Like a sniper

Radiation oncologists use breath hold techniques to shoot tumours with little collateral damage.

by Dr Jonathan Teh

Stereotactic body radiotherapy plan showing treatment of two liver tumours using beams delivered in arcs, concentrating high doses to the tumour while sparing large volumes of normal liver.

In modern military and medical fields, accuracy and precision are highly valued. During wartime, snipers hit their targets from afar with a single bullet that damages nothing else. They hold their breaths as they pull the trigger to ensure unerring accuracy.

In medicine, the 'bullets' in radiotherapy are high energy x-rays that cause tumour cell death through DNA damage. The utmost importance is in minimising the exposure of surrounding normal tissues to 'collateral damage'. Radiation oncologists thus use advanced technologies like stereotactic body radiotherapy (SBRT) incorporating breath hold techniques to achieve these objectives.

SBRT refers to an advanced form of external beam radiation therapy that allows precise delivery of high doses of therapeutic x-rays beam to tumours in the body in one to five sessions. However, tumours in the locations such as the lung and liver move with respiration and therefore present a challenge in targeting them. For liver tumours, the collateral areas comprising normal liver cells are highly sensitive to radiation damage. As such, treating large areas of normal liver could result in the feared complication of radiation induced liver failure.

Surveying the battlefield

One of the ways radiation oncologist deal with tumour motion is by using 4-dimensional computed tomography (4D-CT), which is a special CT scanning and computer processing technique that allows observation of the movement of liver tumours. The radiation beam would then be tailored to exactly where the tumour moves while the patient breathes. While this method implies treating a somewhat larger area than the tumour itself, it is still a safe and effective method, especially if an abdominal compression device is used to reduce the magnitude of movement by limiting the depth of respiration.

If the liver does not move during delivery of radiotherapy, the treatment area could be even smaller, with potentially less radiation dose delivered to the normal liver tissue around the tumour. Holding one's breath in a fixed position presented an opportunity to 'freeze' the liver in place for this purpose. So how is accuracy ensured?

One solution is the use of a spirometry device that can measure the amount of air in a patient's lungs in real time as they breathe into it. The amount of air in the lungs should relate to the position of the liver. The patient therefore undergoes a CT scan to map out the tumour and surrounding organs, while holding their breath at a set level guided by the spirometer. Intravenous contrast can be used effectively for the scan which takes up to 30 seconds only. The lack of respiratory motion and use of contrast gives very clear images of the tumour and surrounding organs, making it easier to mark them out than with the 4D-CT, which is more blurred due to the movement. A radiotherapy plan is designed to create the optimal beam angles and intensities that achieve the desired 'sniper' objectives of maximum tumour kill with the least collateral damage.

Pulling the trigger

The following illustrates how, the radiation oncologist and his team, much like a sniper, makes all the necessary checks and ensures the optimal conditions before going for the target:

Before each treatment:
The CT scanner at the treatment machine take images of his liver in the breath hold position and positional adjustments made by the radiation oncologist. Another scan is done just prior to starting treatment to ensure the positional adjustments are within two millimetres of the original plan.

During treatment:
The patient then starts his treatment, one breath hold at a time with short rests in-between. During treatment, the radiation therapists use the spirometer to check that the lung volume is constantly at the set level during treatment. Simultaneously, the radiation oncologist uses real time two-dimensional x-rays during treatment to ensure that the

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liver position is within safe limits, with the diaphragm as a surrogate. A number of fast radiation beam rotating around the patient delivers the treatment rapidly, thus minimising the number of breath holds taken to complete the treatment.

In-between each treatment beam:
The x-ray images acquired during treatment are also used to reconstruct CT images that allows three-dimensional verification of liver and tumour position in-between breath holds.

All in all, each treatment session is completed in less than an hour. The whole process is done as an outpatient in the radiotherapy department.

First breath hold sniper shot to the liver in Singapore

A 71-year-old man had been treated for rectal cancer three years ago but unfortunately relapsed with tumours in the liver last year, making him Stage IV. He was offered surgery to remove them, but he declined. He was thus started on chemotherapy, which shrank the tumours but did not make them disappear completely. He had a PET-scan that showed two areas of tumour activity in the liver, but the rest of the body was remained clear. As his disease was limited only to the liver, and he declined surgery, SBRT was considered as an alternative.

The patient had a relatively small liver and therefore it was important to spare as much normal liver as possible. The breath hold technique had been previously used by the radiation oncology team to eliminate lung tumours in another patient successfully and so it would be ideal to treat his liver using the same concept.

He was assessed for breath holding capability and deemed suitable as he could hold his breath for 30 seconds at a time. Despite the patient having a relatively small liver, the reduced treatment area afforded through breath hold allowed a radiation therapy plan that was safe for the liver and all the surrounding organs.

He was treated using the methods as detailed above, completing five sessions every other weekday over one and half weeks. During the whole course of treatment, the patient only experienced mild tiredness and did not have any nausea, vomiting or loss of appetite. He continued his usual activities and appreciated the non-invasiveness of the treatment and lack of downtime.

At his first follow-up visit one month after SBRT, the patient remained well and was leading a normal lifestyle. His liver function blood test was almost completely normal. Encouragingly, his CEA tumour maker had halved in the one month. A further PET-CT a month later showed that the two treated tumours had completely resolved metabolically. More importantly, liver function remained stable and the patient was generally well. Unfortunately, there was a secondary tumour found in the brain, which is a site where chemotherapy does not penetrate easily. That tumour was treated using stereotactic surgery (SRS), which is analogous to SBRT but employed in the brain instead of the body.

Patient on the treatment couch using the spirometer linked to the treatment machine, that measures real time lung volumes (screen top left corner). Treatment is only delivered in a fixed breath hold position as predetermined during the mapping session.
Credit: Cleveland Clinic

Highly focused radiotherapy treatment

Breath hold liver SBRT is a result of multiple technological advances coming together to present an elegant, accurate and non-invasive way to treat liver tumours in suitable patients. Increasingly, it seems like the war on cancer is going to be fought with highly targeted treatments. Drug treatments are now targeted towards unique tumour and patient characteristics based on biomarkers and genetics. Similarly, radiotherapy treatments are now highly focused and individualised to patient and tumour anatomy. As research and development continues to further fine tune this armamentarium, one day it may be possible to achieve cures while maintaining durable quality of life. APBN

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