

The Use of Ultrasound to Deform Aqueous Gels

Jeffrey Garcia

Freeport High School, Freeport NY USA

Abstract. An aqueous gel with embedded carbon toner particles was imaged microscopically before and during ultrasound insonification at 3.5 MHz. Difference images revealed motion of the gel of about 30 mm in the approximate direction of the acoustic beam. Attempts at reproducing the motion with streaming water were unsuccessful. It was concluded that the gel motion was due to the acoustic radiation force. Understanding the behavior of gels under the influence of this force can lead to the future use of radiation force as a safe probe of cancers such as breast cancer.

Keywords: breast cancer, ultrasound, gel, deformation

INTRODUCTION

Women in the United States have a 1 in 8 lifetime chance of developing invasive breast cancer. According to the American Cancer Society, approximately 40,000 women die of breast cancer each year [1]. For some diagnosed cases, neoadjuvent therapy is used to shrink breast cancer tumors before surgery [2]. Examples of this therapy are chemotherapy and radiation therapy. Then surgery is performed when the tumor is at a manageable size (about one centimeter). Currently, MRI is used to keep track of tumor size. Gadolinium is used as a contrast agent to improve visualization. Unfortunately the FDA has limited the use of Gadolinium because it is an irritant. Ultrasound is an alternative to MRI for tumor monitoring. New ultrasound techniques are under development. Ultrasound imaging with contrast agents work very well [3,4], but have potentially similar downsides as the MRI contrast agents. Among the most promising are those that use the (safe) radiation force that accompanies an ultrasound beam. The ultrasound beam provides a palpation of tissue that can tell the ultrasound technician about the stiffness of the tissue. Cancer tissue has a different stiffness from healthy tissue, so the ultrasound can be used to image the cancer. However, the mechanical effects of the radiation force on the soft tissue are not fully known. In order to study the mechanical effects in detail, it is important to develop a technique for the study of the mechanical effects in artificial materials that mimic tissue (tissue “phantoms”) and then in vitro tissue samples. As a first step, this project optically tracked the motion of a tissue phantom under the influence of ultrasound radiation force.

METHODS

An aqueous gel was made using granular gelatin (Chemical Abstracts Service registry number 9000-70-8, Nasco, Fort Atkinson WI USA). For every 50 grams of gelatin, 100 grams of water was used, heated to 100 °C. A thin layer (several millimeters deep) was poured into a clear plastic container, and sprinkled with carbon toner particles. When the gel had set, the container was filled with water, and a focused ultrasound transducer with a 35 mm focal length (model SU-107, Sonic Concepts, Inc., Bothell WA USA) was placed on top of the container with the gel, as shown in Figure 1. A function Generator (model 4011A, B&K Precision Corp., Yorba Linda CA USA) was used to produce a 3.5 MHz sine wave at output amplitude of plus/minus one volt. That signal was sent to an RF power amplifier (model 403LA, Electronics & Innovation Ltd., Rochester NY USA), which in turn was used to excite the transducer in continuous mode.

When the transducer was activated, the ultrasound beam, focused on the gel, produced motion in the gel. An inverted microscope (model 3032, Accu-Scope Inc., Sea Cliff NY USA) was used to observe the gel. Images were recorded digitally at a magnification level of 2.7.

The radiation force can also move the water in the container, and the moving stream of water in turn can push on the gel, deforming it. In order to test this effect, a hypodermic needle was used to produce water streaming.

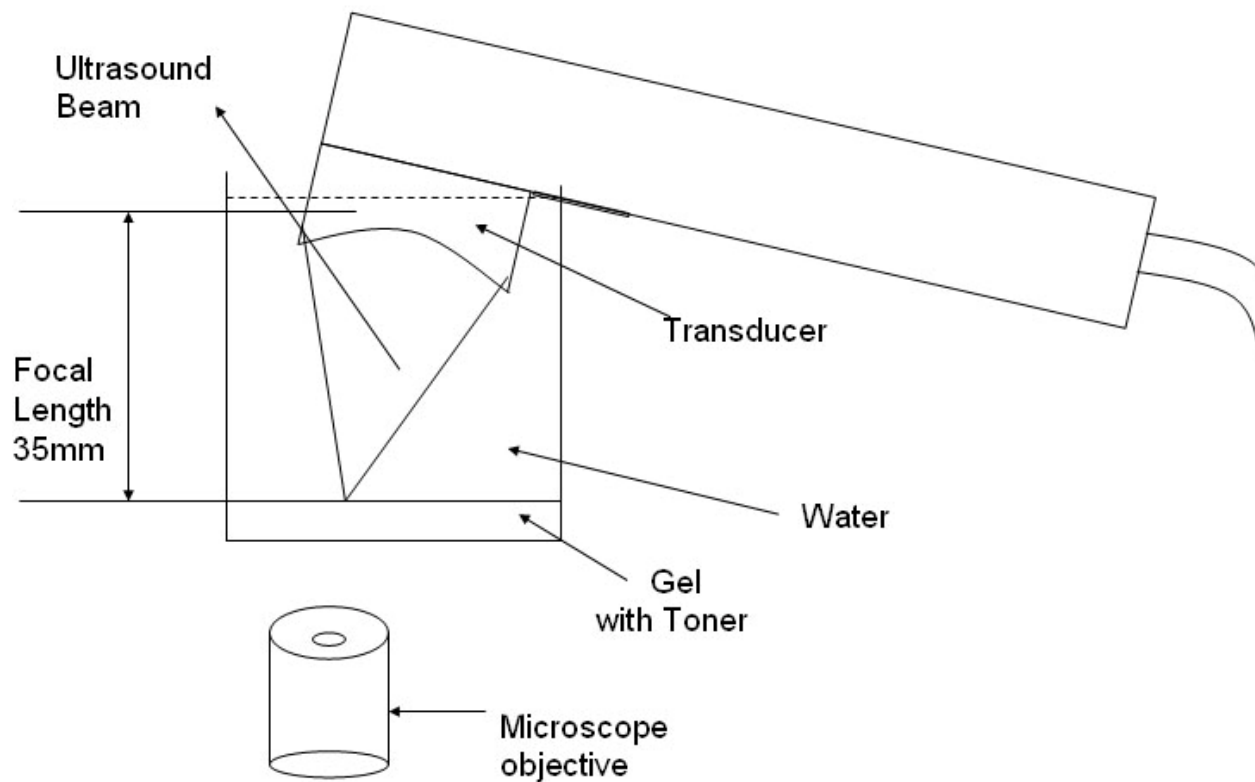


Figure 1. Transducer setup. In some experiments, the ultrasound beam was replaced with a hypodermic needle streaming water towards the gel.

RESULTS

Figure 2 shows a microphotograph of the gel with toner particles. Individual particles are visible, about a few microns in diameter. Irregular clumps of particles dominate the image. The position of the ultrasound focus was uncertain, and inferred by looking at the difference of the before and during insonification images and identifying the region of maximum motion. This is shown magnified in Figure 3. The length of the largest contour feature represents the motion of the gel at the focus, about 30 microns.

In the streaming experiments, the difference images showed small, only unstructured noisy regions. In other words, no motion was observed.

DISCUSSION

A concern was that water streaming was the cause of movement within the gel. A test was performed by shooting a jet of water at the gel; no sign of movement was seen.

CONCLUSIONS

It was possible to track the motion of aqueous gel under the influence of the acoustic radiation force. The motion of the gel was not due to water streaming.

ACKNOWLEDGMENTS

The author gratefully acknowledges the help of Dr. R. Muratore.

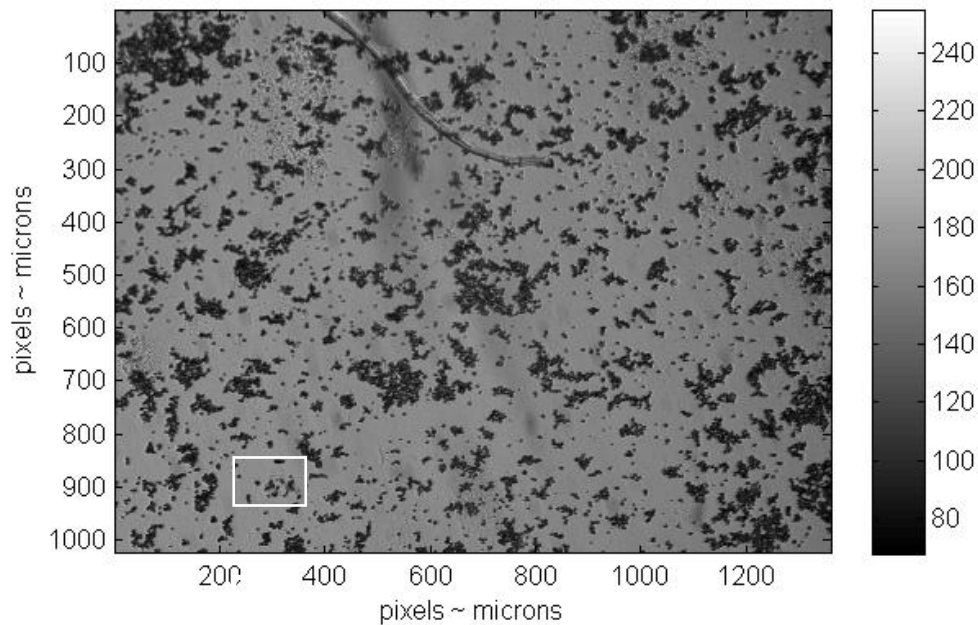


Figure 2. Photomicrograph of gel with toner. Horizontal and vertical scales are in pixels, which at the microscope / digital camera resolution, are approximately microns. The grayscale is image density (0-255). The white rectangle approximately outlines the region shown in Figure 3.

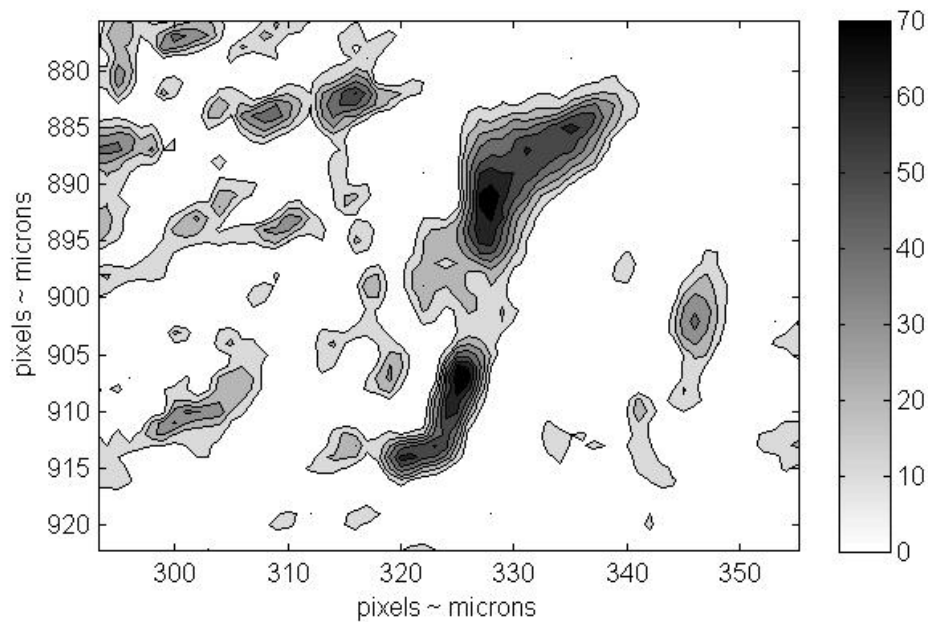


Figure 2. Difference image of an area within the gel that showed significant movement from the acoustic radiation force. The approximate area illustrated here is outlined as a white rectangle in Figure 2. The grayscale is the magnitude of the difference between a gel image before and during insonification.

REFERENCES

1. National Cancer Institute's Surveillance, Epidemiology, and End Results database
2. <http://seer.cancer.gov/statfacts/html/breast.html>
3. <http://www.freepatentsonline.com/6231834.html>
4. <http://www.freepatentsonline.com/EP1020180.html>