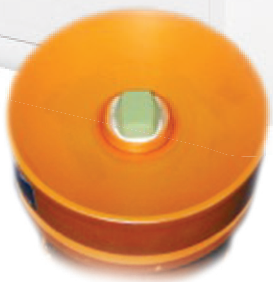
High intensity focused ultrasound

HIFU has the potential to provide a truely non-invasive, targeted treatment option…



JC200 Machine (Haifu Company Chongqing China) with transducer, showing pale diagnostic ultrasound probe centrally surrounded by the orange treatment transducer

High intensity focused ultrasound (HIFU) relies on the same principles as conventional ultrasound, but uses very high energy that is sharply focused within the body. This is similar to focusing sunlight using a magnifying glass.

HIFU can propagate harmlessly through living tissue, but if the ultrasound beam carries sufficient energy and is brought into a tight focus, the energy within that focus can cause a local rise in temperature, which is sufficiently high to cause instantaneous cell death. This occurs without damage to surrounding or overlying tissues. The ability to cause cell death in a volume of tissue distant from the ultrasound source makes HIFU an attractive option for ongoing development as a non-invasive treatment.

HIFU has been used to treat many diseases including tumours in the kidney, pancreas, liver, prostate and the uterus. HIFU is a generally safe procedure and serious side effects are very rare. Occasionally some heating of the skin may occur during treatment and is similar to sunburn. This is likely to resolve fully (without scarring) within one week. More serious skin burns can occur, including those that leave permanent scarring. However, serious burns are rare and occur in less than 1 in 100 cases.

The devices in current clinical use fall into two main categories: extracorporeal and transrectal.

HIFU for prostate cancer

HIFU for prostate cancer uses a transrectal device with a focal length of 3-4cm and most people who have heard of HIFU link it to prostate cancer. However, this is only one area of use, and arguably the extracorporeal device described in the following has a much more exciting range of therapeutic possibilities. HIFU for prostate cancer has been used widely in Europe for complete ablation of the prostate, especially in elderly men who are unwilling or unable to undergo radical therapy. For low or intermediate-risk cancer, the short and intermediate-term oncologic results have been acceptable but need confirmation in prospective multi-centre trials presently under way. Whole gland therapy with transrectal ultrasound guidance has been associated with a risk of acute urinary symptoms, sometimes requiring transurethral resection before or after HIFU. HIFU holds promise for focal ablation of prostate cancer, which should reduce the adverse sexual, urinary and bowel effects of whole gland ablation.

Extracorporeal devices have been used to target many organs, and require a longer focal length of 10-15cm. The extracorporeal devices can be guided by MRI or ultrasound. In Oxford, we have been using and ultrasound guided machine (JC and JC200) supplied by HAIFU Chongqing, China. While many thousand of patients with various malignant and non-malignant conditions have been successfully treated in the China and the Far East, the numbers treated in the West are much lower.

In Oxford, trials were undertaken on the treatment of liver and kidney tumours using the first Chinese machine in the western hemisphere. As a result of these trials, the machine received its CE mark and now there are a number of machines throughout Europe. We have shown that HIFU ablation of liver tumours is safe and feasible in a western population; this is important as this group often has a higher body mass index than Chinese patients. All adverse events were local and self-limiting.

HIFU treatment is accurate, and intraoperative assessment of treatment provided accurate measurement of the zone of ablation when compared with post-treatment MRI. Treatment of renal tumours was more problematic due to the surrounding perinephric fat, which absorbed some of the ultrasound energy. However, around a third of renal tumours were destroyed completely and thus prevented the patients undergoing major surgery.

A number of other tumours including primary and secondary bone lesions are amenable to treatment; however, its scope is not limited to the direct treatment of cancers. It may also be used in a palliative setting for relief of chronic pain of malignant origin, for haemostasis, or even for the treatment of cardiac anomalies. One of the most promising non-malignant indications for its use is in the treatment of fibroids.

HIFU for fibroids

Fibroid HIFU has been in use now for a number of years in the USA and Far East, although is not yet available on the NHS. MRI-guided fibroid HIFU differs from ultrasound-guided fibroid HIFU in that the treatment is guided and targeted using MRI rather than ultrasound. However, the high energy ultrasound is used for the actual treatment is identical.

MRI-guided HIFU is currently the only FDA HIFU treatment approved in the USA. Several different units in Europe have now reported good results with 70-90% of women reporting an improvement in their symptoms using a validated questionnaire. Treatment outcomes depend on a number of factors. These include the number and size of fibroids present as well as their position. HIFU treatment is designed to shrink the fibroid by destroying the adenoma and its blood supply. It may not treat the entire fibroid but as this is not a malignant condition that is not a problem, and partial treatment often leads to a significant reduction or abolition of symptoms. If symptoms do reoccur the procedure can be repeated, unlike radiotherapy treatment to malignant conditions. The National Institute for Clinical Excellence (NICE) has published guidelines on MRI-guided fibroid HIFU and this can be found at http://guidance.nice.org.uk/IPG231.

Experimental uses of HIFU

In the 1940s the Fry brothers in Illinois were experimenting with HIFU and using early experimental equipment to treat Parkinson's disease, but ablating areas in the brain having first removed part of the skull surgically. Exciting new research is now able to put a HIFU beam in through the intact skull using a mechanism known as time reversal therapy, whereby the aberration caused by the skull on the HIFU beam can be overcome. Localised well-defined areas of destruction within the brain are now becoming possible and are likely to be used increasingly for the treatment of brain tumours and other situations where focal ablation of specific areas are required.

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Techniques for increasing the speed of tissue destruction are being actively sought by a variety of means, which include modification of the acoustic field using phased array transducers or modifying the tissue itself by altering the vascular perfusion of introducing small gas bubbles that increases the rate of temperature rise locally. An additional benefit of HIFU is that it may stimulate the immune response and possibly lead to a beneficial effect at a distance from the focal area. This is being further investigated and may lead to a beneficial effect on metastatic tumours.

HIFU is also being investigated for targeted drug delivery, whereby chemotherapeutic agents are put into liposomes and injected into the body. When exposed to a HIFU beam over a specific location, the liposomes rupture and the chemotherapeutic agent is released over a specific target organ.

Conclusion

In spite of the wealth of research in the field of high-intensity focused ultrasound, its application as a non-invasive surgical tool is still in its infancy. Already the scope for its use in the treatment of benign and malignant conditions has been shown to be large, and in combination with other treatment modalities, that scope is likely to expand. As ongoing clinical research lays the foundations for wider clinical acceptance, HIFU will play a prominent role in surgery of the future. HIFU has been shown to have the potential to provide the clinician with a truly non-invasive, targeted treatment option.

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