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Original article

Total body irradiation using Helical Tomotherapy®: Treatment technique, dosimetric results and initial clinical experience

Utilisation de la Tomothérapie® hélicoïdale pour l'irradiation corporelle totale : technique de traitement, résultats dosimétriques, et expérience clinique initiale

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ABSTRACT

Purpose. – Helical TomoTherapy® allows precise and homogeneous tumour coverage and excellent sparing of organs at risk. We present here our treatment technique, dosimetric results, and our first clinical data for patients receiving total body irradiation as part of the conditioning regimen before hematopoietic stem cell transplantation.
Patients and methods. – The cohort consisted of 11 patients who were treated in our institution between August 2014 and January 2016. The total dose was 12 Gy in six fractions in three days. We collected the dose distribution information in the treatment volumes, organs at risk and area of junction. We report retrospectively the clinical events during the first 6 months after the procedure.
Results. – Median age was 31 years (range, 18–57 years). Median D98% was 11.5 Gy (range: 6.6–11.9 Gy). The median of the mean doses to the lungs was 8.7 Gy (range: 8.5–9.3 Gy). The mean dose for the junction area was 12 Gy (range: 11.9–12.1 Gy). All patients had the total procedure, and all underwent successful engraftment. During the first six months, nine patients had at least one grade 3 or 4 toxicity that was due essentially to graft versus host disease. No patient had radiation pneumonitis. The toxicities were both more frequent and of higher grade during the first three months.
Conclusion. – Total body irradiation using helical TomoTherapy® is feasible. It allows a very good homogeneity of dose and conformity with an acceptable tolerance. It could deliver higher doses to sites at high risk of recurrence (bone marrow, sanctuary sites), while sparing major normal organs like lungs, liver, and kidneys. This reduction of dose could lead to reduced severity and frequency of late complications.

Mots clés :
ICT
Irradiation corporelle totale
Tomothérapie
Tomothérapie hélicoïdale

RÉSUMÉ

Introduction. – La tomothérapie hélicoïdale permet une couverture de dose précise et homogène au niveau de la cible tout en évitant efficacement les organes à risques. Nous présentons dans cet article notre technique de traitement, nos résultats dosimétriques, et les données cliniques précoces chez des patients ayant reçu une irradiation corporelle totale dans leur conditionnement avant greffe de cellules souches hématopoïétiques.
Patients et méthodes. – La cohorte a inclus 11 patients qui ont été pris en charge dans notre institution entre août 2014 et janvier 2016. La dose totale était de 12 Gy en six fractions sur trois jours. Nous avons collecté les données de distribution de dose dans les volumes cibles, les organes à risque et au niveau de la zone de jonction. Nous rapportons rétrospectivement la toxicité clinique survenue dans les six mois suivant la procédure.

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Résultats. – L'âge médian était de 31 ans (18 à 57 ans). La médiane du D98 % était de 11,5 Gy (6,6–11,9 Gy). La médiane de la dose moyenne aux poumons était de 8,7 Gy (8,5–9,3 Gy). La dose moyenne au niveau de la zone de jonction était de 12 Gy (11,9–12,1 Gy). Tous les patients ont pu compléter l'ensemble de la procédure, et ont pu recevoir la greffe de cellules souches prévue. Dans les six premiers mois, neuf patients ont souffert d'au moins une toxicité de grade 3 ou 4, qui était due essentiellement à la réaction de greffon contre l'hôte (GVH). Aucun patient n'a été atteint de pneumopathie radique. La toxicité était à la fois plus fréquente et de grade plus élevé dans les trois premiers mois.
Conclusion. – L'utilisation de la tomothérapie hélicoïdale pour l'irradiation corporelle totale est réalisable. Cela permet une très bonne homogénéité de dose et une très bonne conformation à la cible, avec une tolérance acceptable. Cette technique pourrait permettre de délivrer des doses plus élevées aux sites à haut risque de rechute (moelle osseuse, sites sanctuaires), tout en évitant les organes à risque importants, comme les poumons, le foie et les reins. Cette réduction de dose pourrait permettre de réduire la sévérité et la fréquence des complications tardives.

1. Introduction

Total body irradiation is a standard part of the conditioning regimen for stem cell transplantation. The purposes of total body irradiation are immunosuppression and contribution to malignant cell kill, especially in the sanctuary sites such as the testes and central nervous system. Current accepted techniques of total body irradiation use anterior and posterior fields, extended source-to-skin distance, beam spoiler, and lung blocks. In addition, dose prescription and dose verification are limited to a few point measurements using thermoluminescent dosimeters. The advent of dynamic conformal radiotherapy in the form of Helical Tomotherapy® (Accuray Incorporated, Sunnyvale, CA) allows convenient total body irradiation treatment planning, precise delivery of the dose, effective protection of the organs at risk, and a homogeneous dose distribution in the target [1–4].

With Helical Tomotherapy®, the current treatment couch has a maximum travel length of approximately 160 cm, which may not be enough to treat the entire body. One solution is to treat the low extremities on a conventional linear accelerator with anterior-posterior fields and another is to treat the patient in two segments: the upper body and lower body [2–8]. The patient is first positioned in the head-first orientation and then in the feet-first orientation. In this situation, the difficulty is to achieve homogeneity of dose in the area of the junction. In our institution, IUCT-Oncopole of Toulouse, we treated the first patient with total body irradiation using Helical Tomotherapy® in August 2014. We used the field junction technique described by Sun et al. and Chea et al. in two publications, in which they described a dose heterogeneity between 2.5 and 7.5% in the junction area [9,10].

This report details our technique, dosimetric results, and initial clinical experience during the first 6 months post-procedure.

2. Patients and methods

2.1. Patients

The patients received total body irradiation by Helical Tomotherapy® since August 2014. In order to study a homogeneous cohort, we decided to analyse only the patients who were received a total dose of 12 Gy. Patients who had 8 Gy or 2 Gy doses were therefore excluded, as were those who underwent total body irradiation less than 3 months prior to the collection of clinical data in March 2016.

2.2. Data collection

We retrospectively collected the dosimetric data, as well as the toxicities recorded after the transplant by analysing the patients files within the 6 months following the transplant. Toxicity grades were classified using the CTCAE v.4.0 classification, except for the acute graft-versus-host disease which was graded with a specific classication (Glucksberg grading score) [11,12].

2.3. Total body irradiation technique

2.3.1. Immobilization

The ORFIT thermoplastic immobilization device with an open-face mask for the thorax, head and shoulders was used. The patient was in supine position with the arms immobilized along the body (Fig. 1).

2.3.2. Scan acquisition

Two scans were recorded using a slice thickness of 5 mm:

- a head-first scan: from 3 cm above the top of the skull to as far down as possible toward the legs;
- a feet-first scan: from 3 cm before the end of the feet to as far up as possible toward the thorax.

The same immobilization mask was used for both scans. A radio-opaque marker was placed on the front face of each thigh (halfway down the thigh, more than 7 cm away from the hands), corresponding to the junction area. This marker was placed less than 106 cm away from the top of the skull because that was the maximum size of the irradiation field of TomoTherapy. Other radio-opaque markers were placed on the head (three markers), pelvis (three markers), thorax (nipple line), knees, ankles and feet. The distances between these markers in cranio-caudal direction were recorded in the patient's positioning sheet.

2.3.3. Registration

The head-first and feet-first scans were registered using the Eclipse software (Varian Medical System, Palo Alto, CA). The registration was done in the junction area. The radio-opaque markers halfway down the thighs were used to align the two imaging studies.