of interest: None.

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https://doi.org/10.1016/j.adro.2018.04.002

Conclusions: Multifraction SBRT results in a high local control rate for metastatic spinal disease with a low VBF rate, which suggests a favorable therapeutic ratio compared with single-fraction SBRT.

Introduction

Spinal metastases are a common complication of cancer and can result in significant morbidity for patients.[1] Stereotactic body radiation therapy (SBRT) is a technique whereby high doses of radiation can be delivered to the vertebra while limiting doses to the spinal cord and/or cauda equina. This technique allows for dose escalation, which results in improved local disease control for patients with a favorable prognosis or those with relatively radiation resistant histologies.[2] SBRT also allows for the effective and safe reirradiation of previously treated spinal metastases.[3]

However, vertebral body fractures (VBF) have been reported as a common complication of SBRT and rates of VBF as high as 39% have been shown.[4] Analysis has demonstrated that high-dose, single-fraction regimens are associated with this complication.[5] Therefore, the delivery of SBRT in 2 to 5 fractions has been postulated to result in equivalent rates of local control (LC) but a lower rate of VBF. Thus, we report our institutional experience with multifraction SBRT for spine metastases in a cohort of patients who were treated with the Cyberknife System (Accuray, Sunnyvale, CA).

Methods and materials

After approval by the institutional review board (IRB#867840), a retrospective analysis was performed of patients who were treated with multifraction SBRT for spine metastases. All consecutive patients who were treated at our institution between 2009 and 2017 were reviewed. Patient demographics, disease characteristic, treatment parameters, and outcomes were analyzed. The Bilsky Epidural Spinal Cord Compression Scale was used to evaluate the extent of epidural disease before treatment and the Spinal Instability Neoplastic Score to determine mechanical instability prior to treatment.[6,7] The presence of lytic disease and the extent of vertebral body involvement were based on a review of pretreatment computed tomography (CT) and magnetic resonance imaging (MRI) scans.

Patients were evaluated by the multidisciplinary spine tumor team to determine optimal treatment. SBRT was generally selected for patients with spine metastases in or abutting a prior irradiated field, oligometastatic disease, expected long-term survival, or relatively radiation-resistant tumor histology. Oligometastatic disease was defined as disease that was limited to 1 to 3 metastatic sites. Surgery was generally considered for patients with symptomatic cord compression, high-grade radiographic cord impingement (Bilsky grade 2 and 3), or mechanical instability. Biological effective dose (BED) was used to compare various dose-fractionation schedules. BED was calculated using the linear-quadratic formula utilizing an α/β ratio of 10 for tumor and 3 for normal tissues.[8]

SBRT was performed using the Cyberknife System. Patients underwent a CT simulation in the supine position. High-resolution MRI using T1- and T2-weighted sequences with gadolinium contrast were fused to delineate target volumes and organs at risk. If the spinal cord could not be visualized on MRI due to artifacts from hardware, a CT myelogram was performed to accurately delineate the spinal cord. The gross tumor volume, clinical tumor volume, and primary tumor volume (PTV) were defined in accordance with published consensus guidelines.[9,10] Treatment planning was performed using Multiplan (Accuray, Sunnyvale, CA) to optimize PTV coverage and conformality while respecting spinal cord tolerance. The Ray-Tracing algorithm was used for planning. Select lesions in the thoracic spine underwent Monte Carlo algorithm verification and/or reoptimization because the Ray-Tracing algorithm for beams that traverse pulmonary tissue may be less accurate.[11,12]

The maximum dose to the spinal cord was restricted to 22 Gy in 3 fractions and 30 Gy in 5 fractions for de novo treatments. Spinal cord dose constraints were individualized in the retreatment setting and take into account prior radiation cord dose and time interval since the prior treatment. Plans were also optimized to keep the prescription isodose line ≥80% when achievable to minimize hot spots within the treated vertebral body. Treatment dose and fractionation was selected for each case on the basis of tumor volume, prior radiation dose, and spinal cord tolerance. Treatment was delivered utilizing Xsight spine image tracking.

Patients underwent a clinical evaluation and MRI every 3 months for 1 year and then every 6 months thereafter. Actuarial LC and overall survival (OS) were analyzed using the Kaplan-Meier method.[13] Local failure was defined as a progressively enhancing lesion or soft tissue mass at the treated vertebral level(s) or pathology that demonstrated malignancy. SBRT-related complications were evaluated including esophageal toxicity, radiculopathy, myelopathy, and VBF. VBF was defined as a new or worsened compression fracture within the treatment volume.