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# Novel technique for craniospinal radiotherapy with patient supine

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**Abstract:** A simple procedure to plan, verify and implement craniospinal irradiation (CSI) with patients supine is presented. Treatment is conducted with a single posterior spinal field abutting two lateral cranial fields. The opposed lateral fields are half-blocked and the inferior line is perpendicular. The posterior field uses some fixed field parameters so that the cephalad edge of the posterior field is coplanar with the caudal edges of the lateral fields and it is independent of the height of the couch. A steel-shot ball is used to measure the size of overlap or gap at the junction using portal images of an electron portal image device or portal films. The results of analyzing the portal images show that the errors of the junction are within ±1 mm. The dose-volume histograms (DVHs) show that there are not unbearable hot or cold spots in the clinic target volumes (CTVs). Supine craniospinal treatment is a reliable and convenient alternative to treatment in the prone position and avoids the technical difficulties of the latter. The use of fixed field geometry greatly facilitates treatment planning and effectively reduces the amount of time of setup, verification and treatment.

**Key words:** craniospinal radiotherapy; supine position; setup; verification; treatment

Craniospinal irradiation (CSI) remains an important therapy in the management of several neoplastic diseases of the central nervous system (CNS). It is usually carried out with a patient in the prone position, since this permits direct observation of the junction line between the caudal edges of the opposed lateral directed fields that encompass the cranium and the upper cervical spine and the cranial border of the PA directed field that encompasses the remainder of the spine. Obviously, the junction will result in hot or cold spots in some volume of targets. Furthermore, many patients who need CSI are young children who may require general anesthesia or sedation, so we have developed a novel and simple technique to treat young patients in the supine position, which can be applied to adults as well. The technique uses only three fixed fields, two opposed lateral directed fields for the cranium and a single posterior field for the spine. In contrast to other techniques in the supine position[1-4], it is simple to plan and set up, and theoretically the sole junction does not lead to over- or under-dosage in whole clinic target volume (CTV).

Due to the complexities of CTV, many issues have to be considered concerning beam geometry and field matching. One of the most afflicting difficulties relates to the junction between the cranial field and the spinal field. To avoid the inclusion of the mandible in the exit of the spinal field, we introduce a method in which the junction plane between the cranial and spinal fields is perpendicular to the horizontal plane. Careful immobilization is essential to ensure the comfort of patients and the reproducibility of treatment. The opposed lateral directed fields are designed to be two half-blocked ones. The posterior directed field uses a couch 270° (or 90°) rotation and an extended source-to-surface distance (SSD) is required if the length of the spinal field is excessive. One or two other sub-field segments of the spinal field may be required to compensate the under-dosage of the region of the lumbar and coccygeal vertebrae.

The description of the technique is for a digital linear accelerator, and a three-dimensional treatment planning system (3D TPS) is essential.

## 1 Material and Methods

### 1.1 Patient position and CT image acquisition

The patient's head is positioned on a custom head rest in order to allow for maximum neck extension and avoid inclusion of the mandible in the exit of the posterior field used to treat the spine. A custom thermoplastic mask is fashioned to fixate the patient's head and a custom vacuum bead body mold which lies underneath the whole length of the patient provides immobilization assistance for the trunk and the legs. Three fiducial markers which are in a plane perpendicular to the horizontal one are placed at the level of the second cervical vertebral body. The anterior marker is pasted on the central surface and the bilateral ones are placed at the same altitudinal level.

The CT scanning session uses a PET/CT instrument Biograph Sensation 16 (Siemens AG, Munich, Germany). Two CT scans are acquired with the patient in the supine radiotherapy position. The cranium scan, which includes the whole head, down to the level of the fourth cervical vertebral body, is taken with 5 mm slice thickness and separation. The spine scan, which includes the entire body contour from the inferior border of the brain scan to the inferior limit of the fourth sacral vertebral body, is taken with 10 mm slice thickness and separation. The images are transferred to a TPS PresicePLAN (ver. 2.12, Elekta AB, Stockholm, Sweden) using DICOM 3.0 protocols.

### 1.2 CTV delineation and treatment field definition

The surfaces of the brain and the whole length of the spinal cord are carefully contoured on every CT slice and shape the CTV. Some organs at risk, such as the lenses and eyeballs, are precisely delineated in order to avoid direct irradiation. If necessary, image fusion and registration of CT and MRI using CT studies in the supine radiotherapy position and postoperative diagnostic MRI ones are performed to de-

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fine the target volume for the boost treatment which is typically given after the completion of CSI.

The reference isocenter for the lateral cranial fields is defined at mid-plane and mid-line at the level of the C2 vertebral body. The caudal edges of the fields are coplanar and perpendicular to the horizontal plane. The lateral fields are fixed with asymmetrical jaws (or MLCs) ensuring that the fields are half-blocked ($Y_1 = 0$), and have no collimator rotation, in order to provide a non-divergent junction with the posterior spinal field. If the maximum field length of 20 cm can not cover the entire brain and meninges with an adequate margin for some adult patients, extending the SSDs of the lateral fields is needed. As to the posterior spinal field, the most important criterion is that its cephalad edge must be coplanar with the caudal edges of the lateral cranial fields. In general, a lateral couch movement is not needed. We rotate the treatment couch 270° (or 90°), and then rotate the gantry towards the patient's head through a fixed angle (168.7°) given by

$$A = 180° - \theta = 180° - \tan^{-1}\left(\frac{20}{100}\right) = 168.7° \qquad (1)$$

where the value of 20 equals half of the maximum opening size of the collimator in the direction along the patient's body axis, and 100 is the source-to-axis distance (SAD) of the accelerator. Finally, we shift the couch towards the patient's head through a fixed length (19.6 cm) given by

$$L = 20\sin\theta = 20\sin 11.3° = 19.6 \text{ cm} \qquad (2)$$

where the meaning of the value of 20 is the same as that in Eq. (1). Generally, an extended SSD is needed for the posterior spinal field. The length of the distance is

$$D \geqslant \frac{S}{2\sin\theta} \qquad (3)$$

where $S$ represents the length of the whole spine in the direction along the patient's body axis. For example, if $S = 50$ cm, according to Eq. (3), $D$ is no less than 127.6 cm, so we can set the length of the extended SSD to 130 cm. The parameters are shown in Fig. 1.

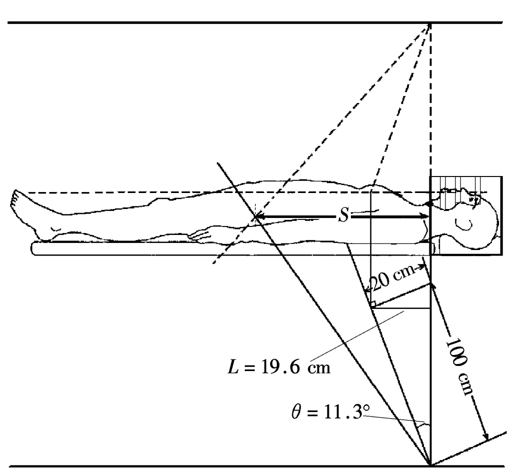
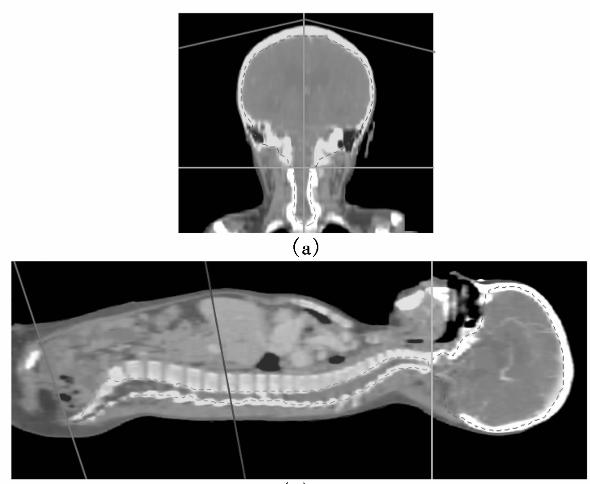



**Fig. 1** Parameters of craniospinal radiotherapy with patient supine

### 1.3 Planning and calculation

Following the above-mentioned methods, three fields are designed in the 3D TPS and the dose distributions are calculated. The shielding is designed such that a 10 mm margin exists between the CTV and the blocks (or MLC), which allows for patient set-up error and patient motion. The lateral cranial fields do not usually require any beam modification. Generally, simple intensity modulation is needed to provide dose compensation for the posterior spinal field. It consists of one or two sub-field segments that simply boost 'cold' regions of the distribution and are automatically delivered using the dynamic MLC mode of the linear accelerator in a step-and-shoot fashion. We typically introduce junction shift (1 cm towards the patient's foot) at one week intervals with shifts superior and inferior to the junction at the brain spine interface. The technique is illustrated for a typical patient with germinoma on a coronal CT reconstruction and a sagittal one in Fig. 2. Its integral DVHs are shown in Fig. 3. A total dose of 30.6 Gy in 17 fractions of 1.8 Gy is prescribed to the brain-CTV and 27.2 Gy in 17 fractions of 1.7 Gy to the cord-CTV, respectively.



(a) (b)

**Fig. 2** Coronal and sagittal multi-planar reconstructions of a patient treated in supine position with CSI technique. (a) Opposed lateral directed fields for the brain on a coronal CT reconstruction; (b) Posterior field for the cord on a sagittal CT reconstruction

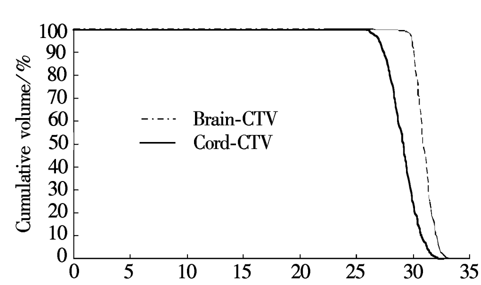
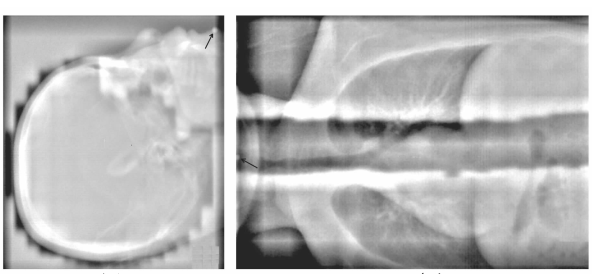



**Fig. 3** Integral DVHs of the patient

### 1.4 Patient setup and portal imaging

Although the patient position determines the integrity of the cranial-spinal junction, the accuracy of treatment is critically dependent on several mechanical tolerances of the treatment unit, namely field size, gantry rotation, gantry setting, collimator rotation, collimator setting, longitudinal couch movement and vertical couch movement. We typically select the tolerance of the IMRT of an accelerator Precise Linac (Elekta AB, Stockholm, Sweden), one of several linear accelerators available at our facility with asymmetric jaws and 40-leaf MLCs with static beam delivery capabilities. Since the location of the spinal field isocenter is always 19. 6 cm distal to the cranial field isocenter along the body axial direction, the couch need only be moved longitudinally for treatment of the spinal field and controlled by using the digital readout of the accelerator. Then we place two markers on the two sides of the immobilization mold for the spinal field. After rotating the gantry 168. 7°, we rotate the treatment couch 270°. Finally, we raise the couch to a certain height by using the digital readout of the accelerator. If necessary, a small longitudinal couch shift is needed to make the left marker of the mold coincide with the plane of the central laser to eliminate the longitudinal error because of vertical couch movement.

Before each patient begins a course of treatment, all fields are imaged using an electronic portal image device (EPID) iView (Elekta AB, Stockholm, Sweden) on a daily basis during the first week of treatment, and once a week (following each junction change) thereafter. If necessary, a shortened SSD may replace the extended SSD of the posterior spinal field avoiding possible collision between the patient and the detector arm of the EPID. A method is designed to measure the size of overlap or gap at the junction. We place a steel-shot ball, 4 mm in diameter, at the location of the anterior marker of the lateral fields[5-6] so that the inferior lines of the lateral light fields seem to divide the ball in two halves. If neither overlap nor gap, the portal images of the partial ball in the lateral cranial field and the posterior spinal field should be two semi-circles or be shaped into a circle after zooming in or out. Two typical portal images with the steel-spot ball projections are shown in Fig. 4. The method can be also carried out using portal films. The portal images are compared with the simulation DRRs transferred from the TPS using DICOM RT protocols as well.



(a) (b)

**Fig. 4** Evaluation of the patient positioning accuracy by measuring the size of two semi-circles in the MV portal images. (a) Of lateral cranial field; (b) Of posterior spinal field

Quality control procedures for reproducibility of several above-mentioned mechanical motions at our clinic have shown the positional accuracy of the jaws to be within ±1 mm. And the results of analyzing the portal images show the size of overlap or gap at the junction to be within ±1 mm. In any event, the patient is protected from any gross over- or under-dosage through the feathering of the junction throughout the treatment.

### 1. 5 Treatment

Patients are treated with 6 MV photons on our Elekta linear accelerator. The entire treatment sequence is automatically transferred to a record-and-verify system. The junction between the fields is feathered during the course of treatment by using the asymmetric jaws. We typically introduce junction shift (1 cm towards the patient's foot) at one week intervals with shifts superior and inferior to the junction at the brain spine interface. The jaw defining the inferior limit of the cranial fields is opened by 1 cm once a week, while the superior limit of the spinal field abutting the cranial fields is decreased by 1 cm.

## 2 Discussion

Target volume definition, immobilization, airway access for anesthesia, dose homogeneity, and junctioning have all been problematic in CSI and are especially critical to young patients and ones with natural kyphosis or lordosis of the cervical and lumbar spine. It is obvious that supine positions address the problems of airway access and poor immobilization. In general, the supine positions are more comfortable, more reproducible and more easily maintained than prone positions, both during a treatment and for repeated positioning over the course of therapy. In the supine position, with the head facing up, children feel less isolated from the activity in the room such that they sometimes do not need anesthesia or sedation[7]. In our experience the use of the CT scanning session or CT with multi-modality image fusion and registration in preparation for CSI results in better definition of the target volume for the cranial fields or for the boost treatment fields[8-9]. The use of sub-field segment techniques for the spinal field addresses the problem of dose inhomegenity. The junction between the fields is feathered during the course of treatment by using the asymmetric jaws and junction shifting.

The use of fixed field geometry such as gantry angle, collimator angle, couch angle, field size, collimator setting, longitudinal couch movement between the spinal field isocenter and the cranial field one, and so on, greatly facilitates treatment planning and effectively reduces the amount of time of setup, verification and treatment. This is especially of importance for young patients who have recently undergone major surgery and are often traumatized and uncomfortable. The problem of junctioning non-coplanar fields over the cervical spinal cord is not easily solved. Our method that uses collimator rotation and half beam-blocking with asymmetric jaws for the cranial fields and uses couch rotation and gantry rotation for the spinal field is a practical solution to the problem that can effectively eliminate over- or under-dosage at the junction. Furthermore, the mirror field of the posterior spinal field, in which parameters consist of couch angle 270°, gantry angle 11. 3° and collimator angle ±180° to the actual, permits direct observation of the junction line between the caudal edges of the cranial fields and the cranial border of the mirror field. Even if the length of the spinal field exceeds 40 cm, we use an extended SSD technique and do not require a second posterior field so as to avoid another junction. For male patients, the testes should be shielded with the scrotum supported on a lead block to avoid direct or indirect irradiation. For some adult female patients, laparoscopic ovarian transposition may be required[10].

For some very young patient whose spinal cord length field usually does not exceed 25 cm, a variant approach deserves introducing, which does not need couch rotation and longitudinal couch movement designs. In summary, the technique procedure is as follows: the designs of the opposed lateral directed cranial fields are the same as the above-mentioned designs. The PA spinal field is rotated with the gantry angle to 180° and its upper half is beam-blocked with asymmetric jaws so the caudal edges of the cranial fields are coplanar with the cranial border of the spinal field. It is necessary to extend the SSD of the latter and to raise the couch. Sometimes, a pair of posterior angulated fields can be substituted for the single posterior field so as to spare the critical normal structures.

Since the development of this approach in 2003, we have applied it in the treatment of almost all of our pediatric craniospinal patients and about half of the adult ones. The technique has been carried out with a linear accelerator and a compatible simulator for the first four patients. In about three-fourths of the pediatric cases, an extended SSD for the posterior spinal field is not required. The variant approach is used in eight pediatric cases, in which the largest spinal field length is 28 cm. For almost all of our adult patients, the extended SSD technique is used for the posterior spinal field, in which the largest SSD is 142 cm and most are 130 cm or so.

## 3 Conclusion

Supine craniospinal treatment is a reliable and convenient alternative to treatment in the prone position. The use of fixed field parameters greatly facilitates treatment planning and effectively reduces the amount of time of setup, verification and treatment. The technique can be carried out with a linear accelerator and a compatible simulator.

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# 一种全新的仰卧位全中枢神经系统放射治疗技术

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**摘要:** 提出了一种全新的仰卧位全中枢神经系统放射治疗技术,包括计划、验证和执行. 治疗采用 2 个侧向全颅野加一个背侧的全脊髓野,2 侧全颅野采用半野技术,下界共面并垂直于地面;固定全脊髓野一些参数以方便设计及摆位,并且上界与全颅野下界共面. 贴一 4 mm 直径的金属小球在衔接处,通过射野摄片确定衔接野的误差. 结果显示衔接野误差小于 1 mm. 剂量体积直方图表明在临床靶体积内没有不可接受的剂量热点和冷点. 仰卧位全中枢神经系统放射治疗技术方便可靠,完全可以替代传统的俯卧位技术,解决了俯卧位技术无法解决的剂量冷、热点问题. 固定射野参数大幅度降低了计划设计的难度,并且有效减少了患者摆位、验证和治疗的时间.

**关键词:** 全中枢神经系统放射治疗;仰卧位;摆位;验证;治疗

**中图分类号:** R730. 55