**Journal of Diabetes Science and Technology**
Volume 3, Issue 3, May 2009


ORIGINAL ARTICLES

# Noninvasive Ultrasonic Glucose Sensing with Large Pigs (~200 Pounds) Using a Lightweight Cymbal Transducer Array and Biosensors

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## Abstract

### *Background:*

To prevent complications in diabetes, the proper management of blood glucose levels is essential. Since conventional glucose meters require pricking fingers or other areas of the skin, a noninvasive method for monitoring blood glucose levels is desired. Using a lightweight cymbal transducer array, this study was conducted to noninvasively determine the glucose levels of pigs having a similar size to humans.

### *Method:*

*In vivo* experiments using eight pigs (~200 pounds) were performed in five groups. A cymbal array with four biosensors was attached to the axillary area of the pig. The array was operated at 20 kHz at special peak–temporal peak intensity ($I_{sptp}$) equal to 50 or 100 mW/cm$^2$ for 5, 10, or 20 minutes. After the ultrasound exposure, glucose concentrations of the interstitial fluid were determined using biosensors. For comparison, glucose levels of blood samples collected from the ear vein were measured by a commercial glucose meter.

### *Result:*

In comparison, glucose levels determined by a cymbal array and biosensor system were close to those measured by a glucose meter. After a 20-minute ultrasound exposure at $I_{sptp}$ = 100 mW/cm$^2$, the average glucose level determined by the ultrasound system was 175 ± 7 mg/dl, which is close to 166 ± 5 mg/dl measured by the glucose meter.

### *Conclusion:*

Results indicate the feasibility of using a cymbal array for noninvasive glucose sensing on pigs having a similar size to humans. Further studies on the ultrasound conditions, such as frequency, intensity, and exposure time, will be continued for effective glucose sensing.

*J Diabetes Sci Technol 2009;3(3):517-523*

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**Abbreviations:** (ANOVA) analysis of variance, (GOx) glucose oxidase, ($I_{sptp}$) special peak–temporal peak intensity, (PBS) phosphate-buffered saline, (PZT) lead zirconate–titanate, (RF) radio frequency

**Keywords:** cymbal transducer, glucose sensing, noninvasive, transdermal, ultrasound

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