1) Imaging Guided Therapy (IGT)

The aim of IGT is a relatively recent (~20 years) technology that has been developed as a response to medical professionals' need to better target and localise the tissue that needs to be treated or removed, and therefore be faster and more efficient. Before the procedure, imaging is performed, and a 3D model of the patient is obtained, which is then used in planning (before the procedure) and during the procedure, helping surgeons differentiate the diseased tissue.[1]

Image Guided Radiation Therapy

This technology can be used to track the position of the tumour during radiation therapy to ensure the delivery of the dose to the proper location. Both external-beam and internal (brachytherapy) radiation therapy require previous imaging of the treated area, on which simulations and planning are performed. In normal cases, the oncologist chooses the number of angles, and the computer calculates the desired doses. However, since the human brain is a highly sensitive organ, often inverse planning is carried out, where the oncologist sets the desired doses for certain areas, and then the computer calculates the angles and intensities. This technique is called Intensity Modulated Radiation Therapy (IMRT).[1] Tomotherapy is a special type of IMRT, where the treatment radiation is guided by CT. The radiation source is rotated around the patient while the latter is moved through the gantry. [2] The initial planning for this procedure is usually done with the help of a CT/PET image. This method can be used to treat multiple brain tumour as the same time.[3] While Tomotherapy uses slices to deliver the doses, their main competitor, the RapidArc system, delivers the desired radiation dose in a single rotation through VMAT (Volumetric Modulated Arc Therapy) [4] VMAT planning is quicker, while Tomotherapy provides slightly better coverage.

In case of glioblastomas (and in cases of metastasis), this method of treatment can deliver higher dose of radiation in a shorter time and with better precision compared to classical radiation methods. Even though the survival rate for this kind of tumour is extremely low, these methods can improve the quality of life of the patient (by having a lower effect on neurocognitive functions) and increase the amount of time they can spend with their loved ones.[5]
RadioSurgery

In Radiosurgery, all the radiation planned for the patient is usually delivered in one session. The head of the patient is fixed to the table through a frame, placed on the head or the body (the latter providing a lower degree of fixation) [6]. Technologies for this procedure are **Gamma Knife** (which uses one procedure, but treats only tumours above the ear and in the cervical spine, and uses a stereotactic frame screwed into the patient’s head) or **CyberKnife** (which can use one or up to 5 procedures, can be used to treat the entire body, and uses real-time tracking) [7].

This procedure is also an alternative to surgery in patients in which this is not an option. The side effects are the same as those from traditional radiation therapy [8].

**Image Guided Brachytherapy** has also been carried out in cases where the 2 aforementioned devices were not available, with promising results [9].

**Image Guided Thermal Ablation**

Thermal ablation of brain tumours can be carried out with the help of **Magnetic resonance-guided focused ultrasound surgery (MRgFUS)** technology.

The ablation is done with **High-Intensity Focused Ultrasound (HIFU)**. A stereotactic frame is used, and the patient is placed in an MRI machine that helps guide the thermal ablation through fast T1 and T2 weighted images, or with a thermal map. CT images can also be registered to improve localization accuracy.

MRI Diffusion Images emphasise the necrotic areas in the tumour 5 days after trans-cranial MRgFUS. Source: [10]
This modality can be suitable for patients with recurrent tumours, in areas that are not suitable for surgical procedures. However, tumour vascularization needs to be considered, as serious bleeding could result from the treatment. However, the procedure is currently in test phase, and is limited only to centrally located tumours (due to the frequencies that can be used), has side effects as heating at contact spaces, the attenuation in bone tissue is high, and the process is lengthy.

Catheter and laser-induced necrosis. Source:[11]

Another modality to carry out this procedure is through either Radio Frequency, Microwave or Laser ablation, when a catheter is inserted in the brain of a patient under general anaesthesia and, as previously, the procedure is guided by a temperature map generated by the MRI.[11]

MR Guided Cryotherapy is also being investigated as an option.[12]

Image Guided Drug Delivery

The main issue in drug treatment brain tumours is the Blood-Brain Barrier, which doesn't permit chemicals to enter the brain's blood-flow. A combination of Focused-Ultrasound and microbubbles can be used to disrupt the BBB, permitting pharmaceutical agents to enter the brain. Furthermore, MRI can be applied to locate the BBB disruption. Animal studies indicated increased survival rate of brain tumor metastasis treatments with this procedure[13].

Research in the domain of Theranostics(therapy + diagnostics) is also carried out. As part of this, particles can be "dragged" into the brain under the influence of the outer magnetic field, e.g. MRI. (rightmost picture). The development of drugs that respond to imaging techniques can give better post-procedural information regarding the efficiency of the tumour targeting.

In order to bypass the BBB, research on intranasal drug delivery is also being researched [14].
Image Guided Surgery

**Image Guided Surgeries (Computer-Assisted Surgeries)** use instruments mapped in real-time that are applied to the 3D model of the patient to help navigation [1]. This procedure requires a high amount of planning, and then the operating system helps with tracking the instruments on a 3D model and guidance during the procedure itself. The most famous systems are Curve[15], Kick [16] and Medtronic[17].

An upcoming technology is the development of **Image Guided Robots** that target and destroy diseased tissue, based on previous imaging information.[18]

With these systems, both patients and medical service providers can have better results, by reducing errors, the effects of different skill levels of different physicians, diminishing surrounding tissue damage, and trauma, therefore hospital stays and costs.[19]

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