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Technical Note

A low gradient junction technique of craniospinal irradiation using volumetric-modulated arc therapy and its advantages over the conventional therapy

Comparaison et avantages d'une arcthérapie volumétrique modulée craniospinale avec des gradients de faible dose au niveau des jonctions de faisceau par rapport à une radiothérapie conformationnelle tridimensionnelle classique

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ABSTRACT

A technique using volumetric-modulated arc therapy (VMAT) fields for craniospinal irradiation with low dose gradients at the field junction was tested for its sensitivity to positional inaccuracy. It was compared against the conventional three-dimensional (3D) conformal radiotherapy in terms of dose uniformity at the junction. Treatment plans generated for ten patients who received craniospinal irradiation (35 Gy in 21 fractions) by VMAT technique at our centre were included in this study. For these patients, 3D conformal radiotherapy plans were also generated in addition to the VMAT treatment plans. Intentional shifting of the cranial field in the superior and then in the inferior directions was done, creating a gap or overlap between the fields. Consequent changes in dose distributions in these two plans to positional inaccuracies were studied. The 3D conformal radiotherapy plans showed large dose variations at the junction due to positional shifts as compared to the VMAT plans. With a 5 mm superior shift of the cranial field isocentre creating a gap between the cranial and spinal fields, the magnitudes of underdosing were 13.9 ± 3.6 Gy and 4.8 ± 2.0 Gy for 3D conformal radiotherapy and VMAT respectively. When the cranial field was moved by 5 mm inferiorly creating an overlap between the fields, overdose to the effects of 10.3 ± 4.0 Gy and 4.9 ± 1.3 Gy were observed for the 3D conformal radiotherapy plans and VMAT plans respectively. The VMAT technique is insensitive to longitudinal setup errors (1–3 mm) in patients because of the existence of low dose gradients at the junction between fields. This is unlike the 3D conformal radiotherapy plans which have steep dose gradients at the field edges and thus are highly sensitive to setup errors. Such an advantage for VMAT circumvents the need for dose feathering often practiced with the 3D conformal radiotherapy technique and makes the technique simpler to follow.

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RÉSUMÉ

Une arcthérapie volumétrique modulée craniospinale avec des gradients de faible dose au niveau des jonctions de faisceau a été testée. Elle a été comparée à une radiothérapie conformationnelle tridimensionnelle classique en termes d'uniformité des doses à la jonction. Les plans de traitement générés pour dix patients qui ont reçu une arcthérapie volumétrique modulée de 35 Gy en 21 fractions dans notre centre ont été inclus dans cette étude. Pour ces patients, des plans de radiothérapie conformationnelle tridimensionnelle ont également été générés. Le déplacement du faisceau crânien vers le haut puis vers le bas a été effectué en créant un écart ou un chevauchement entre les faisceaux, les changements conséquents dans les distributions de doses dans ces deux plans ont été étudiés. Les plans de radiothérapie conformationnelle tridimensionnelle ont montré de fortes variations de dose à la jonction en raison des changements de position par rapport aux plans d'arcthérapie volumétrique modulée. Avec un déplacement supérieur de 5 mm de l'isocentre du faisceau crânien créant un espace entre les faisceaux crânien et médullaire, les « sous-dosages » étaient respectivement de 13,9 ± 3,6 Gy et 4,8 ± 2,0 Gy pour la radiothérapie conformationnelle tridimensionnelle et l'arcthérapie volumétrique modulée. Lorsque le faisceau crânien a été déplacé de 5 mm en créant un chevauchement inférieur entre les faisceaux, des surdosages de 10,3 ± 4,0 Gy et 4,9 ± 1,3 Gy ont été observées respectivement pour les plans de radiothérapie conformationnelle tridimensionnelle et d'arcthérapie volumétrique modulée. La technique de l'arcthérapie volumétrique modulée est insensible aux erreurs d'installation longitudinale (1–3 mm) chez les patients en raison de l'existence de gradients de faible dose à la jonction entre les faisceaux. Cela est différent des plans de radiothérapie conformationnelle tridimensionnelle qui ont des gradients de dose abrupts sur les bords du faisceau et sont donc très sensibles aux erreurs d'installation. Un tel avantage pour l'arcthérapie volumétrique modulée contourne la nécessité d'une jonction mobile souvent pratiquée avec la technique de radiothérapie conformationnelle tridimensionnelle.

Mots clés :
Irradiation craniospinale
Technique de faible gradient de dose
Changement de jonction

1. Introduction

Medulloblastoma is one of the most common paediatric tumour. Post-surgery management of medulloblastoma involves radiotherapy to complete craniospinal axis [1]. Craniospinal irradiation is a complex radiotherapy technique because of the challenges involved in delivering a uniform dose to the brain and the spinal axis, avoiding hot spots and cold spots at the field junctions. Critical issues in any craniospinal irradiation planning include overdosing or under-dosing at the junctions between the cranial and spinal fields and between the upper and lower spinal fields. These over- and under-dose regions occur due to overlap of, or gap between the adjacent treatment fields respectively [2–4].

Spinal cord has a maximum tolerable dose of 50 Gy with resultant risk of myelopathy less than $0.2\% \times Gy^{-1}$ [5]. Brain can receive up to 60 Gy for a complication rate of less than 3% [5]. Hence, it is essential to restrict the hotspot magnitude within these maximum limits through careful manipulation of fields in the junction region.

Until recently, we were following the conventional 3D conformal radiotherapy technique for treating such patients. Patients falling into high-risk category were treated to a dose of 35 Gy in 21 fractions. To keep the dose variations at the junction to the minimum, we adopted the "dose feathering" method of shifting the field junctions by 1 cm every seven-treatment fraction. This is a labour-intensive process requiring multiple treatment plans, crosschecking, extensive paperwork, multiple setup imaging and verification, thus making the entire treatment delivery process a complex one to practice.

There have been many reported studies on craniospinal irradiation by volumetric-modulated arc therapy (VMAT), by fixed gantry intensity-modulated technique (IMRT) and by TomoTherapy [6–18]. Myers et al. have studied the effects of patient positional inaccuracy on the dose distribution in VMAT-based craniospinal irradiation [19].

At our centre, for craniospinal irradiation we are currently using VMAT fields that have low dose gradients on their edges close to the junction. We tested the sensitivity of this VMAT technique to setup errors in the longitudinal direction and compared the results with those for the conventional 3D conformal radiotherapy technique.

2. Material and methods

Treatment plans for ten patients who received craniospinal irradiation were included in this study. The patients group consisted of four female and six male patients with median age of 11 years 3 months (range: 8 years and 4 months to 19 years) with an average height of 137.2 cm (range: 106.7 cm to 178.9 cm).

2.1. Patient immobilization and simulation

The patients were immobilized using an individualized four-clamp head-neck thermoplastic mask, in headfirst supine position with arms by the side of the body and scanned on a flatbed CT-simulator couch. The position of the patient during CT-simulation was checked with an X-ray topograph and suitable adjustments were performed to make the spine position corrected for any tilt. Patients were scanned on a 64-slice CT scanner (Philips, True-flight Select, The Netherland) system with 3 mm slice thickness from top of the cranium to ischial tuberosity area. The DICOM images were transferred directly to a Monaco-Sim contouring workstation (version 5.00.02, Elekta CMS, Sunnyvale, CA) through direct network transfer. All patients underwent magnetic resonance imaging (MRI) for brain and spine in a 3T MRI scanner (Philips, 3D Ingenia, CA).

2.2. Contouring

CT and MRI images were co-registered on the basis of mutual information in the Monaco-Sim workstation. The gross tumour volumes for the brain and the spinal fields were drawn as follows: the cranial contouring included the brain and a portion of the spinal cord, up to the cervical vertebrae level of C5-C6. The cranial end of spinal cord contouring started from the end of thecal sac as seen on the sagittal view of the MRI that marked the caudal limit of cranial contouring. Planning target volume for the brain was generated by