# Phase-Contrast Radiography: A New X-Ray Technique for Cochlear Implant Research

J. Xu[1,2], A.W. Stevenson[3], D. Gao[3], M. Dahm[2], S.W. Wilkins[3], G.M. Clark[1,2] and R. Cowan[2]

[1] *The Bionic Ear Institute, Melbourne, Australia*
[2] *Co-operative Research Centre for Cochlear Implant and Hearing Aid Innovation University of Melbourne, Australia*
[3] *CSIRO Manufacturing Science and Technology, Clayton, Vic. Australia*

## Summary

This study examines the application of a new x-ray modality, phase-contrast radiography, in temporal bone (TB) imaging. Preliminary results from TB samples have shown that phase-contrast imaging offers greater contrast for edge-type features and weakly absorbing soft-tissue resulting in improved visualization of anatomic details of inner ear and microelectrode structures. This is potentially valuable in the development of new electrode arrays for cochlear implants.

## Introduction

Post-operative radiography has become an important clinical tool for demonstrating correct placement of the intra-cochlear electrodes. Currently, the conventional skull radiography is still the mainstay of post-operative radiological assessment[1, 2]. It serves as a valuable reference for evaluation of intracochlear electrode position and correlation of individual stimulating electrodes to pitch perception. However, the development of improved peri-modiolar electrode arrays for use in cochlear implants requires more detailed information from the post-operative radiological assessment.

The present work investigates the possibility of applying a new x-ray modality, phase-contrast radiography in temporal bone (TB) imaging.

Conventional radiography, developed during the last century, has relied on the principles of absorption contrast arising from density differences and variation in composition and thickness of the object. In contrast to conventional radiography, phase-contrast radiography[3, 4] utilizes a micro-focus x-ray source (<40 μm) to achieve a high degree of spatial coherence. When the spherical wave passes through the object; the wave front becomes distorted. A relatively large object-image distance is applied to allow further wave propagation and interference effects to occur, resulting in intensity variation (phase contrast) in the image plane (Figure 1).

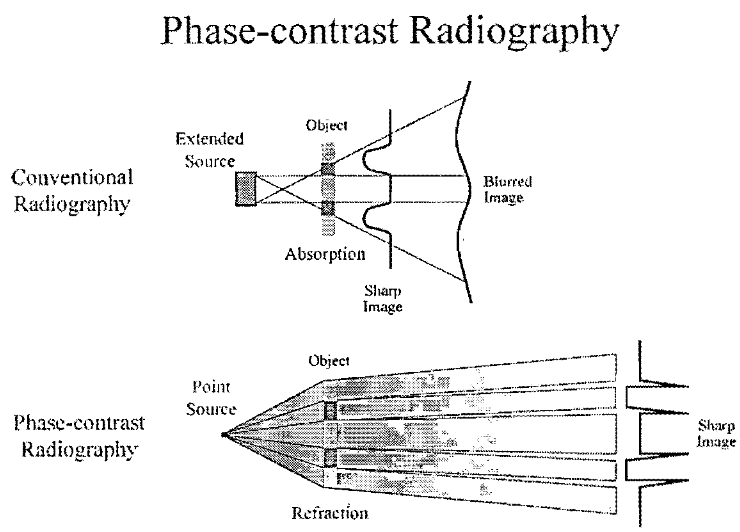


*Figure 1. Comparison of physical principles of conventional radiography and phase-contrast radiography.*

Previous research has proved that phase-contrast imaging is valuable for improving the contrast of weakly absorbing features in small biological objects, such as gold fish, dragonfly, porcine liver, chicken knee, finger etc[3, 4].

The present study was conducted to examine the application of phase-contrast radiography to imaging of the temporal bone - the bone with the most intricate (complicated) anatomy and with the highest density in the human body.

## Materials and Methods

Five formalin-preserved human temporal bones (TB) were trimmed down to the petrous bone size. A Nucleus 22 standard electrode array was inserted into the scala tympani of the cochlea of three of these TBs. A cochlear surface preparation was performed on one of these three TBs after insertion. A new Nucleus 24 Contour electrode array was inserted in another of the TBs. The fifth TB had no electrode inserted.

A conventional macro-radiograph (Cochlear View[1]) was taken for each TB for comparison using a skull radiographic unit (Ultracranio, Isotopan Snc., Italy). We used a focal spot of 0.3 x 1.0 µm, a source-object distance of 99 cm, object-image distance of 35 cm and an exposure of 60 kV and 13 mAs. The radiographs were processed with a UMAX (PowerLook 2000) scanner (optical resolution 8.5 mm pixel size). Phase-contrast radiography was performed using a Feinfocus source (Feinfocus Röntgen-Systeme GmbH, Garbsen, Germany; Model FXE- 225.20). The nominal focal-spot size was 4 mm, the source-object distance was 30 cm and the object-image distance was 170 cm. The exposures were recorded at 90 kV and 6 mAs. Fujifilm Imaging Plates were used as the recording medium and were processed with a Fujifilm BAS-5000 scanner (employing 25 µm pixel size).

## Results

Figure 2 shows conventional radiograph (a) and phase-contrast radiograph (b) of the temporal bone with a standard Nucleus multiple channel electrode array inserted in the cochlea. It is apparent that the imaging contrast was much enhanced for the edge of canal-type structures (semi-

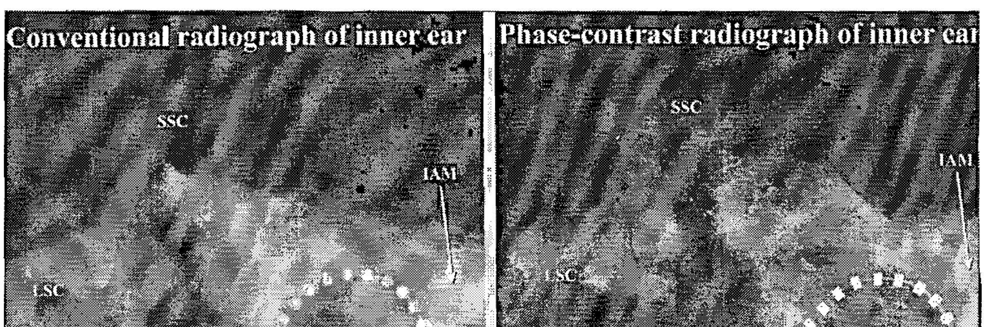


*Figure 2. Conventional radiograph (a) and Phase-contrast radiograph (b) of the temporal bone with an experimental Nucleus standard electrode array inserted in the cochlea. SSC = superior semicircular canal; LSC = lateral semicircular canal; PSC = posterior semicircular canal; V = vestibule; IAM = internal auditory meatus.*

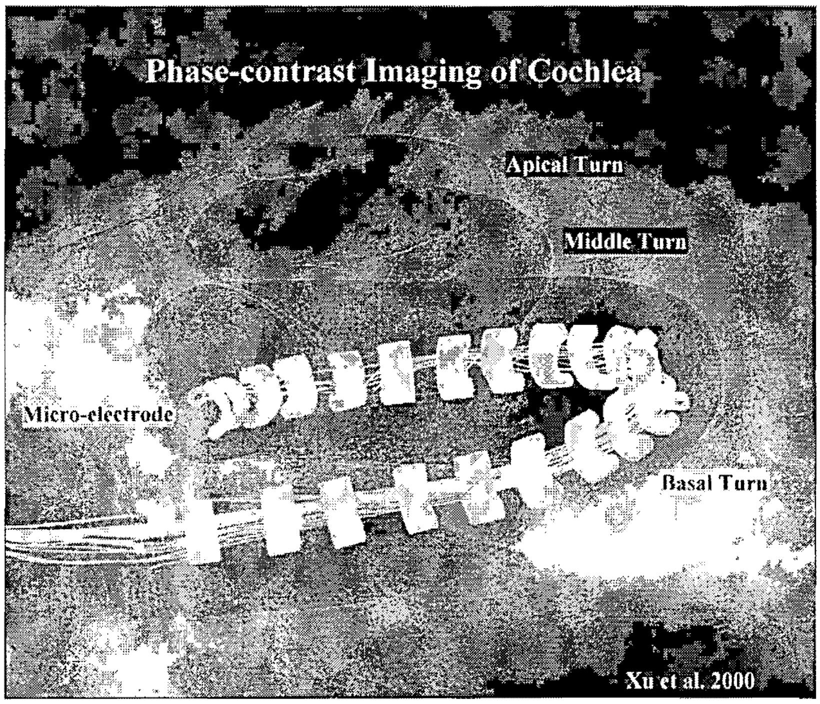


*Figure 3. Phase-contrast image of the cochlea with a prototype version of the Nucleus 24 Contour electrode array inserted in the scala tympani.*

circular canals, cochlea etc.) of the labyrinth using phase contrast radiography (Figure 2b) as compared with conventional radiography (Figure 2a).

Figure 3 shows the phase-contrast image of the cochlea with a prototype version of the Nucleus 24 Contour electrode array inserted in the scala tympani. Such sharp imaging of the cochlear walls and cochlear turns was evident. This detail was not observed using any other radiographic methods previously.

Enlargement (Figure 4b) of the electrode array from Figure 3 contains greater detail of microelectrode structures. The Platinum wires with 25 μm diameter can be clearly differentiated. In contrast, the platinum wires are very blurry and indistinct with either conventional radiograph (Figure 4a) or with computed tomograph (CT).

These preliminary results from TB samples implanted with a variety of Nucleus multiple channel electrode arrays have shown that phase-contrast imaging offers significant improvements over conventional radiography in TB imaging. The improvements include enhanced contrast for edge-type features, inherent imaging magnification and high spatial resolution. The resultant improvement in visualization of anatomical detail for the inner

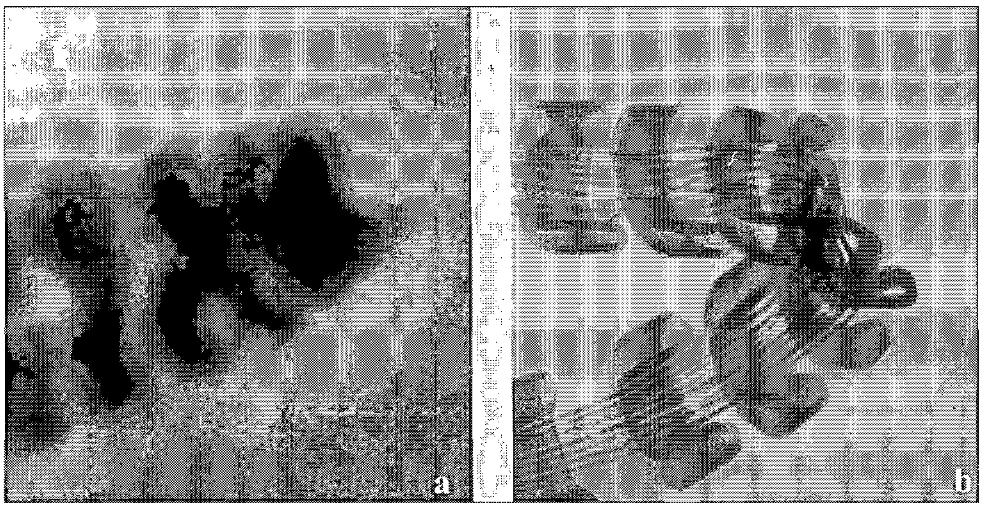


*Figure 4. Enlargements of electrode array from a conventional radiograph (a) and a phase-contrast radiograph (b). The diameter of micro-wires was 25 $\mu m$.*

ear and microelectrode structures has important advantages for development work with advanced electrode arrays.

## Conclusion

This study has demonstrated that phase-contrast radiography provides significant advantages over conventional radiography in imaging of temporal bone details, and is a potentially valuable tool in the development of advanced electrode arrays for cochlear implant systems.

## Acknowledgment

Thanks to Dr. Y Duan for her invaluable information, Ms J Kay for radiographic assistance and Dr. D Lawrence for his photographic and computing assistance. This project was supported in part by X-Ray Technologies Pty. Ltd. and Fujifilm Co. Ltd.

## References

1. Xu J, Xu SA, Cohen LT, Clark GM. Cochlear View: post-operative radiography for cochlear implantation. Am J Otology 21:49-56, 2000.
2. Chen JM, Farb R, Hanusaik L, Shipp D, Nedzelski JM. Depth and Quality of Electrode Insertion, a radiologic and pitch scaling assessment of two cochlear implant system. Am J Otology 20:192-197, 1999.
3. Wilkins SW, Gureyev TE, Gao D, Pogany A, Stevenson, AW: Phase-contrast

imaging using polychromatic hard x-rays, pp.335-338, Nature 384, 1996.

4. Gao D, Pogany A, Stevenson AW, Wilkins SW. Phase-contrast Radiography, 18:1257-1267, RadioGraphics 1998.