Workflow of Carbon-Ion Radiotherapy

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Abstract

The carbon-ion radiotherapy system consists of oncology information system (OIS), radiotherapy treatment planning system (RTPS), and beam delivery system (BDS), which is similar to the standard radiotherapy system. However, there are some differences, such as a big accelerator system, no gantry system (except HIT), and an efficient workflow system. The outline of the carbon-ion radiotherapy (C-ion RT) system and the workflow system is introduced.

Keywords

OIS • Schedule • Workflow

6.1 Overview of Carbon-Ion Radiotherapy System

Particle therapy using carbon-ion beams is a desirable cancer therapy method due to the high-dose localization and the high biological effect around the Bragg peak. On the other hand, the system of C-ion RT is expensive and the number of the facility is very limited. Therefore, the efficient system is required. In HIMAC, there are two treatment facilities: one is inside the HIMAC building (room A/B/C) and the other is in the new treatment facility (room E/F/G) (see Fig. 6.1). The former has a broad beam irradiation system and the latter has a scanning irradiation system. There are three treatment rooms and one or two CT-simulation rooms in each facility. In the new facility, there are six preparation rooms for patients (two preparation rooms per one treatment room) to shorten the occupation time of the treatment room (see Fig. 6.2).

One important feature of the carbon-ion radiotherapy is an absence of the rotating gantry. The treatment room has a fixed horizontal and vertical irradiation ports. The port layouts of the HIMAC are the following:

Room A: Vertical port
Room B: Horizontal and vertical ports
Room C: Horizontal port

The construction cost of the irradiation ports and the beam line can be reduced by the nonidentical irradiation port layout. But the patients are treated in the different rooms day by day. The capable scheduling system is necessary to make best use of the nonidentical rooms.

Recently, the rotating gantry for carbon-ion radiotherapy has been developed in Heidelberg University (HIT) and NIRS. The world's first carbon-ion gantry was designed and constructed at HIT (total weight of over 600 t). The clinical operation of the gantry was started in 2012. A lightweight rotating gantry using superconducting magnets (~3T) has been constructed at the new treatment facility (room G) in NIRS (see Fig. 6.3). The adoption of the gantry will be an important point for the future carbon-ion radiotherapy facility.

The carbon-ion radiotherapy system supports the workflow not only accurately but also efficiently. It consists of a radiotherapy treatment planning system (RTPS), a patient handling system (PTH), a beam delivery system (BDS), a quality assurance (QA) system, and an oncology information system (OIS) in Fig. 6.4. The PTH covers a wide range of

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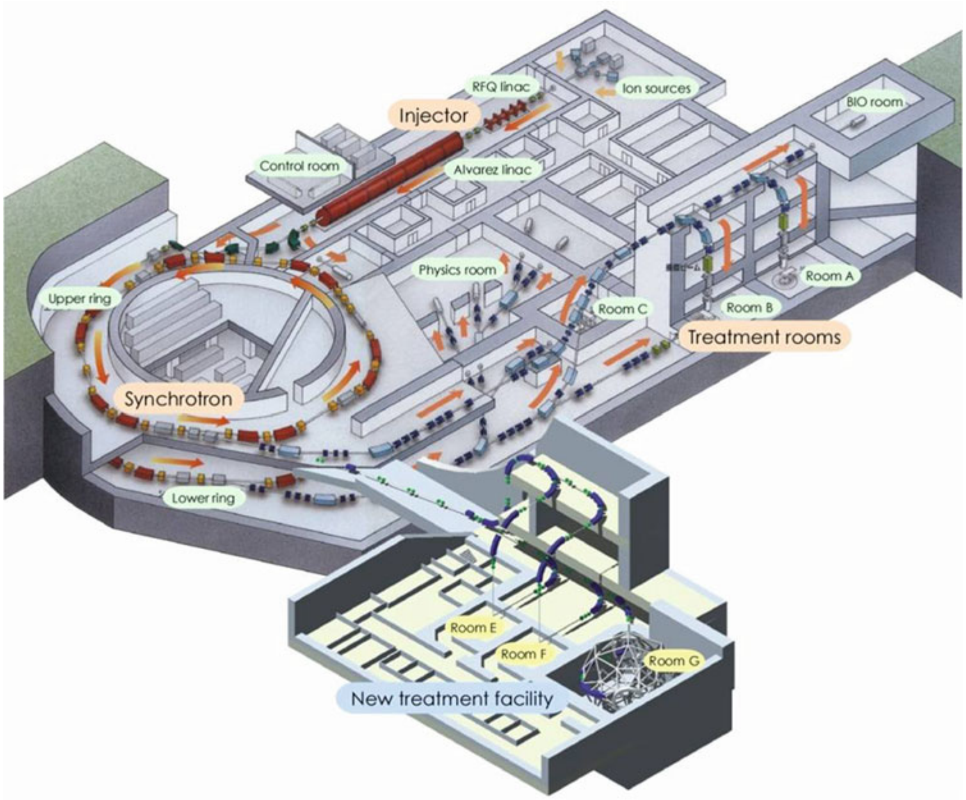

Fig. 6.1 Bird's-eye view of the HIMAC

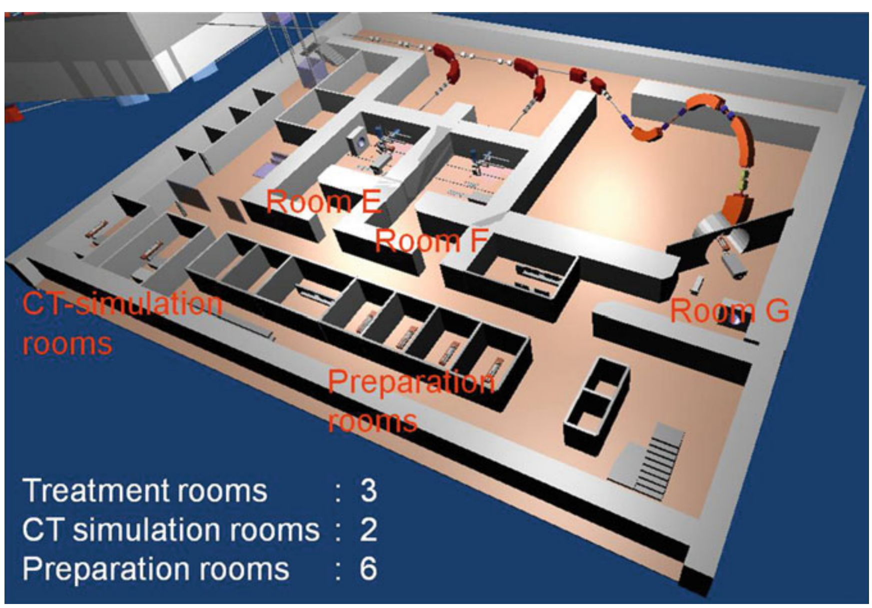

Fig. 6.2 Layout of the treatment floor in the new facility

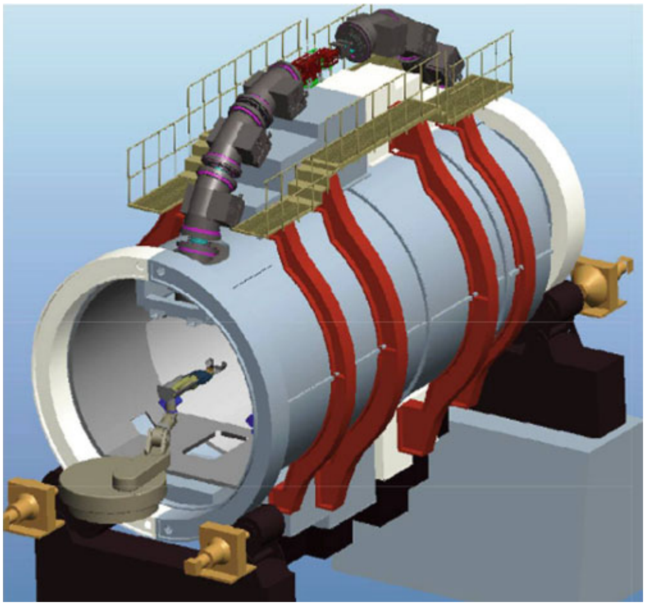

Fig. 6.3 Bird's-eye view of the rotating gantry for carbon-ion radiotherapy using superconducting magnets at HIMAC

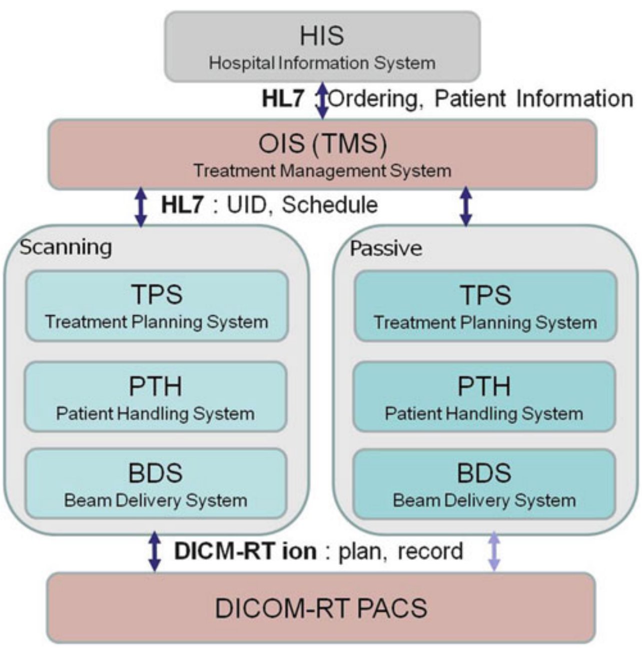

Fig. 6.4 The block diagram of the carbon-ion radiotherapy system in HIMAC

patient data management, and the treatment scheduling functions. Especially the scheduling system is important to enhance the efficiency of the facility. The OIS also transfers the patient and order information from the hospital information system (HIS) to subsystems. The patient data for the treatment is stored in the database. The database of digital imaging and communications in medicine—ion radiation

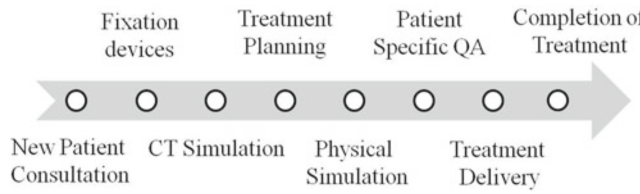

Fig. 6.5 Workflow of the carbon-ion radiotherapy

therapy (DICOM RT ion)—is used as a multi-vendor one at HIMAC. The industry standards, such as Health Level 7 (HL7), are also used as a message format between subsystems

6.2 Workflow of Carbon-Ion Radiotherapy

Figure 6.5 shows the typical workflow of the carbon-ion radiotherapy at HIMAC. Because of the lack of the gantry, the treatment table is rolled for substantive multifield irradiation. Therefore, the preparation of the fixation devices is an important process and the rolling angle is decided at this time. In many cases, there are multiple setup positions and rolling angles for one patient. The fixation devices and the treatment planning CT are required for each setup. The physical simulation is performed in the simulation room to reduce the occupation time of the treatment room, especially for patients with large rolling angle of the bed. Digitally reconstructed radiography (DRR) images are replaced by flat panel display (FPD) images in the physical simulations. When the physical simulation is omitted, DRR images are used in the treatment. The patient-specific QA is optional at HIMAC. It is carried out for the selected treatment plan in the passive delivery system and all plans for the scanning delivery system at this moment.

6.3 Scheduling of Carbon-Ion Radiotherapy

The patient number at HIMAC is close to 1,000 per year and the efficient scheduling method has been developed for years because of the limited number of the medical staff. There are three steps in the scheduling process at HIMAC, a patient scheduling, a beam scheduling, and a treatment room scheduling. The OIS scheduling system at HIMAC supports all three steps of the scheduling.

The patient scheduling uses the idea of "treatment frame." The treatment frame is a set of the schedule for one patient such as a preparation of the fixation device, a CT simulation, and irradiations (see Fig. 6.6). The treatment

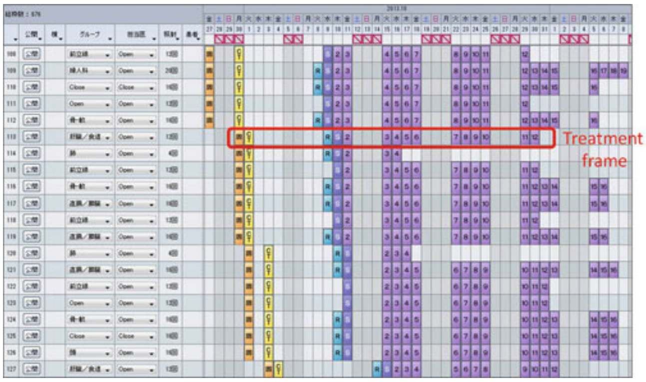

Fig. 6.6 OIS screenshot of the treatment frame table

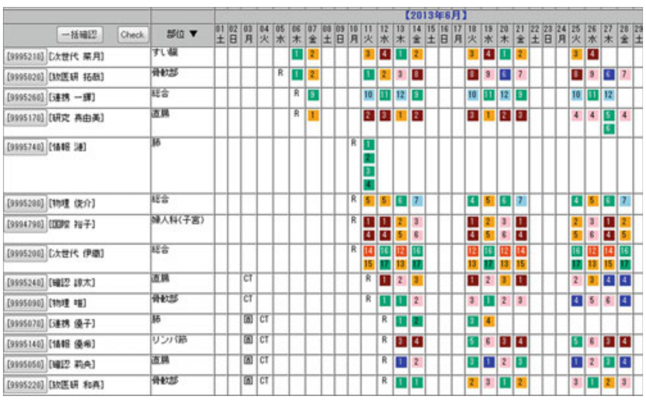

Fig. 6.7 OIS screenshot of the beam schedule

frame is created regularly (e.g., every half year) according to the predicted patient number and the capacity of the facility. Figure 6.6 shows an example of the screenshot of the OIS. The schedule of the new patient is fixed by the assignment

Fig. 6.8 OIS screenshot of the treatment room schedule

to the treatment frame and at the same time, the ordering of the CT and the irradiation is completed. Using the idea of the treatment frame, the number of the patient in the treatment workflow can be equalized.

The second step of the schedule is a beam scheduling. Figure 6.7 shows the screen of the beam schedule for patients. The fraction scheme is determined by the treatment planning process, but when the imbalance for the irradiation system is too large, the beam schedule can be changed by OIS scheduling system within the acceptable range.

The third step of the scheduling is the treatment room scheduling. Figure 6.8 shows the screen of the treatment room schedule for room A/B/C in 1 day. According to the beam scheduling, the treatment room schedule is determined automatically by OIS scheduling system in order to equalize the patient number among three rooms. The medical staffs can also change not only the patient order in the room but also the room of the patient, if the beam port is compatible between treatment rooms. The compatibility of the irradiation port is an important feature in the nonidentical treatment room design.