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Comparison of a new noncoplanar intensity-modulated radiation therapy technique for craniospinal irradiation with 3 coplanar techniques

Anders T. Hansen, M.S.,* Slavka Lukacova, M.D., Ph.D.,† Yasmin Lassen-Ramshad, M.D., Ph.D.,† and Jørgen B. Petersen, M.S.*

*Department of Medical Physics, Aarhus University Hospital, Nørrebrogade 44, Building 5, DK-8000 Aarhus C, Denmark; and †Department of Oncology, Aarhus University Hospital, Nørrebrogade 44, Building 5, DK-8000 Aarhus C, Denmark

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ABSTRACT

When standard conformal x-ray technique for craniospinal irradiation is used, it is a challenge to achieve satisfactory dose coverage of the target including the area of the cribriform plate, while sparing organs at risk. We present a new intensity-modulated radiation therapy (IMRT), noncoplanar technique, for delivering irradiation to the cranial part and compare it with 3 other techniques and previously published results. A total of 13 patients who had previously received craniospinal irradiation with standard conformal x-ray technique were reviewed. New treatment plans were generated for each patient using the noncoplanar IMRT-based technique, a coplanar IMRT-based technique, and a coplanar volumetric-modulated arch therapy (VMAT) technique. Dosimetry data for all patients were compared with the corresponding data from the conventional treatment plans. The new noncoplanar IMRT technique substantially reduced the mean dose to organs at risk compared with the standard radiation technique. The 2 other coplanar techniques also reduced the mean dose to some of the critical organs. However, this reduction was not as substantial as the reduction obtained by the noncoplanar technique. Furthermore, compared with the standard technique, the IMRT techniques reduced the total calculated radiation dose that was delivered to the normal tissue, whereas the VMAT technique increased this dose. Additionally, the coverage of the target was significantly improved by the noncoplanar IMRT technique. Compared with the standard technique, the coplanar IMRT and the VMAT technique did not improve the coverage of the target significantly. All the new planning techniques increased the number of monitor units (MU) used—the noncoplanar IMRT technique by 99%, the coplanar IMRT technique by 122%, and the VMAT technique by 26%—causing concern for leak radiation. The noncoplanar IMRT technique covered the target better and decreased doses to organs at risk compared with the other techniques. All the new techniques increased the number of MU compared with the standard technique.
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Introduction

Medulloblastoma represents approximately 20% of intracranial malignant tumors in children.[1-3] This disease typically spreads through the cerebrospinal fluid within the central nervous system. The standard treatment consists of maximal surgical resection followed by radiation therapy and chemotherapy.[1,3] The whole craniospinal axis is treated with radiation followed by a boost in the posterior fossa. The standard radiotherapy technique used for craniospinal irradiation consists of 2 almost opposing lateral photon fields, rotated slightly in the anterior direction, to place the anterior field edges just behind both lenses, as seen in Fig. 1B. To these 2 lateral fields, several posterior fields are typically added end to end to irradiate the spine from the caudal field edge of the 2 cranial fields to the sacrum.[4-8] It has previously been shown that sufficient dose coverage of the whole central nervous system, including the cribriform plate, is essential in preventing recurrence of the disease.[9,10] The disadvantage of the standard conformal x-ray technique is inadequate target coverage, mainly of the cribriform plate, when certain organs at risk like the parotid glands, the inner ears, or the lenses are to be spared.[11] The risk of xerostomia increases when the parotid glands receive doses more than 25 Gy.[12,13] The risk of hearing loss has been reported to increase when doses to the inner ears are more than 35 Gy.[14,15] Especially for

Reprint requests to: Anders Traberg Hansen, Department of Medical Physics, Aarhus University Hospital, Nørrebrogade 44, 8000 Arhus C, Denmark.
E-mail: andehans@rm.dk

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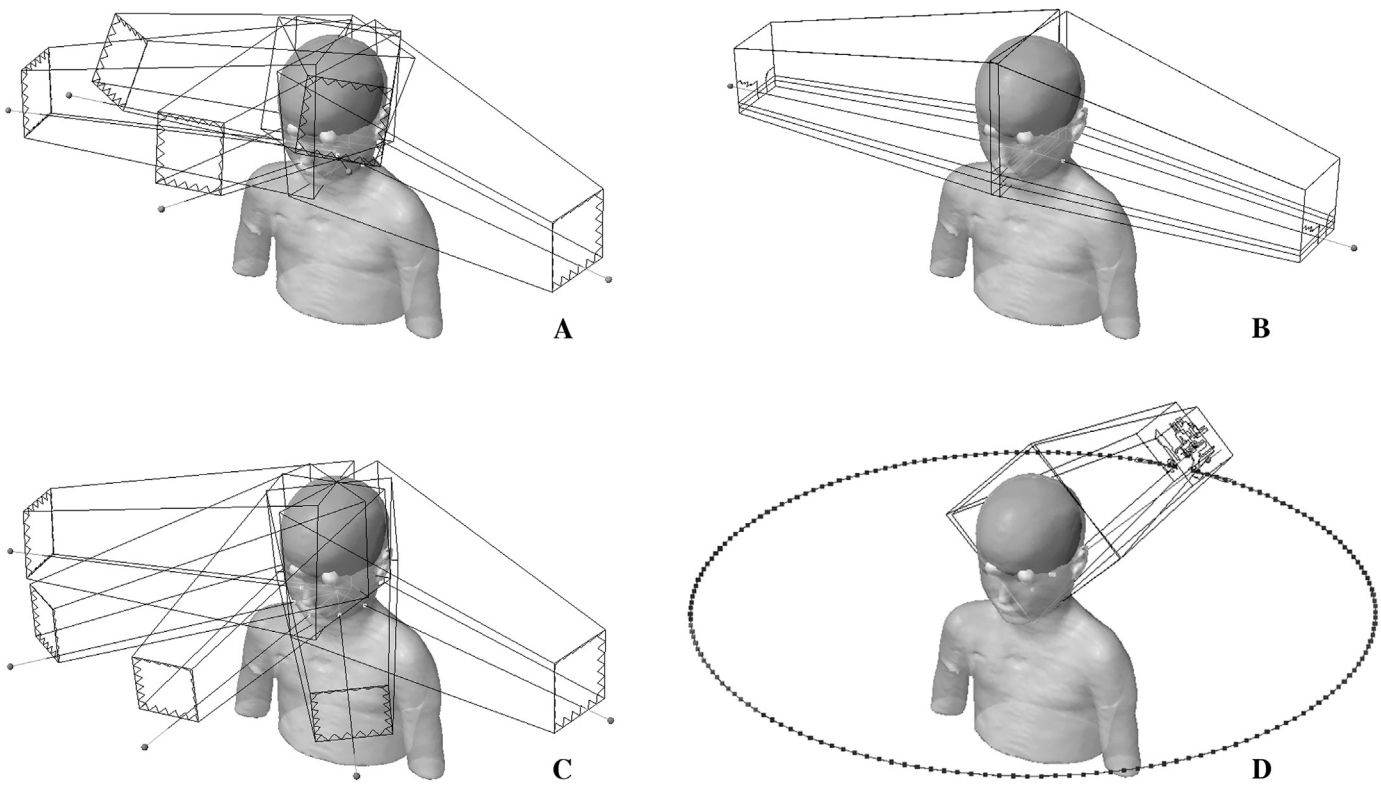

Fig. 1. The field arrangements for the 4 treatment techniques are displayed. In the top left illustration is the noncoplanar IMRT treatment technique (A) and in the top right the standard technique (B). In the bottom left is the coplanar IMRT technique (C) and in the bottom right the VMAT technique (D).

young children, the cribriform plate tends to be more anteriorly located, which is why a full irradiation of the lenses often is unavoidable. If doses more than 0.5 Gy are given to the lenses, there is an increased risk for development of radiation-induced cataract.[16] Additionally, radiotherapy for medulloblastoma may lead to a series of other late side effects.[1,2] Therefore, a radiation technique that is able to cover the target with a sufficient dose and at the same time limits the doses given to the described organs at risk is needed.[17] This can be achieved using proton therapy.[18] However, the use of proton therapy is associated with large economic cost and limited capacity. Therefore, we propose a new noncoplanar intensity-modulated radiation therapy (IMRT)–based technique for craniospinal irradiation, which improves the dose coverage of the target and reduces the dose to the described critical organs.

Methods and Materials

Treatment plans for 13 patients who had been treated for medulloblastoma, at our hospital, in the time period 2007 to 2013 with the standard conformal x-ray technique were collected for this study. In total, 6 patients were children (2 to 17 years), 2 patients were young adults (18 to 30 years), and 5 were adults (30 to 60 years). In the treatment plans, the cranial part as well as the spinal part of the craniospinal treatment was point normalized for all patients. The cranial normalization points were in all cases located centrally in the brain. The spinal normalization points were in all cases placed at representative positions in the medulla spinalis. The original spinal part of the treatment plans was left almost unchanged, but the cranial part of the treatment plans was replanned using 3 planning techniques: our novel noncoplanar IMRT, a coplanar IMRT, and a coplanar volumetric-modulated arch therapy (VMAT) technique.

Delineation

The original computed tomography (CT) scans were in 1 case performed with a slice thickness of 4.5 mm and in 12 cases with a slice thickness of 3 mm. They encompassed the whole cranium, the thorax, and the abdominal and pelvic regions. Typically, parts of the arms and legs were not included in the CT scans. The CT scans were used for delineation of the clinical target volume (CTV) and organs at risk. The CTV consisted of the whole brain including the cribriform plate and the spinal canal. The planning target volume (PTV) was generated by adding a margin of 5 mm to the CTV; however, a margin of 6 mm in the cranial and caudal direction was used because of the uncertainty introduced by the spacing between the CT slices. The critical organs defined for this study were as follows: the parotid glands, the inner ears, the lenses, and the frontal and posterior parts of the eyes. To

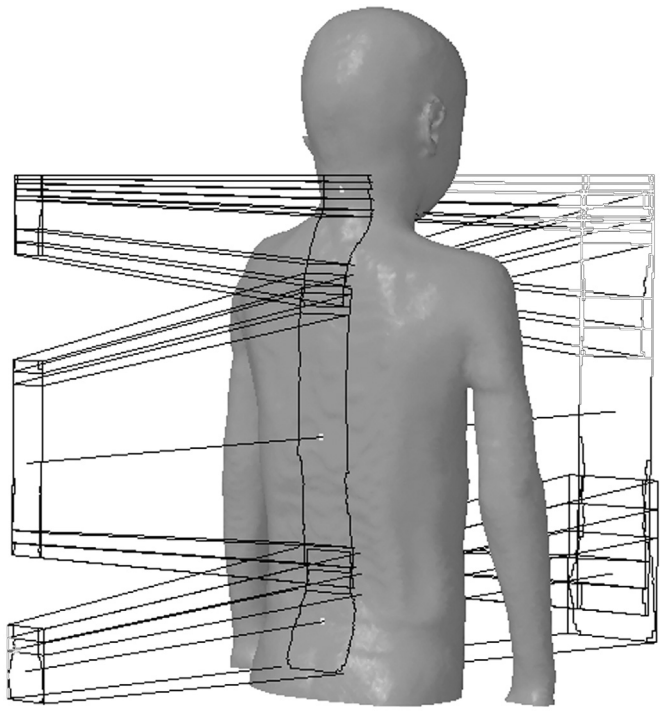

Fig. 2. An example of the spinal part of the original conventional treatment plan. Notice the 6 segments in the cervical junction zone.

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