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Short Communication

Customized mouthpieces designed to reduce tongue mucositis in carbon-ion radiotherapy for tumors of the nasal and paranasal sinuses

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ABSTRACT

Mouthpieces are used to fix the positions of the lower jaw and teeth during carbon-ion radiotherapy for head and neck tumors. We used a customized mouthpiece to reduce radiation mucositis by displacing the tongue. Acute radiation mucositis gradually increased for the palate and tongue after approximately six irradiation fractions (maximal mean grade: palate, 2.5 during radiation fractions 15; tongue, 0.8 during radiation fractions 12 and 13). The mean grade of mucositis was significantly lower for the tongue than for the palate from irradiation fraction six until two weeks after irradiation.

1. Introduction

High-precision external beam radiotherapy (RT) techniques, such as intensity-modulated RT, proton therapy, and carbon-ion RT (C-ion RT), can provide excellent dose distributions for head and neck cancers [1]. When administering these types of RT, it is necessary to minimize bone and muscle movements of the head and neck region during inter- and intra-fractionated irradiation. A reproducible daily set-up is also required to deliver planned doses. Thermoplastic shells and mouthpieces have been used to minimize motion and allow a reproducible set-up.

A customized mouthpiece can be used to fix the positions of the teeth of both jaws and to maintain the position of the lower jaw. Theoretically, the incidence of radiation mucositis on the displaced tongue could be reduced by combining high-precision external beam RT with the use of a customized mouthpiece [2]. However, there is little published information about the methods that can be used to create customized mouthpieces and the planning techniques that can be used to reduce adverse events. Tumors of the nasal and paranasal sinuses are rarely found in the head or neck. In many cases, these tumors are X-ray-resistant non-squamous cell carcinomas. C-ion RT has been shown to be effective against RT-resistant head and neck tumors [3]. Here, we report our experiences creating and applying customized mouthpieces to reduce the incidence of tongue mucositis in patients receiving C-ion RT for tumors of the nasal and paranasal sinuses.

2. Materials and methods

2.1. Creation of the customized mouthpiece

A careful evaluation of the condition of the teeth and trismus is necessary. Treatment for dental caries was provided if required. The mouthpieces were made from thermoplastic ethylene-vinyl acetate. The shape of the mouthpiece was customized to fit the teeth. When making a customized mouthpiece, a few points should be considered.

First, it is important to fix the positions of the teeth of both jaws and to maintain the position of the lower jaw. Therefore, the customized mouthpiece should be close-fitting. To obtain a close-fitting mouthpiece, we used dental impression materials. A plaster figure was made using dental impression material and the mouth-

Abbreviations: ARM, acute radiation mucositis; C-ion RT, carbon-ion radiotherapy; OMDS-model, oral mucosal dose surface model; RBE, relative biological effectiveness; RTOG, Radiation Therapy Oncology Group.

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piece was formed on the plaster figure. In the case of an edentulous jaw, we created the mouthpiece in a manner similar to making a complete denture. Each customized mouthpiece was created to match the individual's dentition.

Second, customized mouthpieces should not cause mouth discomfort. If the mouthpiece is uncomfortable (for example, too large), then saliva production may increase and induce the swallowing reflex. Moreover, an uncomfortable mouthpiece may cause reflex vomiting. Additionally, placement and removal of the mouthpiece can be difficult if it is too large. Caution is necessary regarding trismus as well.

2.2. Carbon-ion radiotherapy technique

The lateral penumbra of carbon-ion beams are much sharper than that of a proton [4]. To provide an example of this, a head and neck case involving 16 beams was randomly selected at our institution and measured. The dose band lateral to the field edge on the isocenter was analyzed. We found that the dose decreased from 80% to 20% over a distance of 4.6–7.4 mm (median, 5.3 mm). Therefore, adverse events may be suppressed by creating a distance of approximately 5 mm in the head and neck region.

We checked the tongue irradiation dose of the treatment plan involving C-ion RT for tumors of the nasal and paranasal sinuses. In a previous study, we predicted the risk of acute radiation mucositis (ARM) during treatment planning for C-ion RT using an oral mucosal dose surface model (OMDS-model) [2]. If the tongue was in the high-irradiation area of the OMDS-model, then we tried to displace the tongue to the low-irradiation area by using a customized mouthpiece. We again performed computed tomography scan, which showed that the mouthpiece displaced the tongue to the low-irradiation area.

2.3. Acute radiation mucositis

Between 2011 and 2012, 39 patients with head and neck tumors were treated via C-ion RT at our institute; 18 of these patients had nasal cavity tumors. These included malignant melanoma ($n = 12$), adenoid cystic carcinoma ($n = 4$), basal cell adenocarcinoma ($n = 1$), and olfactory neuroblastoma ($n = 1$). The T stages (as per TNM classification) were T4 b ($n = 2$), T4a ($n = 9$), T3 ($n = 2$), T2 ($n = 4$), and T1 ($n = 1$). The gross tumor volumes ranged from 3.13 cm^3 to 84.06 cm^3 (median, 23.41 cm^3; average, 30.05 cm^3). We investigated the temporal patterns of mucositis of the 18 patients with nasal cavity tumors (from the first irradiation day to 1 month after radiation). Because all patients were provided with customized mouthpieces during C-ion RT, our study could not include a control group of patients who did not use mouthpieces. Mucositis occurrences in the palate and tongue were evaluated separately.

Mucosal reactions occurring on the palate and tongue were assessed and graded according to Radiation Therapy Oncology Group (RTOG) grading criteria. Oral care was provided by a dental hygienist at least once per week before, during, and two weeks after C-ion RT for a total duration of six weeks.

All patients reported in this study provided informed consent for the use of customized mouthpieces and each medical procedure.

2.4. Statistical analysis

Patients undergoing C-ion RT were divided into two groups, the palate group and the tongue group. The statistical significance of differences was evaluated using a two-sided Student's *t*-test for successive comparison. A *t*-test was used to compare differences in the RTOG mean grade of ARM for the palate and tongue.

3. Results

A representative case of malignant melanoma of the right nasal cavity is shown in Fig. 1. A total dose of 64.0 Gy (relative biological effectiveness [RBE]) was administered in 16 fractions. Without a customized mouthpiece, the mucosal dose to the tongue was estimated to be 58.0 Gy (RBE) based on our OMDS-model (Fig. 1a, b). However, with the customized mouthpiece in place (Fig. 1c), the tongue was displaced to the lower side and it was pushed outside of the planned target area (Fig. 1d, e). Therefore, the mouthpiece can decrease the radiation dose (31.0 Gy [RBE]) to the tongue.

The mean RTOG grades for ARM in the palate and tongue gradually increased after approximately six fractions of irradiation (Fig. 2). The mean RTOG grades for ARM in the palate and tongue gradually increased over the course of approximately the first week after initiation of the C-ion RT. The maximal mean grade of the palate was 2.5 (during radiation fraction 15), whereas that of the tongue was 0.8 (during radiation fractions 12 and 13). After administration of all 16 irradiation fractions, the mean ARM grades gradually decreased over a 1-month period. The mean grade of mucositis was significantly lower for the tongue than for the palate from irradiation fraction six until two weeks after irradiation. The ARM recovery period did not differ significantly based on the C-ion RT dose.

4. Discussion

At our institute, patients receiving C-ion RT for head and neck tumors were fitted with customized mouthpiece. This technique provides good position accuracy. All customized mouthpieces were made according to the individual dentition. Therefore, the lower jaw could be strongly fixed in the mandibular rest position, which is reliable and is influenced by head support and body posture [5]. Movement of the mandible may impair accuracy during C-ion RT because organ locations are affected by the muscles involved in swallowing and opening and closing the mouth. If patients do not use a mouthpiece, then the lower jaw may become loose and displaced, resulting in errors in C-ion RT plans.

The mouthpiece should displace the tongue in the direction that is opposite from the high-dose irradiation area (e.g., the buccal mucosa or mandible). The desired thickness between the palate and tongue is approximately 5 mm. If prepared appropriately, then the customized mouthpiece can benefit the patient by reducing the risk of mucositis. In a previous study, we developed an OMDS-model to evaluate the doses and dose volume histogram parameters associated with ARM in patients with head and neck tumors treated with C-ion RT [2]. Using the developed OMDS-model, a dose of 54.3 Gy (RBE) to the tongue was predicted to result in the development of an ARM grade ≥ 2, as evaluated using the RTOG criteria [2]. In this study, we first assessed the ARM grade using the OMDS-model. Based on this, the mouthpiece design was improved so that it would contribute to the prevention of mucositis onset (Fig. 1). We recommend that the medical team (radiation oncologists, head and neck surgeons, dentists, dental hygienists, nurses, nutritionists, radiotherapists, and medical physicists) should share information about the onset area and severity of oral mucositis, which is difficult to prevent even when using a mouthpiece.

Two points should be kept in mind when using our technique. First, we may not be able to prepare a customized mouthpiece that it is suitable for fixation and mucositis prevention and that avoids causing the gag reflex, which is a normal defense mechanism [6]. Second, the preparation of customized mouthpiece is time-consuming and may not be convenient. However, this simple precaution is necessary to alleviate the adverse effects caused by C-ion RT of head and neck tumors.