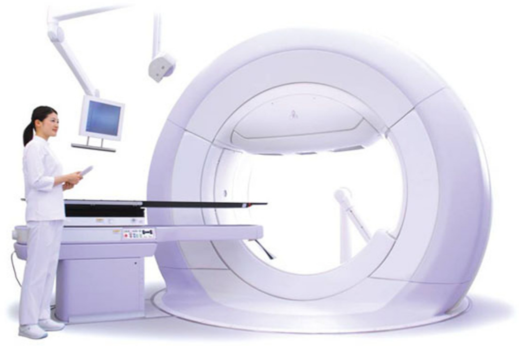
The Mitsubishi Heavy Industries vero 4-Dimensional Radiation Therapy (MHI vero4DRT) System: The World's First Dynamic-Tracking Irradiation with Real-Time Monitoring



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In May 2011, Mitsubishi Heavy Industries, Ltd. (MHI) launched the world's first application using its newly developed dynamic-tracking capability designed for MHI-TM2000 radiation therapy equipment, at Kyoto University Hospital, a development partner. After further functional improvements based on clinical trials at the hospital, an accurate, rapid, dynamic-tracking method using both gold markers and breathing signals was established for more universal application. Using this new method, the first dynamic-tracking radiation therapy with real-time monitoring in the world was successfully performed at the hospital on September 14, 2011. This led to the adoption of the new brand name, MHI vero4DRT, which combines the Latin word vero, meaning "truth," and MHI's innovative four-dimensional radiation therapy (4DRT) technique.

This article provides an overview and describes the characteristics of the dynamic-tracking method, which uses both gold markers and breathing signals.

1. An Overview of MHI vero4DRT

The MHI vero4DRT radiation therapy system (**Figure 1**) is equipped with two pairs of kilovolt (kV) X-ray imaging systems and a gimbal mechanism that controls MV therapeutic beam direction. In addition to well-proven functions, such as high-accuracy beam irradiation, automatic image fusion, and high-precision patient setup, the system offers an innovative dynamic-tracking irradiation capability for four-dimensional radiation therapy by identifying the exact location of the moving target tumor in real time and adjusting the beam direction according to changes in tumor location.

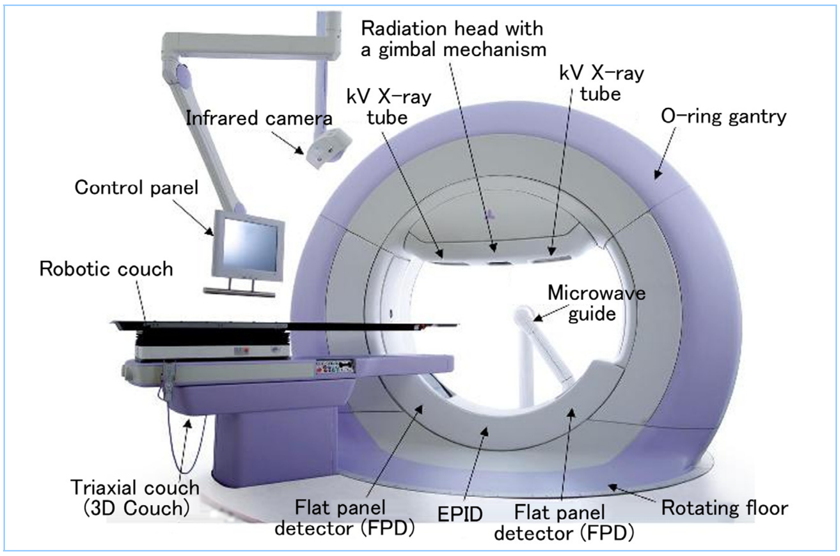

Figure 1 Mechanical configuration of the MHI vero4DRT system

In dynamic-tracking irradiation, X-ray beams are delivered directly to a target tumor that moves as the patient breathes. The method improves the dose concentration on the target, while minimizing unwanted exposure to the surrounding normal tissues.

Dynamic-tracking irradiation is achieved using the following steps (**Figure 2**):

(1) Obtaining sequential three-dimensional positions of the target tumor as it moves in real time while the patient breathes, using the kV X-ray imaging system;

(2) Adjusting the direction of the therapeutic X-ray beam by tracking the tumor location continuously with the gimbal mechanism; and

(3) Applying therapeutic X-ray beam continuously until the desired dose is reached.

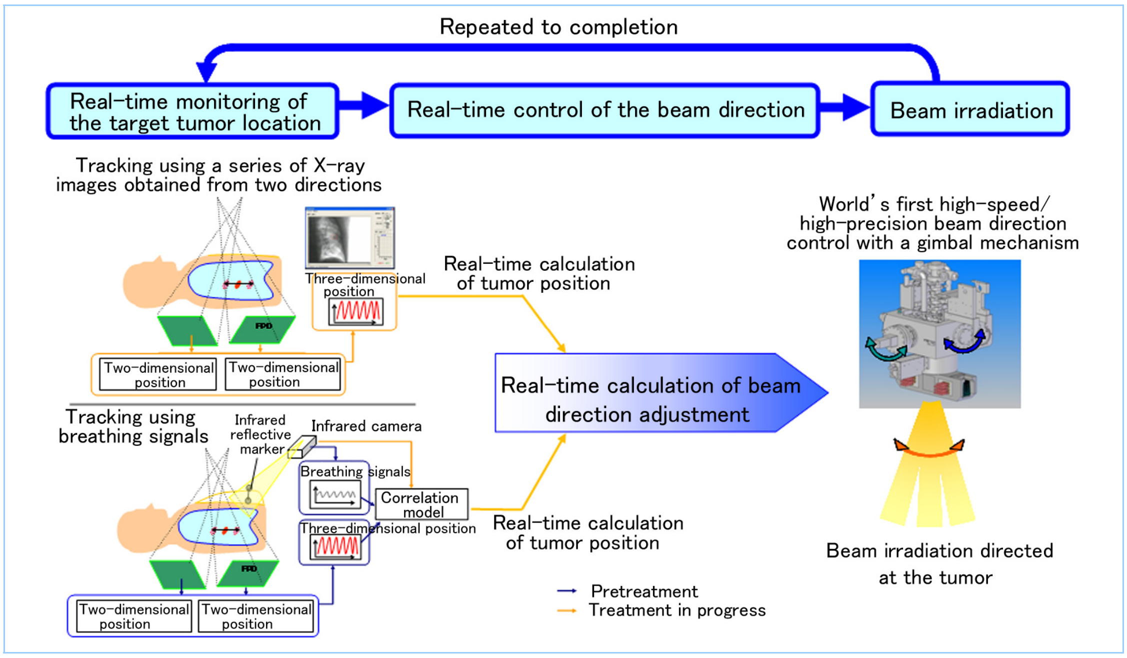

Figure 2 Dynamic-tracking irradiation process

2. Characteristics of the Tracking Method using Gold Markers and Breathing Signals

The newly adopted tracking method using gold markers and breathing signals is a more precise tumor-detection technique, in which a gold maker is implanted as a tracking point inside or near the target tumor, which is not clearly visible in Step 1. This enables more robust tracking of the tumor during radiation therapy by automatically detecting the precise position of the marker, which appears in the image regardless of the tumor visibility (**Figure 3**). MHI vero4DRT uses gold markers approximately 1.5 mm in diameter, which can be inserted into the bronchus near the tumor without an incision, resulting in less physical strain on the patient compared with methods requiring surgery.

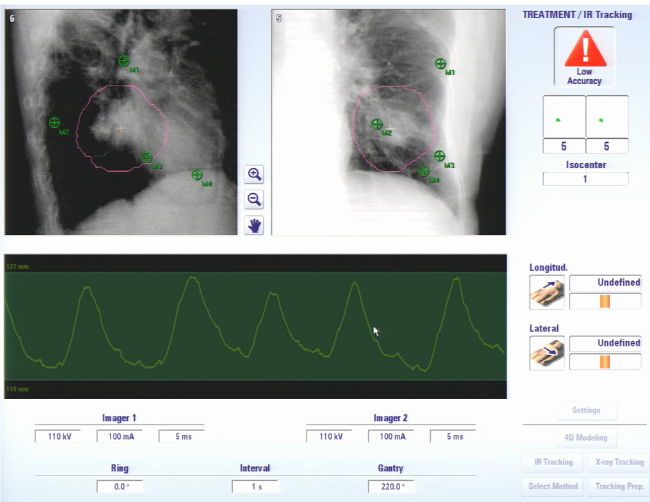

Figure 3 Example of tracking images using gold markers and breathing signals

Furthermore, the position of the tumor inside the body is estimated by using the high correlation between the tumor location and breathing signals, including the vertical movement of the abdomen and chest. This approach requires fewer images for therapy. Therefore, a significant reduction in unnecessary radiation exposure is achieved compared with tracking methods that use a series of X-ray images obtained from two directions.

As a result, the new system offers more patient-friendly tumor tracking, while maintaining the advantages of improved dose concentration in the dynamic-tracking method.

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