Low Cost Three-Dimensional Ultrasonographic Imaging in a Military Women’s Health Center Using the Continuous Linear Acquisition Method

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Precis: The authors present several three-dimensional sonographic images from a population of obstetric patients in a military medical center. The presentation will include images that demonstrate areas for which our inexpensive three-dimensional sonographic techniques have distinct advantages over traditional two-dimensional means.

Disclaimer: The opinions expressed in this paper are those of the authors and do not necessarily represent official policy of The Department of Defense, The United States Army Medical Department, or The Madigan Army Medical Center.

Abstract:

Title: Low Cost Three-Dimensional Ultrasonographic Imaging in a Military Women’s Health Center Using the Continuous Linear Acquisition Method.
Authors: Christian Macedonia MD, Troy Patience BS., Arthur Maslow DO., Jerome Kopelman MD.
Objective: To determine the clinical usefulness of our three-dimensional ultrasonographic system in a population of female military health care beneficiaries.
Design: Using the previously described "continuous linear acquisition method" of three-dimensional ultrasonography, we collected an archive of three-dimensional ultrasound images then reconstructed serial frame sets using NIH IMAGE. All study subjects were volunteers who were patients seen at the Madigan Army Medical Center's (MAMC) Antenatal Diagnostic Center.
Method: Volunteers from a population of women undergoing screening and diagnostic ultrasounds were evaluated by conventional two-dimensional ultrasound. Each subsequently underwent examination using the continuous linear acquisition transducer system. The scrolled images were then uploaded to a Macintosh 8100/80 workstation (Power PC) with SCION LG3 frame grabber card operating NIH IMAGE software. We created three-dimensional interactive data sets for image projection. In the case of our three-dimensional fetal echocardiography, we used a manual pseudo-gating process to create a running 0-degree projection of one fetal cardiac cycle. All other projections were 360 degree, rotating, brightest point projections.
Results: We have assembled a montage of three-dimensional ultrasonographic images to include: a complete but not central placenta previa highlighting for the first time the unique three dimensional character of this pathology, a diamnionic-dichorionic twins gestation which shows our ability to perform off line image optimization and biometry, a normal singleton gestation revealing spinal ultrastructure in a compounded image, a cleft lip and palate, a complex cystic adenexal mass, and finally a three-dimensional fetal
echocardiogram using a manual pseudo-gating process to create a running 0-degree projection of one fetal cardiac cycle.

**Conclusion:** The continuous linear acquisition method of 3D sonographic image generation provided clinically useful, inexpensive, and unique information which proved to be a useful adjunct to the management of several patients with pregnancy and non-pregnancy related pathologies. This initial work-in-progress study demonstrates the need for further research into low cost/portable three-dimensional imaging systems.
Background:

Investigation into the feasibility of three-dimensional ultrasound has been evolving over the past 25 years. While the concept of three-dimensional ultrasound has intuitive advantages, the ability to bring the technology to clinical practice has lagged due to numerous engineering hurdles. Our group at the Madigan Army Medical Center in Tacoma, Washington has been working toward the creation of a low cost system which could provide researchers and clinicians with a practical first step toward office 3D Ultrasound.

In the spring of 1993 we presented a report at the AIUM on the use of simple, off-the-shelf, equipment for the generation of 3D reconstructions of fetal anatomy ultrasound. Our system at that time utilized a Black and Decker cordless screwdriver in the linear translation mechanism. Some called this the "Black and Decker Solution" to the problem of image acquisition.

There were several cost advantages to our system. In addition to using simple equipment acquired for less than $40 at the local hardware store, we also used off the shelf freeware from the Internet called NIH IMAGE written by Wayne Rasband at the NIMH. This unique application of this software (originally written to aid in reading electrophoresis gels) allowed us to rapidly reconstruct serially acquired two-dimensional ultrasound images into rotating, nearest-point projections. The final cost advantage was our use of computer equipment obtainable at any consumer electronics store. Our platform was and has remained Macintosh.

Since our original work in 1992, we have improved upon our linear translation device. Our current mechanism is a self contained Lucite housing surrounding a worm-in-gear. The transducer cradle can accommodate a number of different conventional 2D transducers. We have also upgraded to PowerPC which has significantly improved rendering speed.

Design:

Using the "continuous linear acquisition method" of three-dimensional ultrasonography, we collected an archive of three-dimensional ultrasound images over a one year period using the NIH IMAGE software to reconstruct serial frame sets. All study subjects were unpaid volunteers who were patients seen at the Madigan Army Medical Center's (MAMC) Antenatal Diagnostic Center. Subjects were selected for study based upon their anatomic findings during conventional 2D scanning. Gravid subjects were scanned in fetal biometry mode. Attention was given toward selecting patients with findings which could be validated by other means (i.e. direct visualization at the time of surgery).
Method:

Volunteers from a population of women undergoing screening and diagnostic ultrasounds were evaluated by conventional two-dimensional ultrasound. Each subsequently underwent examination using the continuous linear acquisition transducer system (Dia 1). The conventional 2D image engine was an ATL Ultramark 9 (Bothell WA). Image field depth, focal zones, and time gain compensation were set in the conventional fashion. A 5 MHz curved array was used in all scans. Before each linear sweep, time trials were performed to determine the speed of linear translation in order to calibrate frame stack spacing.

Linear sweep 2D images sets were scrolled onto conventional VHS videotape. The NTSC signal was then uploaded to a Macintosh 8100/80 workstation (Power PC) with SCION LG3 frame grabber card operating NIH IMAGE software. We created three-dimensional interactive data sets for image projection using the projection macro.

In the case of our three-dimensional fetal echocardiography, we used a manual pseudo-gating process to create a running 0-degree projection of one fetal cardiac cycle. All other projections were 360 degree, rotating, brightest point images sectioned into 10 degree increments.

Results

We have assembled a montage of three-dimensional ultrasonographic images to include:

1) A complete but not central placenta previa highlighting for the first time the unique three dimensional character of this pathology

2) A diamnionic-dichorionic twins gestation which shows our ability to perform off line image optimization and biometry, a normal singleton gestation revealing spinal ultrastructure in a compounded image

3) A three-dimensional fetal echocardiogram of a fetus at 19 wks estimated gestational age with a dual outlet left ventricle using a manual pseudo-gating process to create a running 0-degree projection of one fetal cardiac cycle

4) A serous cystadenoma detailing the internal architecture of this complex mass. A surgical pathology photograph is presented for comparison.

5) A cleft lip and palate clearly demonstrating involvement of the left maxilla. A photograph of the newborn is presented for comparison.

Discussion:

The images presented give a glimpse into the potential of 3D ultrasound. As one would expect, this modality is an excellent tool for the elucidation of
structural details. In addition, it allows the end user to manipulate the image offline to gain new insight into previously acquired data. The image can be queried for such information as the gestational age of the fetus contained within an acoustic window.

Given the current climate in research and medicine, any researcher must carefully consider costs. Our system features almost all off-the-shelf equipment which cost less than $10,000. When one considers that diagnostic ultrasound systems typically cost $250,000, the price of the system upgrade is negligible.

While our system is relatively easy to use, finding ways to reduce the size and complexity of the equipment is an ongoing challenge. Since part of our work is in the direction of creating portable 3D systems, we have placed a priority on optimizing the size of the linear translation device.

Conclusion:

The continuous linear acquisition method of 3D sonographic image generation provided clinically relevant, inexpensive, and unique information which proved to be a useful adjunct to the management of several patients with pregnancy and non-pregnancy related pathologies. This work-in-progress study demonstrates the need for further research into low cost/portable three-dimensional imaging systems.


