About Heavy Ion Cancer Therapy

Gunma University, Gunma Prefecture

(Information provided by Gunma University)
Cancer: the Leading Cause of Death in Japan

Cancer is the leading cause of death in Japan. Therefore, cancer control is the most important issue in the field of public health. Cancer therapy in the future should provide a high rate of cure and a low incidence of adverse effects for the patients.

What are Heavy Ions?

Radiation releases energy while traveling through space or matters in the form of waves or particles. Radiations composed of particles heavier than electrons is called a particle beam, and radiation composed of particles heavier than helium is specifically called a “heavy-ion” beam. Currently, carbon ion beams are used in heavy ion facilities.

Heavy Ion Therapy

Heavy ions are accelerated to approximately 70% of the speed of light and applied to patients in order to treat deep-seated cancer within the bodies. Heavy ion cancer therapy allows the tumors to be treated with non-invasive procedures such as surgery.

Heavy ion beams (Carbon ion 1C+)

Accelerated to about 70% of the speed of light by a special accelerator.

By making individually customized treatment devices, the irradiation can be adjusted to the shape and depth of the cancer to be treated.
3 Advantages of Heavy Ion Therapy

1. Superior Dose Localization
   Heavy ion therapy can severely damage the tumor while minimizing damage to surrounding tissues. Heavy ion therapy has less toxicity (adverse effects) than conventional radiotherapy.

2. Effective Against Cancers Which are Resistant to Conventional Radiations
   Heavy ion beams have stronger biological effects than X-ray. For example, heavy ion therapy is more effective against tumors such as osteosarcoma, which are difficult to cure with conventional X-ray radiotherapy.

3. Short Treatment Period
   The treatment period for heavy-ion radiotherapy is relatively short (3 weeks on average). Compared to conventional X-ray radiotherapy, which requires 6-7 weeks, the treatment time can be reduced dramatically.

Comparison with other therapies

<table>
<thead>
<tr>
<th>Surgery</th>
<th>Particle/Radiation Therapy</th>
<th>Chemotherapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indications</td>
<td>• Localized Cancer (mainly early-stage diseases)</td>
<td>• Localized Cancer (from early-stage to advanced-stage diseases)</td>
</tr>
<tr>
<td>Advantage</td>
<td>• Considered more likely to be curative.</td>
<td>• Relatively smaller damage to organ function and morphology. • Relatively smaller damage to the patient. • The treatment results for early-stage cancer in selected sites are equivalent to those of surgery.</td>
</tr>
<tr>
<td>Disadvantage</td>
<td>• Relatively large depreservation of organ function and morphology • Indication for surgery can be limited due to location of cancer and conditions of patients (age, concomitant diseases, etc)</td>
<td>• The financial cost for particle therapy is more expensive compared to other therapies. • Adverse effects can occur in organs near the tumors.</td>
</tr>
</tbody>
</table>

Types of cancers which heavy ion therapy is expected to be effective.

- Brain tumors
- Skull-base tumors
- Eye tumors
- Head and neck cancer
- Lung cancer (Stage 1)
- Liver cancer
- Pancreatic cancer
- Prostate cancer
- Uterine cancer
- Rectal cancer (post-operative recurrence)
- Bone tumors (especially in pelvis and spine)
- Soft tissue tumors

○Heavy-ion therapy proven effective
Processes of Heavy Ion Therapy

This flow chart is an example of heavy ion therapy. The processes can differ depending on facilities and individual disease.

**Step 0 Referral**

If a patient is diagnosed with cancer by a primary care physician or in a hospital and found that he/she is likely to be indicated for heavy ion therapy, the patient should be referred by the physician to facilities which are offering heavy ion therapy.

**Step 1 Detailed Diagnosis / Tests**

The patient is checked in detail by his/her history, physical examination, and other diagnostic tests, and the treatment method will be discussed. It is possible that the patient is considered not to be indicated for heavy ion therapy at this time.

The patient will be informed about the therapy in detail (Informed consent will be obtained before the start of therapy).

**Step 2 Preparation for Heavy Ion Therapy**

Preparation for Treatment Planning

An immobilization device will be prepared in order to achieve accurate body position for the treatment. Using the immobilization device, CT scan will be performed for treatment planning.

**Treatment Planning**

Using the obtained CT scan images, the staff will complete the treatment planning such as defining treatment area and its dose. The treatment plan will be discussed and approved by multidisciplinary team staff in a cancer board.

Based on the shapes of the body and the tumor to be treated, devices will be custom-made for each patient to create a desirable irradiation dose.

**Step 3 Heavy Ion Therapy**

About 1-2 weeks

After the area to be treated is precisely positioned using X-ray imaging, and the patient will be irradiated with heavy ion beams.

The treatment will be once a day, and the irradiation will take about a few minutes. The total treatment time will be about 20 minutes to 1 hour including the preparation.

**Step 4 Patient Follow-Up**

About 1 day to 5 weeks

The patient will be followed up after the treatment.

The patient will be followed carefully by continuing regular out-patient visits and scheduled tests.

**Numbers of treatment sessions** (examples of Gunma University)

<table>
<thead>
<tr>
<th>Cancer Type</th>
<th>Number of Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung/liver cancer</td>
<td>4 sessions</td>
</tr>
<tr>
<td>Prostate cancer</td>
<td>16 sessions (4 weeks)</td>
</tr>
</tbody>
</table>

The patient will not feel any pain or heat during the treatment.
Case Reports of Heavy Ion Therapy

1. **Lung Cancer**
   - Irradiated dose: 28 Gy (RBE)
   - Irradiated fractions: 1 fraction
   - Total treatment duration: 1 day
   - Before the treatment
   - 6.5 months after the treatment

2. **Malignant Melanoma**
   - Irradiated dose: 57.6 Gy (RBE)
   - Irradiated fractions: 16 fractions
   - Total treatment duration: 4 weeks
   - Before the treatment
   - 15 months after the treatment

3. **Osteosarcoma on Sacrum**
   - Irradiated dose: 52.8 Gy (RBE)
   - Irradiated fractions: 16 fractions
   - Total treatment duration: 4 weeks
   - Before the treatment
   - 5 years after the treatment

**Gy (RBE)**

The unit of irradiated dose for heavy ion therapy
Results of Heavy Ion Therapy

Breakdown of a Heavy Ion Therapy of Gunma University (A total of 470 cases)

Data From March, 2010 to September, 2012

Disease distinction

- Recurrence of rectal cancer (7)
- Lymph node recurrence (11)
- Pediatric tumor (2)
- Bone and soft-tissue sarcoma (19)
- Head and neck tumor (29)
- Lung (30)
- Liver (27)
- Prostate (345)

Address distinction

- Gifu (3)
- Ibaragi (4)
- Niigata (6)
- Kanagawa (8)
- Tokyo (11)
- Shizuoka (2)
- Yamaguchi (2)
- Others (10)
- Hokkaido
- Miyagi
- Akita
- Yamanashi
- Kyoto
- Nara
- Miyazaki
- Okinawa
- Gunma (305)

The Registration Number of Patients of Heavy Ion Therapy in Natl. Inst. of Radiological Sci.

Data From June, 1994 to March, 2012

Total Number of Registered Patients: 6,535
Advanced Medical Technology: 3,509

- Prostate
  - 1,492 (22.8%)
  - Advanced Medical Technology: 1,160

- Bone and Soft Tissue
  - 830 (12.7%)
  - Advanced Medical Technology: 623

- Head and Neck
  - 796 (12.2%)
  - Advanced Medical Technology: 473

- Lung
  - 674 (10.3%)
  - Advanced Medical Technology: 96

- Liver
  - 425 (6.5%)
  - Advanced Medical Technology: 200

- Others
  - 1176 (18.0%)
  - Advanced Medical Technology: 523

- Abdominal Lymph Node
  - 38 (0.6%)
  - Advanced Medical Technology: 31

- Gastrointestinal Tract
  - 68 (1.0%)

- Skull Base
  - 84 (1.3%)
  - Advanced Medical Technology: 55

- Central Nervous System
  - 106 (1.6%)

- Eye
  - 118 (1.8%)
  - Advanced Medical Technology: 76

- Gynecological
  - 180 (2.8%)
  - Advanced Medical Technology: 269

- Pancreas
  - 183 (2.8%)
  - Advanced Medical Technology: 3

- Rectum (Post-operative recurrence)
  - 333 (5.1%)
  - Advanced Medical Technology: 269

- Scanning irradiation
  - 11 (0.2%)

- Lacrimal gland
  - 21 (0.3%)
Current Situation of Heavy Ion Therapy Facilities

Heavy Ion Therapy Facilities in Japan (operating facilities)

Outside Japan, only 3 facilities (Germany, Italy, China) are operating heavy ion therapy. Only Heidelberg University in Germany and Institute of Modern Physics in China are practicing heavy ion therapy.

1. Gunma University Hospital Heavy Ion Medical Center
2. National Institute of Radiological Sciences Research Center for Charged Particle Therapy
3. Hyogo Ion Beam Medical Center

Data from December, 2012.

Treatment Fees (for Overseas Patients)

The Cost of Heavy Ion Radiotherapy

<table>
<thead>
<tr>
<th>Items</th>
<th>Cost</th>
</tr>
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<tbody>
<tr>
<td>Heavy ion radiotherapy</td>
<td>JPY 3,140,000</td>
</tr>
<tr>
<td>Medical services other than heavy ion radiotherapy</td>
<td>Variable</td>
</tr>
<tr>
<td></td>
<td>(depends upon patient requirements)</td>
</tr>
<tr>
<td>Equipment depreciation costs</td>
<td>JPY 260,000</td>
</tr>
<tr>
<td>Administration</td>
<td>JPY 340,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>JPY 3,740,000 + medical service cost</td>
</tr>
</tbody>
</table>
Inside the heavy ion irradiation facility.

In order to accelerate heavy ions (carbon ions) up to about 70% of the speed of light and irradiate a cancer which is deep inside a body, the facility has the following equipments.

**Treatment room:**
The patients are irradiated with accelerated heavy ions in this room. The patients feel no pain during the irradiation.

**Synchrotron:**
The carbon ions which are sent from the linear accelerator are accelerated up to 70% of the speed of light while circulating in the synchrotron.

**Ion source:**
Carbon ions are extracted from methane gas.

**Linear Accelerator:**
The linear accelerator provides preliminary acceleration to the carbon ions before they are sent into the synchrotron.

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