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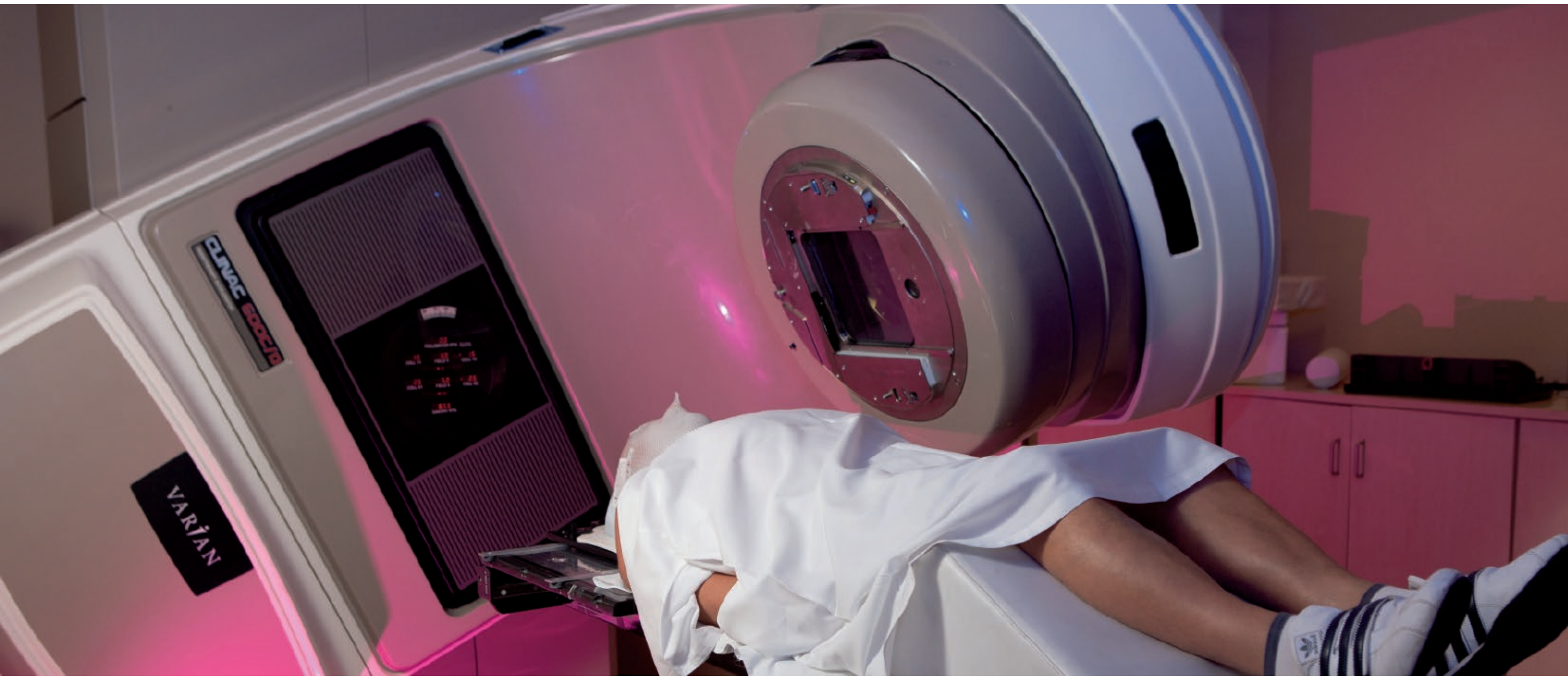


Hexapods for Patient Couches in Radiotherapy

MULTI-AXIS, PARALLEL-KINEMATIC PRECISION DRIVES FOR PATIENT POSITIONING

Radiotherapy and Patient Positioning

On a global scale, the human population is aging. As the incidence of cancer rises with age the prevalence of cancer is continuously increasing. Developed countries with a high median age typically show the highest incidence rates per size of the population.

Prevalence of Different Cancers in Top Countries, 2016 (Number)

Country	Tracheal, Bronchus & Lung Cancer	Esophagus	Stomach	Liver	Colorectum
United States	426,608	26,382	70,682	31,297	829,751
China	1,005,498	278,769	984,929	670,208	1,469,937
Germany	102,208	13,052	48,288	10,448	299,828
India	74,306	40,614	112,227	1,1970	185,388
United Kingdom	78,792	11,378	19,899	5,450	173,993

Source: Our World in Data

There are three basic forms of cancer therapy: Classical surgery, chemotherapy, and radiation therapy. Which treatment is chosen depends on many aspects: The type of tumor, the tumor location, and considerations based on which method is likely to produce the best therapeutic results. Other aspects comprise patient acceptance, side effects, etc... For many types of tumors, radiation therapy performs best in many of the aspects mentioned. Interestingly, radiation therapy usually also has the lowest cost per treatment.

In average, classical surgery is three times more costly per case than radiotherapy; chemotherapy is even five times more costly than radiotherapy. Because of all these aspects, this theraphy technique has grown into a 13bn US$ market (2017). This market splits off into the radiopharmaceutical and in radiotherapeutics markets. The medical, device-based radiotherapeutics market further segments into: External beam radiotherapy, internal radiotherapy, and systemic radiotherapy.

The most important forms of external beam radiotherapy are: X-ray radiation generated by a linear accelerator (LINAC), gammaradiation (typically generated by a Cobalt-60 source), and proton radiation. Proton therapy is costly but strongly growing, due to a higher specifity to destroy tumor cells in preference to healthy tissue. Still, the LINACS are the working horses of radiotherapy. Roughly 70% of all installed radiotherapy devices are based on this technology and their number is growing worldwide, according to BCC research. The installed base of LINACS numbers 13,100 units (2015) in a total of 7,700 radiotherapy departments. By 2035 it is expected, that there will be 10,900 radiotherapy departments with a total of 21,800 units.

External beam radiotherapy is mainly applied to tumors located in the head, breast, lung, and prostate. Here very accurate patient positioning is needed to make sure that the applied radiation dose only hits the tumor volume and does as little harm as possible to the surrounding, healthy tissue. This means, a precision within the typical size of human cells, i.e. between 30 µm – 100 µm, is ideal in order to irradiate only the affected cells.

Image Guided Radiotherapy Systems

Today most radiotherapy systems work in the so-called Image Guided Radiotherapy mode (IGRT-mode). This means, one or several methods are used to measure the topical patient's and tumor's position before and during radiation treatment.

These methods include:

- Optical body surface profiling
- X-ray scans
- Thermal imaging (adding a further dimension to monitor the patient's position)
- MRI

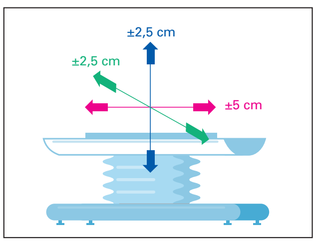
The aim of these methods is a patient-friendly, frameless stereotactic radiosurgery (SRS), e.g. of brain tumors.

Optical body surface profiling is done using visible light.

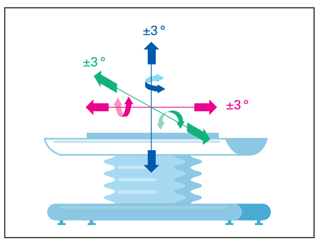
X-ray scans help to precisely determine the position and the topical position of the tumor.

In compact, advanced radiotherapy systems that use radio nuclides (e.g. Cobalt-60) the radiation source is positioned so that the tumor is in the center. Based on previously taken images, the patient is precisely positioned in LINAC devices. Here the patient couch (operating table) plays a key role in the entire process. By superimposing all the various images, the patient position is determined (in relation to the 3D recorded tumor data and also in relation to the radiation source). Before the actual treatment starts, the couch moves the patient into the correct position.

Translational Ranges



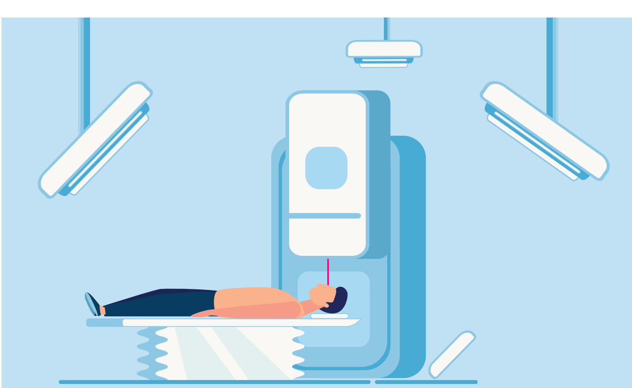
Rotational Ranges



To correctly position the patient, the operating table needs to be moved with six degrees of freedom: Three translational directions (X, Y, Z) and three rotational directions ΘX, ΘY and ΘZ.

In some cases, the couch has to correct the patient's position also during radiation treatment. This depends on the type and the position of the tumor as well as other aspects and and it depends on the motion data of the closely monitored patient and tumor. As pointed out earlier, a submillimeter precision is required as is also the ability to carry loads of up to 200 kg or even more.

For this highly specific task, PI offers multi-axis, parallel-kinematic, high-precision positioning solutions – the so called Hexapods.



The actual radiotherapy can only begin after the patient and the cancerous tumor has been positioned correctly.

Motion and Positioning Solutions from PI

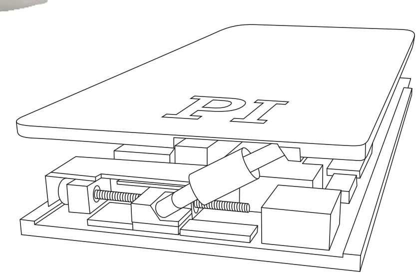
Hexapods, as the denomination unveils, are motion platforms based on six struts with variable length. They all act together on a platform and so enable movements in six degrees of freedom. PI has a decade-long experience with the design and manufacturing of hexapods. A huge variety of models have been developed up to now, reflecting customer needs with respect to positioning precision, speed, and dynamic of motion, payload (from a few grams to several tons), size, and shape. Besides their compact design, the precision of hexapods in comparison to stacked stages when following given motion trajectories is especially high. Because of the joint guidance of the movement platform, errors in individual axes cannot add up – parallel kinematics. Therefore, hexapods are perfectly suited to positioning patients for radiotherapy.

The H-850, a PI standard product, generally meets or even exceeds the typical specifications for patient couches:

- Load capacity to 250 kg
- Travel ranges to 50 mm (XY) / 25 mm (Z) / ± 15° (ΘX, ΘY, ΘZ)
- Max. velocity: 0.5 mm/s
- Repeatability (unidirectional): ±0.5 µm

In order to take the specific boundary conditions of patient couches into account, PI (for the principal lay-out of an already realized mulit-axis precision positioning for patient couches, see drawing below). PI offers different types of hexapods or other parallel-kinematic motion systems with a lower number of motion axis. We are open to solve individual customer requests in radiotherapy. Talk to PI!

The H-850 is a standardized hexapod for heavy loads to 250 kg with high precision and reliability.



Drawing of a hexapod design for patient couches.

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