Hypothesis: Extracorporeal high-intensity focused ultrasound (HIFU) would be used as a non-invasive local ablation for the treatment of patients with various kinds of solid tumor. Methods: A total of 1038 patients with solid tumors underwent HIFU ablation in ten Chinese hospitals. The tumors included primary and metastatic liver cancer, malignant bone tumors, breast cancer, soft tissue sarcomas, kidney cancer, pancreatic cancer, uterine myoma, benign breast tumors, hepatic hemangioma and other solid tumors. The real-time sonography-guided HIFU therapeutic system (Chongqing Haifu (HIFU) Tech Co., Ltd, China) was used in this study. The focused ultrasound was produced by 12-cm diameter therapeutic transducers with focal lengths from 90 to 150 mm, and operating frequencies of 0.8 and 1.6 MHz. The target tissue was exposed at the various acoustic focal peak intensities from 5,000 to 20,000 W cm\(^{-2}\). A randomized clinical trial was performed in breast cancer patients for assessing pathological changes of primary tumor treated with HIFU. Diagnostic images, including DSA, CT, MR, SPECT, and color Doppler ultrasound, were used to investigate the immediate efficacy of HIFU, and the regression of treated tumors during follow-up. By using the Kaplan-Meier method, a cumulative survival rate was calculated for long-term survival in patients with breast cancer, primary liver cancer, and osteosarcoma. Results: Pathological examination showed that the target region presented clear evidence of cellular destruction. Small blood vessels less than 2 mm in diameter were severely damaged. Furthermore, significant changes in malignant characteristics of treated cancer cell including proliferation, invasion, metastasis, and immortalisation were observed. Follow-up DSA, CT, MR and color Doppler US revealed that there was no, or reduced, blood supply in the treated-tumor, and SPECT showed that no uptake of radioisotope was observed after HIFU, both indicating a positive therapeutic response and an absence of viable tumor. Imaging at 6-12 months can showed obvious regression of the lesion. 4-year follow-up data were significantly observed in patients with HCC, osteosarcoma, and breast cancer. Among patients treated with HIFU, an extremely low major complication rate was observed.
Conclusion: Real-time sonography-guided extracorporeal HIFU ablation is a safe, effective, and feasible modality for the local ablation of patients with various kinds of solid tumor. This work was supported by Ministry of Science and Technology of China (grant No. 96-905-02-01) and the National Natural Science Foundation of China (grant No. 39300125, 39630340, 39630340, 39670749, 39770841, 39770712, 30070217, 30171060).

2B-2 2:00 p.m.

A STUDY OF THE RELATIONSHIP BETWEEN ULTRASOUND EXPOSURE CONDITIONS, ABLATED VOLUME AND GREYSCALE APPEARANCE IN EX VIVO TISSUE

G. TER HAAR*, J. KENNEDY, and F. WU

Institute of Cancer Research, Sutton, UK, Churchill Hospital, Oxford, UK, Chongqing University of Medical Sciences, Chongqing, China.

Corresponding e-mail: gail@icr.ac.uk

While treating patients with HIFU using the JC-Tumor Therapy system (HAIFU Technology company, Chongqing, China), the aim is to use a combination of ultrasound intensity and exposure time that results in a change in the greyscale appearance of the targeted tissue on an ultrasound image. The hyperechoic region may appear transiently or may be persistent. It is therefore important to understand the relationship between these greyscale changes and the ensuing tissue ablation.

Methods: Ultrasound treatments at pre-determined intensity, frequency and exposure times are carried out in freshly excised bovine liver. Single exposures and linear scanning regimes are investigated. Acoustic powers between 150 and 300W are used, with frequencies in the range 0.8-1.8 MHz, exposure times of 1-15s for single lesions, and scanning speeds of 1-4 mm/s. A region of interest split into 9 pixels is drawn around the hyperechoic region and the change in amplitude of the greyscale signals is recorded as a function of time following exposure. The dimensions of the bright region are measured from the image and these are compared with the macroscopic dimensions of the dissected sample following treatment.

Results: Grey scale changes following HIFU exposure may be transient or persistent. Clear decay patterns of the echo amplitude can be seen for different exposure conditions. The relationship between lesion dimensions as measured on the ultrasound image, those measured on the dissected sample and these decay patterns is presented.

Conclusion: It is important to understand the significance of greyscale changes seen during patient HIFU treatments. This study allows better interpretation of the clinical implications of images seen.

James Kennedy is supported by Ultrasound Therapeutics Ltd
A TRANSVAGINAL IMAGE-GUIDED HIGH INTENSITY ULTRASOUND ARRAY

S. VAEZY*1, B. HUGUENIN2, G. FLEURY2, J.R FLEXMAN1, and R. HELD1,
1Applied Physics Laboratory, University of Washington, 2Imasonic Corporation.
Corresponding e-mail: vaezy@apl.washington.edu

The goal of this project is to develop a transvaginal image-guided High Intensity Focused Ultrasound (HIFU) device using piezocomposite HIFU array technology and commercially-available ultrasound imaging.

The HIFU array design specifications included an annular phased array with a focal length range of 30-60 mm, an overall elliptical shape of 35x60 mm, and an operating frequency of 3 MHz. The maximum focal intensity, in water, was 3000 W/cm^2. The HIFU array is designed to be integrated with an intra-cavity imaging probe (C9-5, Philips) such that the focal axis of the HIFU transducer was within the image plane. A 4-mm diameter, 30 degree optical scope (Olympus) is being integrated into the device to provide visual confirmation of proper water coupling in the vaginal cavity.

An 11-element (concentric rings) array using 1-3 piezocomposite technology was designed and manufactured at Imasonic Corporation. The design included 6 complete rings in the center, and 5 side-truncated rings in the periphery. The natural radius of curvature of all elements is 50 mm. The HIFU transducer has about 1 MHz bandwidth for all 11 elements. The impedance of all elements is approximately 50 ohms, with better than 10% accuracy for both real and imaginary parts, using a custom-made matching network. The adjacent element cross coupling is less than -40 dB. High power measurements on the central transducer element showed more than 75% efficiency, at surface intensity of 2.66 W/cm^2. Schlieren imaging showed effective focusing at all focal lengths (30-60 mm).

The transvaginal image-guided HIFU device requires careful water coupling in the vaginal cavity. Entrapment of air bubbles was a significant problem in a recent survival study in sheep, using a transvaginal device. The HIFU array needs to be fully characterized for lesion formation in tissue-mimicking phantoms and biological tissues. Possible applications include uterine fibroids and abnormal uterine bleeding.

Supported by NIH, USA

EXPERIMENTAL METHODOLOGIES FOR STUDYING THE EFFECTS OF PERFUSION ON HIGH INTENSITY FOCUSED ULTRASOUND (HIFU)

L. N. COURET*1, N. R. MILLER2, G. R. TER HAAR1, and I. H. RIVENS1,
1Institute of Cancer Research, Sutton, Surrey, U.K., 2Royal Marsden NHS Trust, Sutton, Surrey, U.K.
Corresponding e-mail: Lisa.Couret@icr.ac.uk

Supported by NIH, USA
The liver is a highly perfused organ. The temperature rise induced by HIFU adjacent to blood vessels might be lowered due to conductive cooling. Our aim was to develop novel biological and non-biological flow phantoms to investigate this phenomenon.

The biological model employed freshly excised whole porcine livers perfused via the portal vein with Lactate Ringer solution. This perfusate is designed for kidney transplantation, but is considerably cheaper and easier to prepare than conventional liver perfusate and was found to maintain liver cell viability for up to 36 hours. The liver was collected from an abattoir and immediately flushed with 5 liters of heparinized perfusate to remove whole blood clots. At the laboratory, the liver was continually perfused using a pump system converted from pulsatile to laminar flow. Under diagnostic ultrasound guidance a 0.1mm-diameter manganese/constantan thermocouple was implanted within 1mm of a blood vessel (∼2cm diameter) and the flow rate of perfusate within the vessel was varied. The thermocouple junction was exposed to 1.7MHz HIFU and the thermocouple heating/cooling curves were recorded. Preliminary results showed that for a HIFU spatial peak intensity of 250Wcm\(^{-2}\) and an exposure time of 10s, the temperature rise was reduced by ∼27% when the perfusion rate was doubled.

The higher perfusion rate (840ml/min) corresponded to a physiologically realistic flow rate. The second phantom was non-biological so that unlike existing phantoms, it could be used repeatedly even at high intensities. It consisted of polyacrylamide gel enhanced with pulverized, vulcanized rubber. The phantom remained stable at temperatures >85°C and possessed acoustic parameters close to that of tissue, e.g., attenuation of 0.7dB/cm at 1.7MHz. A 'wall-less' vessel will be incorporated to investigate the effects of flowing perfusate.

We have developed a cost-effective biological flow phantom that is relatively easy to construct and highly clinically realistic. Preliminary results with this model demonstrated a reduction in temperature rise with increasing flow rate. The phantoms developed in this study are likely to be useful for many applications.
an initial X pattern from the two (crossing depth adjustable 1 to 1.2 cm). The pattern rapidly grew towards the applicator forming a filled V shape in 15 s at 95 W/each applied. The system and applicators were tested in 3 anesthetized juvenile pigs. Liver incisions with varying lengths (3.5 ± 1.3 cm) and depths (0.42 ± 0.3 cm) were treated. Two approaches were used: (A) applicators were oriented so they straddled the incision (one on each side) as they were moved along it or (B) they were aligned so each applicator passed sequentially along the incision. It was found that A tended to stop the bleeding from deeper sites more readily. However, tissue emulsion (important for hemostasis) was more readily formed with B. In this approach, as the first applicator moved along the incision it tended to slow the bleeding and the second formed the emulsion. In shallow cuts, one B pass along the incision was sufficient to achieve hemostasis. In deeper wounds, an A pass followed by a B pass was sufficient. In very deep cuts, more than 2 passes were needed. The area (Ar) of the incision (length x depth) correlated (r = 0.79) with the time (Ht) required to achieve hemostasis (linear regression: Ht = 40 Ar + 24.) Ht was shorter with dual than with a single applicators and difficult bleeds more readily managed. The shortcoming was the cumbersome of two and difficulty in accessing some sites. Based on these findings, a more streamlined method of combining two or more piezoelectric elements to spread the focal area but maintain the intensity is under investigation.

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Session: 3B
GUIDED ACOUSTIC WAVE SENSORS
Chair: L. Lynnworth
GE Panametrics

3B-1 1:30 p.m.

ANIMATION OF SURFACE ACOUSTIC WAVE PROPAGATION ON A SPHERE FOR PRECISE DESIGN OF THE BALL SAW SENSORS
S. ISHIKAWA*1, N. NAKASO2, N. TAKEDA3, T. MIHARA1, Y. TSUKAHARA2, and K. YAMANAKA1, 1Tohoku University, 2Toppan Printing Co., Ltd., 3Ball Semiconductor Inc.
Corresponding e-mail: ishikawa@stu.material.tohoku.ac.jp

The unique propagation of surface acoustic wave (SAW) on a ball [1,2] is expected to provide high performance SAW devices (ball SAW devices) applicable to sensors. Since we have to deal with a 3 dimensional wave fields for precise design of ball SAW devices, numerical methods such as finite element or finite difference method need too many elements and it is not practical. In our previous paper, we verified by a precise laser ultrasonic measurements that the calculation taking the higher radial modes up to the 9 th order into account