New Laser Literature

review across the disciplines, researched and coordinated by Mr F.W. Cross

A MODEL FOR THERMAL ABLATION OF BIOLOGICAL TISSUE USING LASER RADIATION

Partovi F, Izatt JA, Cothren RM, Kittrell C, Thomas JE, Strikwerda S, Kramer JR, Feld MS. *Lasers Surg Med 1987, 7:141–54*

This paper presents a three-dimensional model for thermal ablation of tissue that predicts ablation thresholds, the rate of tissue removal, and the extent of peripheral tissue damage for laser light of a given wavelength, pulse duration, power, spot size, and beam profile. The authors state that such information can be an important guide in selecting the appropriate treatment parameters for a given surgical application. Physical modelling of tissue ablation is rather difficult to formulate due to, for example, the abrupt change in thermal behaviour at the water–steam phase transition temperature, the simultaneous occurrence of heat flow and mass removal, and the difficulties associated with incorporating scattering into the model. The authors made the following assumptions. (1) A known and pre-set light distribution function within the tissue. The maximum light intensity is at the surface of the tissue and hence the hottest point is at the centre of the laser beam on the surface of the tissue. (2) Optical and thermal properties of the tissue are independent of temperature. (3) Tissue removal is caused by evaporation of water. (4) The authors applied heat balance arguments, mathematically integrated over the tissue volume. (5) The diameter of the ablation crater is equal to that of the incident laser beam. (6) When a phase-change temperature is reached within the tissue, this tissue volume will continue to absorb laser energy without further temperature increase. (7) When the absorbed latent heat per unit volume reaches a certain critical energy density, the tissue water vaporizes, carrying away microscopic tissue fragments. (8) The rate of ablation rapidly reaches a steady-state ablation velocity. The spatial temperature profile is then taken fixed with respect to the moving front of ablation. (9) The model neglects the possible attenuating influence of the escaping gas and debris. The reported results encompass graphically the ablation velocity versus (irradiation) intensity for different spot sizes, the depth of the 100 °C region versus intensity, the crater depth versus exposure time for different intensities, and the intensity versus exposure time for several crater depths.

The paper is well written and should be considered as an important contribution to the field. It could also be used as a useful start for further work where more realistic light distributions are being taken into account. It would be interesting to compare the results of this model with those on CO_2 laser ablation, published previously by A.L. McKenzie (*Phys Med Biol 1986, 31:967–83*) as the present model is expected to be more accurate for highly absorbing tissues than for lower absorbing and high scattering materials. Unfortunately, the authors did not refer to McKenzie's paper.

INOSINE PRANOBEX IN RECURRENT LARYNGEAL PAPILLOMATOSIS

Carruth JAS, Patel P, Gemmell RJ. *J Laryngol Otol 1987, 101:1306–7*

It has been recognized for several years that the carbon dioxide laser provides the ideal surgical tool for the precise, bloodless atraumatic removal of laryngeal papillomas. It is now without doubt 'the instrument of choice' for the performance of the multiple procedures necessary to keep open the airway with the avoidance of a tracheostomy and to preserve the voice as far as possible. However, the problem of recurrence remains, and the disease is no longer termed 'juvenile' as it often continues into, or even begins in, adult life. A large number of techniques have been tried to prevent and to reduce these recurrences, but none has been regularly successful. The new antiviral agents have

been, and are being, investigated in this role, and some success has been achieved using interferon—but this is somewhat toxic, has to be given by intramuscular injection, and recurrence appears to follow cessation of treatment.

This paper presents a very small series of patients with recurrent respiratory papillomatosis treated by surgical ablation of the lesions with the carbon dioxide laser followed by administration of Imunovir which is a non-toxic antiviral agent that can be given by mouth. The patients acted as their own controls and had, over a period of months or years, developed an established pattern of recurrence, and in five of the six patients there was a significant reduction in the need for surgery. In none of the patients in whom an improvement was achieved has the drug been stopped, and it is therefore impossible to know whether or not recurrence would follow cessation of treatment. Undoubtedly, other units will evaluate this drug in carefully constructed trials, and it is hoped that it will prove to be of value in this most distressing and difficult-to-manage condition.

STIMULATION OF THE HEALING OF EXPERIMENTAL COLON ANASTOMOSES BY LOW-POWER LASERS

Asencio-Aranaand F, Martinez-Soriano F. *Br J Surg 1988, 75:125–7*

There have been many claims over the past ten to fifteen years that laser energy at low power has a beneficial and healing effect. Until very recently, such reports were rather anecdotal and not of a controlled nature. There have been some controlled studies which suggest that the stimulation of healing by low-power lasers does occur (and even fewer suggesting a believable mechanism), and it is into this group that this paper falls. The paper describes the use of helium–neon (HeNe) laser light to stimulate healing in rat colonic anastomoses. Two small groups of rats underwent colonic division and anastamosis; the experimental group then had the anastomosis irradiated with a 'biostimulatory dose' of HeNe light on two occasions. At set times after the operation the colon was removed and the bursting pressure of the anastomosis and the colon wall measured. The group that received HeNe irradiation had significantly higher pressures than did the control group. From this the authors conclude that such a technique may have a place in reducing the problem of anastomotic leakage in human colonic surgery. They wisely do not try to explain the phenomenon. This paper can be criticized on some points of method, including the way in which the colonic anastomoses were irradiated and the timings of sacrifice and measurement of bursting pressures. It does, however, represent a serious study in the field of biostimulation that raises the possibility of the clinical use of such a technique based on careful experimental work.

UNSCHEDULED DNA SYNTHESIS IN HUMAN SKIN AFTER IN VITRO ULTRAVIOLET EXCIMER LASER ABLATION

Green HA, Margolis R, Boll J et al. *J Invest Derm 1987, 89:201–4*

Now that clinical uses for the excimer laser are being demonstrated, serious consideration is being paid to the possible mutagenic effects of high intensity UV light on human tissue. This paper from Boston presents a careful investigation into the effects of 249 nm and 193 nm laser light on living human skin. The work is a development of the cell culture work performed by the same group (*Cancer Res 1987, 47:410–3*), reviewed in *Lasers Med Sci 1987, 2:228*). Fresh human skin was removed during the course of a routine surgical operation in a short series of patients and, while still living, was exposed to laser light and then incubated with radioactive thymidine. The thymidine is taken up into the intracellular DNA as part of the excision repair process that follows genetic damage. This repair process could then be quantified by using autoradiography to define the number of intranuclear grains in the cells which are themselves an indicator of unscheduled (and therefore possibly harmful) DNA synthesis (UDS). Skin was irradiated at several energy doses (at 640 mJ/cm^2/pulse) from both lasers and from an incoherent low-intensity UVC discharge lamp known to be mutagnic. A fourth series of skin specimens were treated with radioactive thymidine and autoradiographs were

prepared, but without prior laser or light irradiation, in order to act as a control group. The laser ablated tissue to varying depths, depending on the total energy dose, and UDS was sought in the tissue immediately beneath and lateral to the craters. No UDS could be detected in the control skin or in that irradiated at 193 nm. There was sparse UDS in the group exposed to the lamp, and marked UDS in the specimens exposed at 249 nm. The results suggest that 249 nm laser light is potentially genetically damaging to human tissue. Possible reasons for the lack of damage at 193 nm are given as follows. (1) The high absorption coefficient at this wavelength protects tissue deep to the crater. (2) Genetic damage exists which is not repaired by excision repair and which is therefore not detected by this method. (3) Thermal effects at the shorter wavelength prevent repair mechanisms from working in the tissue.

The results of this study will be applicable largely to work with bare beam delivery (ophthalmology and dermatology) rather than to work with fibre delivery (e.g., laser angioplasty) since these shorter wavelengths do not easily pass a fibre. The work does not address long-term problems in tissue but it does not set out to do so; as the authors point out, there may also be genetic damage not detectable by these methods. This is nevertheless an important scientific study which confirms earlier in vitro findings and, taken with other work on mutagenicity, will have a bearing on the clinical use of excimer lasers.

PERCUTANEOUS TRANSLUMINAL CORONARY ANGIOPLASTY RESTENOSIS: POTENTIAL PREVENTION WITH LASER BALLOON ANGIOPLASTY

Spears JR. *Am J Cardiol 1987, 60:61B–4B*

Percutaneous techniques for relieving coronary artery stenosis in the treatment of angina have slowly been gaining ground since the introduction of the Grüntzig balloon in 1975 and its first application to the coronary artery in 1979. A major problem with balloon dilatation is restenosis; this paper presents a review of recent work with a laser-assisted balloon method for stenosis dilatation which, it is hoped, will reduce the restenosis rate.

Spears originally described his laser balloon catheter in 1984. The device is not intended to cross occlusions in the way that conventional laser angioplasty does; rather, it is a device intended for percutaneous treatment of coronary stenoses. It consists of a conventional coronary balloon dilatation catheter which is inserted and inflated in the normal way. Inside the balloon is an optical fibre intended to deliver laser light in a diffuse manner such that the internal surface of the vessel is irradiated while the balloon is inflated. The laser used is the CW Nd-YAG, at 10–30 W, chosen because of its relatively high tissue penetration. The idea is that the vessel wall is heated to around 80–120 °C at which temperature the lining coagulates and any fissures formed by the balloon dilatation fuse together. This should prevent immediate collapse of the plaque leading to acute restenosis when the balloon is deflated. Spears outlines the careful in vitro and animal work which has been performed in order to bring this method to the point of human clinical application. It has been used both in human cadaver vessels in vitro and in the animal model with encouraging results; this review article is a good source of references for anyone interested in applying the technique. One of the potential problems associated with this device is the possible damage to the surrounding vessel wall. Spears argues that this is in fact an inherent advantage of the device. Death of the cells in the vessel wall, and thermal coagulation of the medial muscle, should lead to reduced platelet aggregation and to reduced proliferative regeneration, which is thought to be a cause of late restenosis. With the advent of the intracoronary stent, which has now been in clinical use for the prevention of restenosis for over a year, it will be interesting to see whether the clinical results from the laser technique represent an improvement over a mechanical device; a controlled comparison would be useful for resolving this question.

CONTACT LASER OR CONVENTIONAL CHOLECYSTECTOMY: A CONTROLLED TRIAL

Steger AC, Moore KM, Hira N. *Br J Surg 1988, 75:223–5*

The successful use of the laser as a scalpel has been confined largely to applications in ENT and gynaecology where the CO_2 laser is used with bare beam delivery in the larynx and cervix. The use of this laser for routine cutting tasks in general surgery has been limited by the bulk of the tissue

involved and by unwanted skin charring; the process is slow, and the advantages of the laser as a precision instrument are lost. In addition, there is little tactile feedback in a 'no-touch' situation. An Nd-YAG laser used for cutting has the advantage that it can be delivered fibre-optically, and the addition of a contact probe restores tactile feedback to the surgeon. This study investigates such a combination (CW Nd-YAG laser with contact sapphire probe) in a controlled trial of laser versus scalpel during cholecystectomy.

Twenty-one patients were entered in the trial, being randomized to laser surgey ($n = 10$) or coventional scalpel ($n = 11$). In the laser group the laser was used in all situations where the knife or diathermy was used in the control group. All operations were straightforward with no duct exploration. A number of parameters were compared, and the majority of these, such as in-patient stay and analgesia requirement, did not differ significantly between the groups. The laser group did fare poorly in two respects: the operations took significantly longer (30 minutes control versus 60 minutes laser), and there was an increased number of wound infections (1/11 control versus 5/10 laser). In addition, gross and histological examination of the skin wound showed marked charring in the laser group, but the pathological significance of this was not clear.

There is much subjective work in the literature concerning the advantages of a laser scalpel, but controlled data are hard to come by. This paper represents a small but expanding group of such controlled trials and contains some important negative findings. While there is no doubt that a tactile laser probe has technical advantages over bare beam delivery in this situation, no other advantage of the laser scalpel has been shown, and the increased operative time and wound infection rate suggest that neither the problems of bulk cutting nor of charring demonstrated in the CO_2 work have been solved by this approach.