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Intensity-modulated radiation therapy and volumetric-modulated arc therapy for adult craniospinal irradiation—A comparison with traditional techniques

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ABSTRACT

Craniospinal irradiation (CSI) poses a challenging planning process because of the complex target volume. Traditional 3D conformal CSI does not spare any critical organs, resulting in toxicity in patients. Here the dosimetric advantages of intensity-modulated radiation therapy (IMRT) and volumetric-modulated arc therapy (VMAT) are compared with classic conformal planning in adults for both cranial and spine fields to develop a clinically feasible technique that is both effective and efficient. Ten adult patients treated with CSI were retrospectively identified. For the cranial fields, 5-field IMRT and dual 356° VMAT arcs were compared with opposed lateral 3D conformal radiotherapy (3D-CRT) fields. For the spine fields, traditional posterior-anterior (PA) PA fields were compared with isocentric 5-field IMRT plans and single 200° VMAT arcs. Two adult patients have been treated using this IMRT technique to date and extensive quality assurance, especially for the junction regions, was performed. For the cranial fields, the IMRT technique had the highest planned target volume (PTV) maximum and was the least efficient, whereas the VMAT technique provided the greatest parotid sparing with better efficiency. 3D-CRT provided the most efficient delivery but with the highest parotid dose. For the spine fields, VMAT provided the best PTV coverage but had the highest mean dose to all organs at risk (OAR). 3D-CRT had the highest PTV and OAR maximum doses but was the most efficient. IMRT provides the greatest OAR sparing but the longest delivery time. For those patients with unresectable disease that can benefit from a higher, definitive dose, 3D-CRT– opposed laterals are the most clinically feasible technique for cranial fields and for spine fields. Although inefficient, the IMRT technique is the most clinically feasible because of the increased mean OAR dose with the VMAT technique. Quality assurance of the beams, especially the junction regions, is essential.

Introduction

For patients with primitive neuroectodermal tumors such as medulloblastoma, brain tumors with the risk of leptomeningeal spread, and other neurologic diseases, it can be necessary to treat the entire central nervous system (CNS) to control the disease.[1,2] In adults, this technique poses a technically challenging planning process because of the complex shape and length of the target volume. The traditional craniospinal irradiation (CSI) technique typically treats the CNS using classic 3D conformal radiation therapy (3D-CRT) with opposed lateral fields to treat the brain and posterior fields to treat the spine.[3] This technique does not spare any organs and causes significant acute and late morbidities.[4,5] In an attempt to develop an efficient clinical technique that will improve dose conformity and decrease dose to organs at risk (OAR), intensity-modulated radiation therapy (IMRT) and volumetric-modulated arc therapy (VMAT) for CSI will be considered. The hypothesis driving this research is that the conformity provided using these advanced treatment modalities will promote OAR sparing and reduce toxicity, both acute and late. In the acute setting, decreased dose to the bowel and lungs may decrease the incidence and severity of nausea and vomiting, diarrhea, and pneumonitis. In the long term, reducing dose to organs, such as the kidneys, liver, and heart, may reduce the incidence of organ dysfunction. In addition, because patients often proceed to total body irradiation subsequently, it is valuable to minimize any excess dose to OAR.

The idea of using IMRT, tomotherapy, and proton therapy to treat CSI patients has already been proposed by several groups, although

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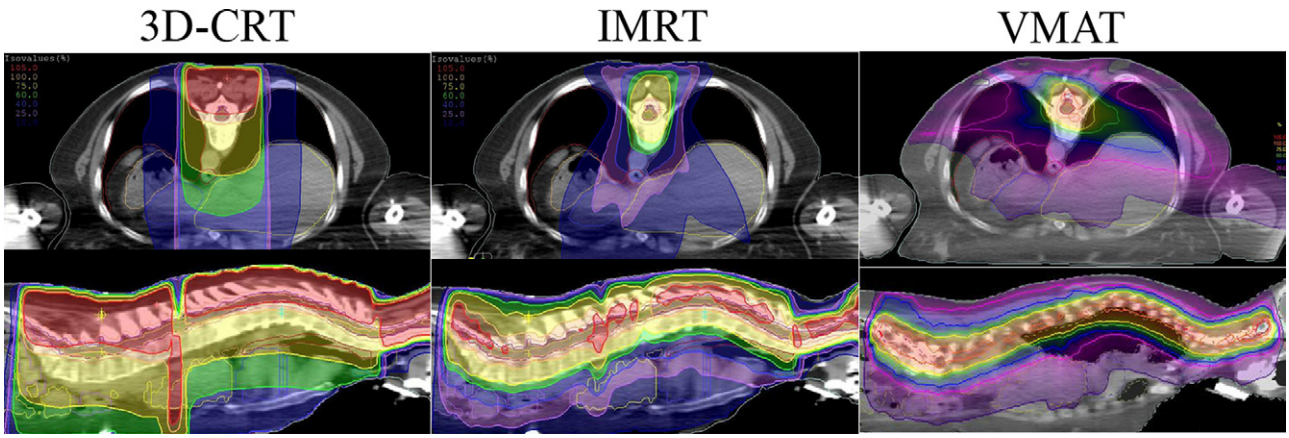

Fig. 1. Axial and sagittal slices from the treatment plans for 1 patient from the dosimetric study showing the differences in isodose distributions among 3D-CRT, IMRT, and VMAT. The conformity achieved by the IMRT and VMAT techniques is evident. The low dose spread associated with the VMAT technique can also be observed.

these studies focus on pediatric cases because the length of the treatment volume is reduced, eliminating the need for a junction of the upper and lower spine fields.[6–12] Knowledge of the dose distribution in the junction region is critical to ensure there are no hot spots that could damage the spinal cord of the patient.

For adult patients, work demonstrating the benefits of IMRT has been done, but the typical end point is dose homogeneity in the target when compared with 3D-CRT.[13,14] VMAT has also been considered for adult spinal treatment but only in terms of a methodology for using VMAT, and the study contains only 5 patients.[15] Here the dosimetric advantages of IMRT and VMAT in terms of both dose homogeneity in the target and critical organ sparing for adult patients are analyzed to develop a clinically feasible delivery technique that is both effective and efficient. To accomplish this, the quality assurance (QA) of these

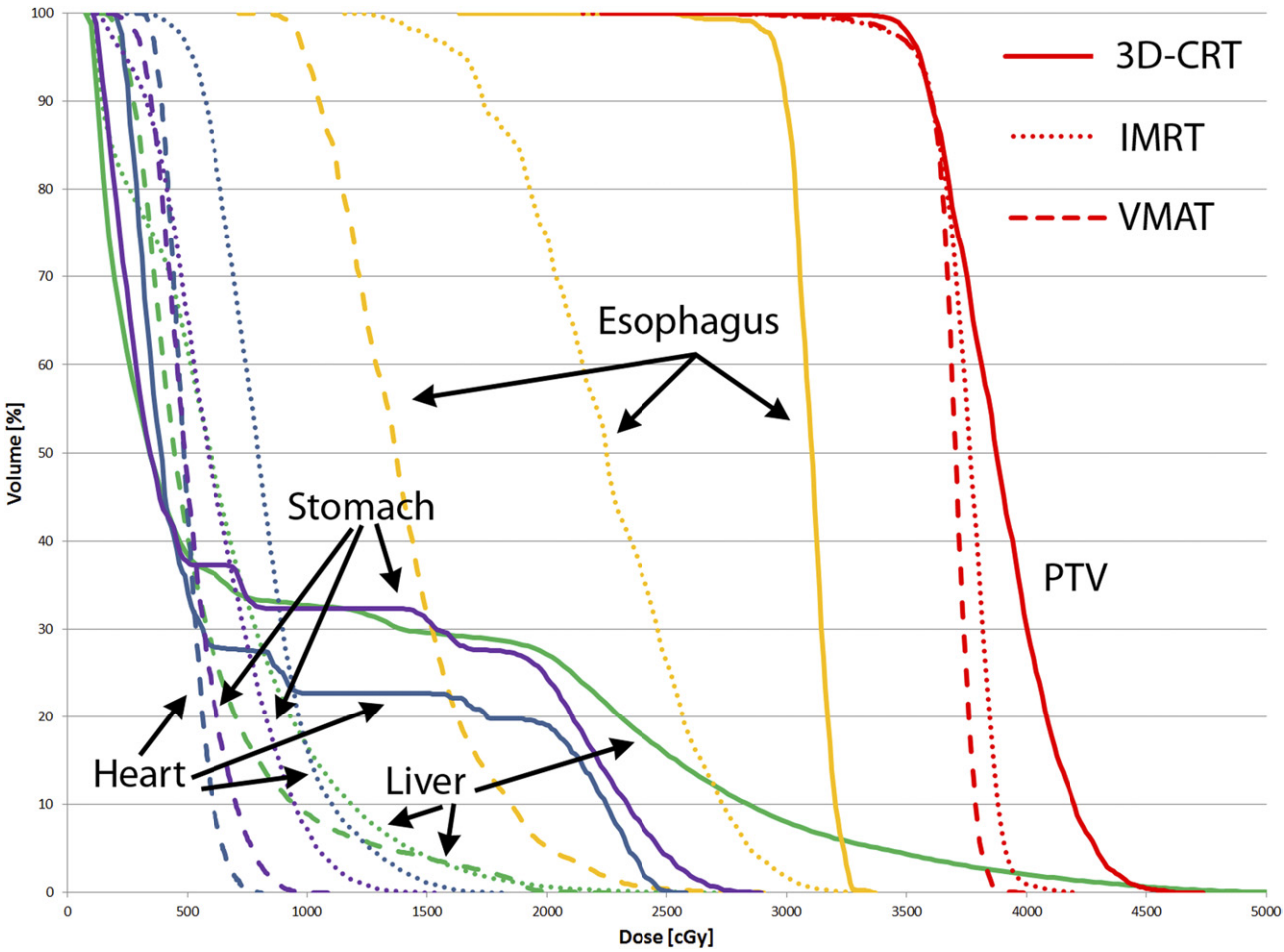

Fig. 2. DVH for the 1 patient from the dosimetric study showing the difference in PTV homogeneity and dose to the esophagus, heart, stomach, and liver for 3D-CRT (*solid lines*), IMRT (*dotted lines*), and VMAT (*dashed lines*).