

Virtual Fetal Touch Through a Haptic Interface Decreases Maternal Anxiety and Salivary Cortisol

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OBJECTIVE: To evaluate whether a virtual reality (VR) workstation (Fetouch system) offering three-dimensional (3D) fetal visual and kinesthetic interaction may affect maternal stress.

METHODS: Maternal-fetal visual and kinesthetic interaction was obtained through a haptic interface based on 3D reconstruction of sequential bi-dimensional ultrasound images of the fetus. Maternal stress was assessed before and after visual/kinesthetic interaction with the fetus: 1) by using the State Trait Anxiety Inventory-fromY (STAI) test, and 2) by measuring salivary cortisol levels. Statistical analysis was performed by paired t test and analysis of variance (ANOVA) for repeated measures.

RESULTS: After the fetal visual and kinesthetic experiences, a significant reduction was observed in anxiety (low state anxiety group, $P < .0034$; high state anxiety group, $P < .0108$), as well as in salivary cortisol concentration ($P < .0004$).

CONCLUSION: Physical interaction with the fetus through a 3D model may reduce maternal stress. (*J Soc Gynecol Invest* 2004;xx:xxx) Copyright © 2004 by the Society for Gynecologic Investigation.

KEY WORDS: Pregnancy, three-dimensional ultrasound, haptic interface, cortisol, stress.

Maternal-fetal attachment represents the earliest and most basic form of human intimacy, and has both theoretic and clinical significance. Three critical attributes related to the concept of maternal-fetal attachment exist: 1) the cognitive attachment is the desire to know the baby; 2) the affective attachment is the pleasure associated with thoughts of or interaction with the fetus; and 3) the altruistic attachment refers to a desire to protect the unborn child.¹ This relationship with the fetus increases gradually during gestation and mainly after the first perception of fetal movements.² A recent study showed also that maternal prenatal attachment during the third trimester of pregnancy is strictly associated with the postnatal maternal involvement, representing an important diagnostic tool in identifying those women for whom the mother-child interaction is suboptimal.³

A classic method for facilitating maternal-fetal interaction is medical ultrasound imaging, which is inherently tomographic, ie, it provides all of the information necessary for three-dimensional (3D) reconstruction.^{4,5} One possible way to enrich the fruition of 3D volumes and to improve the maternal impression is based on the use of haptic devices. Haptic devices (from Greek *Haptesthai*, "touch") are small robotic structures

that allow users to touch virtual objects.⁶ Haptic devices are now widely used for training purposes in the field of medical simulation.^{7,8} To delineate the feasibility and the applicability of combined ultrasound and haptic technologies, the Fetouch system was developed and its effect was tested on maternal stress, evaluated by performing a psychologic test and by measuring salivary cortisol.

MATERIALS AND METHODS

Subjects

Healthy pregnant women ($n = 12$; age range, 25 to 35 years) were enrolled between 30 and 32 weeks' gestation; all were primigravidas. All subjects gave their informed consent, and all experimental procedures were approved by the Ethical Committee of the University of Siena. Before and after the Fetouch test, patients were submitted to the State Trait Anxiety Inventory-fromY (STAI) test and collection of salivary cortisol samples (time = -15, 30, and 60 minutes) through oral plugs (Omni-SAL Saliva Collection Device, SDS International).

Fetouch Test

The Fetouch test is based on the Fetouch system, whose functional scheme is reported in Figure 1. The system is divided into two main blocks that serve different functions. The first block (US3D) is devoted to creating a 3D visual haptic model that gives a set of ultrasound scans. The second block (US3Dtouch) allows the user to interact with the system using a haptic device (Phantom⁹ or Delta¹⁰) and a 3D image (personal computer screen alone or enhanced by stereo glasses). The ultrasound system that actually

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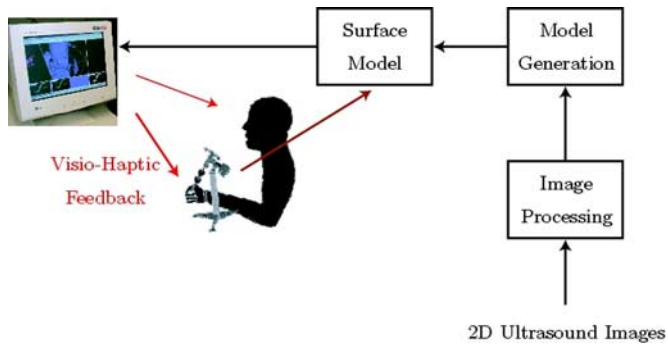


Figure 1. The visual and haptic interaction generates a closed feedback loop in the overall system.

works with the virtual reality (VR) workstation is the Sonoline Elegra Millennium Edition, by Siemens Medical Solutions, Erlangen, Germany. For a particular sequence of 2D ultrasound scans, the system generated the VR model (Figure 2). This surface model is then used for haptic and visual interaction with the user in a system layout. The US3DTouch software has been developed to allow users to interact physically with any fetal model extracted using the US3D software (Figure 2). The system is Phantom-based, but Delta devices can be easily supported.

Psychologic Test

The STAI test is a scale that evaluates feelings of apprehension, tension, nervousness, and worry, which increase in response to physical danger and psychologic stress. The Trait Anxiety scale is ideal for screening anxiety problems and for evaluating the immediate and long-term outcome of psychotherapy, counseling, behavior modification, and drug-treatment programs.¹¹ The STAI scale consists of 40 statements describing various emotional states. Twenty of these statements require the subjects to describe their emotional reactions in terms of anxiety at a particular moment or period in time, ie, state of anxiety. Another 20 items require subjects to describe how they generally feel and their general tendency to respond to a situation perceived as threatening, ie, trait anxiety.^{12,13}

Salivary Cortisol Assay

Salivary cortisol levels were determined by radioimmunoassay using a commercially available kit (Radim, Pomezia, Italy) after extraction and chromatographic partition on a C18 Sep-Pak cartridge. The sensitivity of the assay was 10 pg/mL and the intra- and interassay coefficients of variations were 3.75% and 5.8%, respectively.

Statistical Analysis

The statistical analysis was performed using paired *t* test and analysis of variance (ANOVA) for repeated measures. Statistical significance was assumed at *P* < .05.

RESULTS

STAI Test

Women were divided into two groups according to the score range: 1) a low state anxiety group (STAI scores from 23 to 29),

and 2) a high state anxiety group (STAI scores from 34 to 54). After physical interaction with the fetus through the Fetouch system, mothers experienced a reduction of stress indexes (low state anxiety group, from 25.71 ± 2.28 to 21.14 ± 1.07 [mean \pm SD], *P* < .0034, Figure 3, Panel A; high state anxiety group, from 44.20 ± 8.49 to 33.80 ± 7.53 , *P* < .0108, Figure 3, Panel B).

Salivary Cortisol Concentration

Cortisol levels were measured in all samples. Concentrations significantly decreased (Figure 4) from 3.28 ± 1.79 pg/mL before (time 0) to 2.06 ± 1.30 pg/mL after 30 minutes (time 1) (*P* < .0045) and to 1.47 ± 1.15 pg/mL after 60 minutes (time 2) (*P* < .0004).

DISCUSSION

The Fetouch system allowed a more profound and emotional contact of the mother with the fetus, thus decreasing her anxiety. The relevance of this result derives from the observation that maternal stress and anxiety have negative conse-

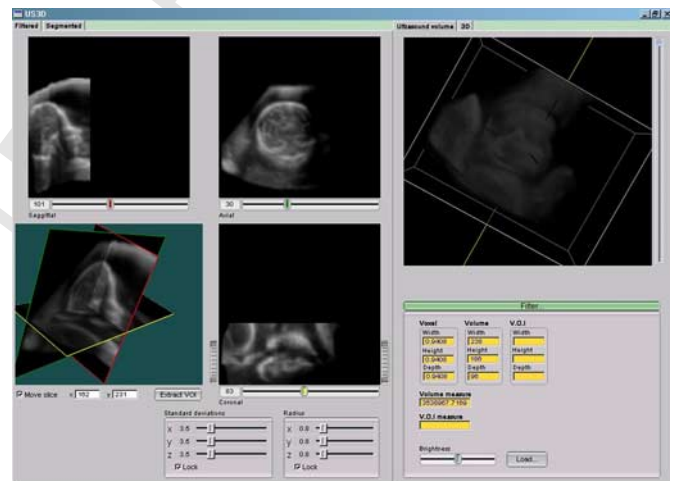


Figure 2. A) The 3D surface model of the fetus build from 2D ultrasound images and used for haptic visual interaction and the VR workstation comprising haptic and visual feedback. B) The hand moves the stylus of the Phantom desktop to touch the 3D VR model of the fetus.

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quences on the fetus. In fact, an association between maternal anxiety and fetal distress, low birth weight, prematurity, or intrauterine growth retardation has been shown (22–53%).¹⁴ High maternal anxiety affects newborn right frontal electroencephalogram activation and lowers vagal tone. Newborns of mothers with high anxiety levels spent more time in deep sleep and less time in quiet and active alert states and showed more state changes and less optimal performance on the Brazelton Neonatal Behavior Assessment Scale (motor maturity, autonomic stability, and withdrawal). Moreover, high-level mother's anxiety has been shown to determine high prenatal norepinephrine, and low maternal dopamine levels were followed by low dopamine and serotonin levels in their neonates.¹⁵

The STAI is a well-established instrument to test maternal anxiety levels during pregnancy. After the mothers experienced Fetouch and recompiled the psychologic test, their new answers showed recovered tranquility or at least lower anxiety. Women reported that their experiences with the Fetouch

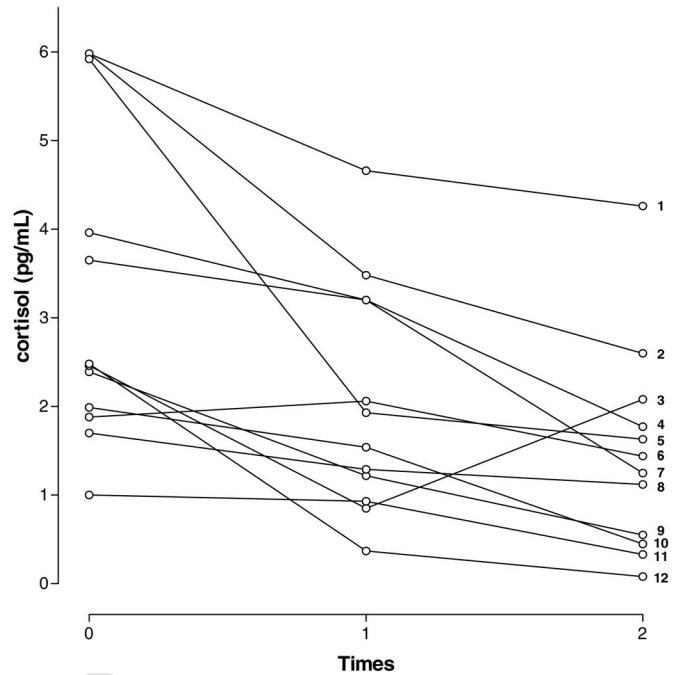


Figure 4. Changes of salivary cortisol levels in all patients after Fetouch.

system determined a positive sensation for the virtual interaction with their fetus.

The evaluation of salivary cortisol concentration reflects maternal stress levels. Salivary cortisol profiles exhibited a clear circadian rhythm during pregnancy, from the 25th to 28th week onwards, reaching concentrations in late pregnancy more than twice as high as in nonpregnant controls and rapidly returning to normal concentrations after delivery.^{16,17}

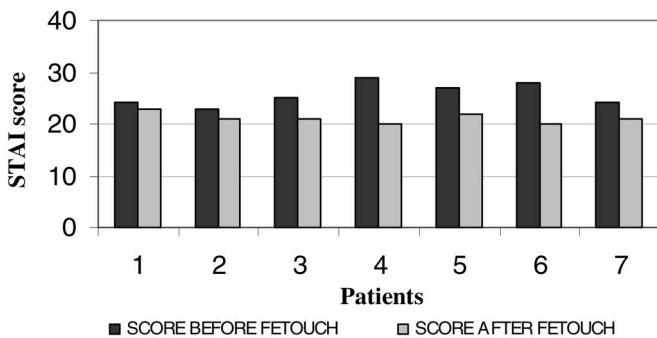
An advantage of the salivary cortisol sampling technique is that it is noninvasive and can be performed in nonstressful conditions outside of the laboratory.¹⁸ The reliable use of salivary cortisol measurement requires certain methodologic prerequisites concerning the sampling techniques (collection and storing) and the control of endogenous (individual factors, circadian variations, age, gender, hormonal status, weight) or behavioral (smoking, meals, posture) factors implied in the regulation of saliva.^{19,20}

In conclusion, the Fetouch system is an innovative tool that allows physical interaction with a 3D fetus model. Because users can only interact with the 3D model holding a stylus and the fetus model is inanimate, the system's capabilities are still limited. However, tests showed that the overall level of realism obtained using the system was satisfactory. Future work will also focus on making the overall haptic simulation more realistic, so that mothers' experiences will be more satisfying. It could decrease maternal anxiety levels to a degree significant and lasting enough to offer long-term preventive and protective care for the fetus.

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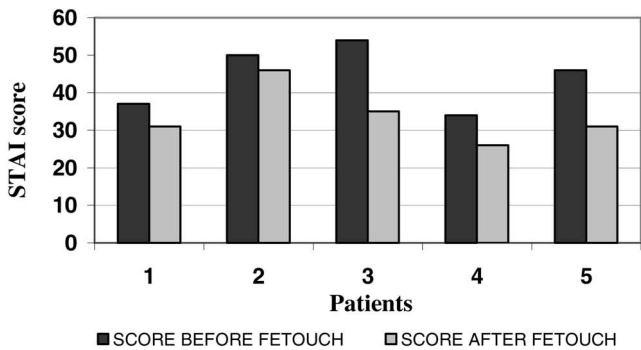


Figure 3. A) STAI scores of the low state anxiety group. B) STAI scores of the high state anxiety group. Anxiety levels are lower after Fetouch.

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