## The search for free-radical production in the ultrasonic beam produced by duplex ultrasound systems

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Duplex ultrasound equipment is now widely used in paediatric and adult investigations, particularly in cardiology. The higher acoustic output levels obtainable in pulsed Doppler mode currently restricts its use in fetal examinations. Theoretical studies indicate that cavitation effects may be generated by high-intensity microsecond pulses of ultrasound. The high temperatures and pressures produced within a collapsing or oscillating bubble in an ultrasonic field can produce free radicals and visible light is emitted from the gas within the bubble. The light generated in this manner is called sonoluminescence. Under certain conditions, sonoluminescence can be detected with the naked eye when water is insonated by physiotherapy ultrasound equipment. To extend our knowledge of biological effects arising from the use of commercially available diagnostic ultrasound equipment, sonoluminescence and free-radical production have been studied. Sensitive photon detection equipment has confirmed sonoluminescence production in the ultrasonic field of physiotherapy equipment at the output levels greater than 1 W/cm. A Hewlett Packard 77020 phased array duplex system (2.5 3.5 and 5 MHz transducers) and Ultramark 4 ultrasound equipment (3 and 5 MHz transducers) have therefore been evaluated. All ultrasound equipment control parameters have been selected to maximize the peak negative pressure in the ultrasonic beam. In each acoustic field the photon count obtained during ultrasonic irradiation was compared with that measured when power was disconnected to the transducer. Using a terephthalic acid dosemeter the free-radical concentration has been assessed. Sonoluminescence was not detected and the paired photon counts never exceeded that attributable to random (N) fluctuations (typically 1%). Free-radical production could not be detected using the terephthalic dosemeter.

## Wound healing acceleration by ultrasound

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Ultrasound increases the rate of tissue repair after injury. However, the mechanisms involved in this are not yet fully understood. With the objective of contributing to the elucidation of these mechanisms, the effects of therapeutic ultrasound at two different dosages on the repair of full-thickness skin lesions have been tested. The effects were compared with those in sham-insonated controls at 5 days after injury. Treatments were given on Days 0, 1, 2, 3 and 4, *i.e.* in the inflammatory and early proliferative phases of repair. The treatment regimes used were either 0.1 W/cm$^2$ continuous ultrasound or 1:4 pulsed ultrasound with a "temporal peak" (pulse average) intensity of 0.5 W/cm$^2$. The temporal average intensity was therefore kept constant at 0.1 W/cm$^2$. In both regimes the frequency used was 3 MHz; ultrasound was applied for 5 min daily. It was expected that the use of the same temporal average intensity in the two regimes would produce similar thermal changes in the tissues irradiated and that they would be below a physiologically significant level. However, the higher peak intensities in the pulsed treatments were expected to affect the incidence of cavitation and acoustic microstreaming differentially. The criteria used for quantification of wound healing were angiogenesis and changes in the differential cellularity of the wound beds. The results obtained confirmed that low-intensity ultrasound stimulates repair and demonstrated that this stimulation includes an increase in angiogenesis. There was also a decrease in the number of inflammatory phase cells (polymorphonuclear leukocytes and macrophages) and an increase in the number of proliferative phase cells (fibroblasts and endothelial cells). Since the levels of ultrasound used were too low to produce a therapeutically useful temperature increase, predominantly nonthermal effects, *e.g.* stable cavitation and/or acoustic microsteaming, must be involved. Intensities (spatial average, temporal average) as low as 0.1 W/cm$^2$ can stimulate tissue repair.

## Absence of sonoluminescence in the human cheek

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When a bubble in a liquid is subjected to the pressure wave produced by an ultrasound field, it will undergo radial oscillations. If the ultrasound is of sufficiently high power, bubbles may collapse adiabatically at the point of maximum pressure in the cycle. This is known as transient cavitation. Very high temperatures (1000s K) are reached and molecules of gas or vapour in the bubble may break up into free radicals, which on recombination emit visible light, known as sonoluminescence (SL). The conditions that give rise to cavitation and SL should be avoided in the clinical use of ultrasound, because of the high temperatures and free radicals produced. An attempt was made to look directly for evidence of SL in the human cheek by placing a physiotherapy transducer on the outside of the cheek and a light guide, leading to a photomultiplier, on the inside of the cheek. A photon counter was used to count the pulses of SL received by the photomultiplier. The maximum intensity (spatial average) at which experiments were performed was that at which subjects just began to feel pain. This was 2 W/cm$^2$. With continuous-wave ultrasound of up to 2 W/cm$^2$, no SL was detected from the cheek. A simple theoretical analysis of the collection efficiency of SL by the light guide was performed. From this, and from data obtained from subsidiary experiments, a calculation was performed to show that the amount of SL produced in the cheek on exposure to therapeutic ultrasound is less than 1/200th of the amount of SL produced in the equivalent volume of water.

## The potential of seismic migration for medical ultrasound image enhancement

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Present-day medical ultrasound techniques are indispensable in many fields of medicine, in particular obstetrics and cardiology. Substantial advances in diagnosis have resulted from improvements in spatial resolution, achieved by beam-width reduction using techniques such as focusing and aperture synthesis. As the limit of these techniques is approached, further enhancement of the image is possible only by employing