Magnetic Resonance Imaging of Children Without Sedation: Preparation With Simulation

DAVID R. ROSENBERG, M.D., JOHN A. SWEENEY, PH.D., JOSEPH S. GILLEN, B.S., JAE KIM, B.S., MICHAEL J. VARANELLI, M.D., KIRSTEN M. O'HEARN, B.F.A., PATRICIA A. ERB, R.N., B.S.N., DENISE DAVIS, B.S., R.T., AND KEITH R. THULBORN, M.D., PH.D.

ABSTRACT

Objective: It was hypothesized that a scanner simulator that replicates the magnetic resonance imaging (MRI) environment could be used to prepare pediatric subjects for successful completion of a diagnostic-quality MRI examination without pharmacological sedation. **Method:** Sixteen healthy children, 6 to 17 years of age, were matched for age and sex with 16 psychotropic medication–naive children with obsessive-compulsive disorder. Distress was measured throughout simulation and scanning procedures using heart rate and a self-report distress scale. Ten healthy children, 6 to 17 years of age, also underwent the same actual MRI scanning procedure but did not undergo the simulation scanning procedure. **Results:** Significant decreases in heart rate and self-reported distress level were observed in all subjects during the simulator session that were maintained to the end of the actual scanner experience. All subjects successfully completed MRI examinations *without chemical restraint.* Subjects who were not trained in the simulator had higher heart rates and self-reported distress levels in the actual scanner than did simulation-trained subjects. **Conclusions:** Simulation without pharmacological sedation successfully prepared pediatric subjects in this pilot study for high-quality MRI studies. Subject preparation may be an alternative procedure to sedation for routine MRI examination in healthy and anxious children 6 years of age and older. *J. Am. Acad. Child Adolesc. Psychiatry,* 1997, 36(6):853–859.

Key Words: magnetic resonance imaging, pediatric, pharmacological sedation.

Neuroimaging is used to explore brain development through morphometric changes (Keller, 1990; Ross et al., 1989) and potentially through functional changes (Kwong et al., 1992). Compared with other neuroimaging procedures, magnetic resonance imaging (MRI) has superior temporal and spatial resolution without ionizing radiation exposure. This is of particular relevance to longitudinal studies in pediatric populations. The experiences of MR physicians, technologists, and nursing staff suggest that high-quality MRI examinations of pediatric subjects require more preparation than do those with adults. A variety of explanations have been proposed including anxiety, fear, curiosity, and the lack of understanding of instructions (Greenberg et al., 1993, 1994). The strange equipment, noises, new faces, and demands can be overwhelming for a child unless suitable preparation is provided. Sedation often is used to improve compliance. Pharmacological sedation in children can, however, produce problematic side effects (Greenberg et al., 1993, 1994). Fitz (1989) found a high rate of routine pharmacological sedation in 1,600 pediatric subjects requiring clinical MRI procedures. Fifty percent of 6-year-olds, more than 30% of 7- and 8-year-olds, and 10% of 9- to 12-year-olds required sedation for clinical MRI procedures. A higher rate might be expected in pediatric psychiatric subjects, particularly those suffering from anxiety. Although sedation has an excellent track record of safety in pediatric subjects, the drugs used for sedation are very powerful CNS agents that can have problematic side effects. Common agents include chloral hydrate, thiopental, meperidine (Demerolr), fentanyl, midazolam (Versedr), as well as cocktails, i.e.,

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Drs. Rosenberg, Sweeney, Varanelli, Thulborn, and Ms. O'Hearn are with the Department of Psychiatry and Mr. Gillen and Mr. Kim, Ms. Erb and Ms. Davis, and Dr. Thulborn are with the Department of Radiology, University of Pittsburgh Medical Center.

Reprint requests to Dr. Rosenberg, Western Psychiatric Institute and Clinic, University of Pittsburgh Medical Center, 3811 O'Hara Street, Pittsburgh, PA 15213; telephone: (412) 624-8428; fax: (412) 383-9748; e-mail: Rosenbergdr@a1.isd.upmc.edu

DPT (Demerolr, Phenerganr, Thoraziner) and AMPS (atropine, meperidine, promethazine, secobarbital). Drugs may also interfere with cognitive function and alter brain physiology. Such preparation requires time for familiarization and establishment of rapport. For efficient utilization of expensive equipment and personnel, preparation should not be performed in the actual scanner.

In our experience, pediatric patients with anxiety disorders present an extreme of anxiety and distress, but normal pediatric subjects also demonstrate intense curiosity. We have found that most children are curious about how the table moves in and out, why the magnet makes noises, what the head coil feels like, and what is inside the magnet. Common requests of our staff have been to "inspect" the magnet by looking into both ends, watch the table move, put the head coil into place, look out of the mirror, and be put in and out of the bore multiple times. We have found that when a child's curiosity and anxiety are not attended to adequately, the child may not hold still during the study or may refuse to participate in the study, resulting in loss of scanner time or poor image quality.

We hypothesized that the use of an MR simulator would allow the child to experience all of the sensations associated with the MRI study in a nonthreatening, unhurried environment, thereby increasing compliance and decreasing the scanner time required to achieve high-quality images without sedation. This hypothesis is not new. Behavioral approaches for preparing children for surgery and medical procedures have been utilized to reduce anticipatory anxiety (Melamed et al., 1982). Children and adults have been treated successfully by exposing them either in imagination or in real life to medical events and concerns. Fear of injections (Taylor et al., 1977), dental treatment (Gale and Ayer, 1969; Sawtell et al., 1974), and intravenous procedures (Katz, 1974; Nimmer and Kapp, 1974) have been treated by desensitization. This educational process is particularly critical for younger psychiatric patients as they may have a higher risk of anxiety and emotional distress during medical procedures unless carefully desensitized. We report on a procedure to prepare healthy and psychiatrically ill pediatric subjects for MRI studies.

METHOD

Subjects

Sixteen healthy subjects (mean age: 12.2 ± 3.8 years) matched for age and sex with 16 psychotropic medication–naive outpatients (eight male, seven female; mean age 12.1 ± 3.5, range: 6 to 17 years) with obsessive-compulsive disorder (OCD) underwent a simulation scanning procedure (described below) before entering the actual MR scanner. All subjects were assessed with a semistructured diagnostic interview, the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present Episode and Epidemiologic versions (Chambers et al., 1985; Orvaschel et al., 1982), with both parent(s) and child as informants. A board-certified pediatric psychiatrist also interviewed the child, confirmed the presence of *DSM-III-R* (American Psychiatric Association, 1987) criteria for OCD with the child and parents, and reviewed all other diagnostic information for each case. Case-control pairs were matched within 1 year of age. All legal guardians gave informed, written, institutional review board (IRB)-approved consent, and all subjects gave written, IRB-approved assent. Clinical inclusion criteria for patients and controls included having no lifetime history of psychosis, bipolar mood disorder, anorexia or bulimia nervosa, substance abuse, neurological disorders including seizures, head injury with sustained loss of consciousness, Tourette's disorder, Huntington's disease, dyskinesia, chronic debilitating medical illness, pervasive developmental disorder, mental retardation, borderline intellectual functioning, or learning disabilities. Eight of the 16 OCD patients had comorbid anxiety disorders (e.g., overanxious disorder), 1 had attention-deficit hyperactivity disorder, 3 had oppositional defiant disorder, and 2 had dysthymia. Only three subjects had OCD as a sole diagnosis. All patients and controls also met standard MRI inclusion criteria, including (1) ambulation, (2) good physical health, (3) ability of legal guardians to give informed consent and ability of subjects to give assent and follow instructions, (4) no cardiac pacemaker, (5) no previous head surgery including aneurysm clip placement and cochlear implant, (6) no risk of metallic foreign body in eyes, (7) weight of less than 250 lb, (8) no head injury with sustained loss of consciousness, (9) no neurological abnormalities, (10) no history of substance dependence or abuse, (11) no mental retardation or autism, and (12) no reported nicotine or caffeine use within 3 hours of participating in the study. In addition, to determine the true efficacy of the simulation scanning procedure, 10 healthy pediatric subjects (mean age: 13.9 ± 3.8 years) assessed with the same clinical measures served as a control group and did not receive any preparation prior to being placed in the actual scanner for their MRI studies. All studies were performed for research purposes.

Clinical Measures

Severity of OCD symptoms was measured by the child version of the Yale-Brown Obsessive Compulsive Scale-revised edition (Riddle et al., 1992; Wolff and Wolff, 1991) (median total score = 21, range = 12 to 30), and severity of anxiety was measured by the Hamilton Anxiety Rating Scale (Hamilton, 1959) (median total score = 14, range = 0 to 36).

Neuropsychological Screening

A screening neuropsychological examination was performed to confirm normal intelligence (Ammons and Ammons, 1962), motor coordination (Knights and Norwood, 1980), and attention (Wechsler, 1991) in all subjects. Controls and OCD patients performed comparably well on these measures, and no significant differences between groups were observed on any measure.

Preparation of Child

Before their arrival at the MR Research Center for the MRI study, children and their parents were educated about the scanning procedure. In the physician's office (D.R.R.), the child and his or her parents were told step by step what the procedure would entail. Parents and their children were reassured that they could ask to terminate the study at any time and that this would be done immediately. Children and their parents were informed about the safety of the procedure and were told explicitly that the study involved no needles, which frequently is a major cause of distress in children. The child and his or her parents were allowed to ask as many questions as they wished about the procedure. Five parents and their children, out of 42 subjects, accepted the opportunity to tour the MR Research Center before their scan to begin implementing the desensitization process before the day of the scheduled MRI procedure.

Simulation Scanner

Before entering the actual scanner, the 16 OCD patients and their age- and sex-matched controls were trained in our simulated scanner, which mimics the actual scanning environment (Fig. 1). The simulator was built in-house using a genuine scanner patient tube, 55 cm in diameter, thereby providing the same subject access. Subject positioning was performed by a manually operated table that moved in and out of the patient tube. Sounds taped during an actual MRI protocol from the scanner were replicated in an unattenuated but abbreviated form with a high-fidelity audio system for 20 of the subjects (10 OCD patients and 10 healthy controls). An additional 12 subjects (6 OCD patients and 6 healthy controls) received the same procedure without the sound component to determine whether reassurance and desensitization to a confined space were sufficient to reduce distress and maximize the subject's ability to cooperate with the procedure. Seven subjects (five OCD patients and two controls) requested the presence of their parent and the clinician of their choice to be present during both the simulation procedure and actual MR scanner.

A nurse (P.A.E.) experienced in pediatric care led the subject through the simulator experience and the MR procedure. First, the child was shown the rooms for the simulated scanner and for the actual scanner. Upon initiation of the simulation procedure before the subject went into the scanner, subjects were monitored for distress both by physiological measurement of pulse rate, blood pressure (for ages 12 and older), and percutaneous oxygen saturation and by self-report as measured by the Subjective Units of Discomfort Scale (SUDS) (Wolpe, 1988), a scale that uses 0 to 100 units, with 0 being no distress and 100 being crippling distress with both physiological and psychological distress. This instrument has been used extensively in behavioral therapy research of anxiety disorders and has been found to be sensitive to measuring a patient's current level of distress. One subject, whose obsessions frequently made him noncommunicative, refused to communicate his level of distress during the simulation procedure (and afterward). His mother was present, and he did not appear to be in distress. Nonverbal communication (subject's nodding his head in the affirmative about continuing the procedure), indicated no distress. His mother supported the decision to continue the procedure and stated that this was not unusual behavior for the patient.

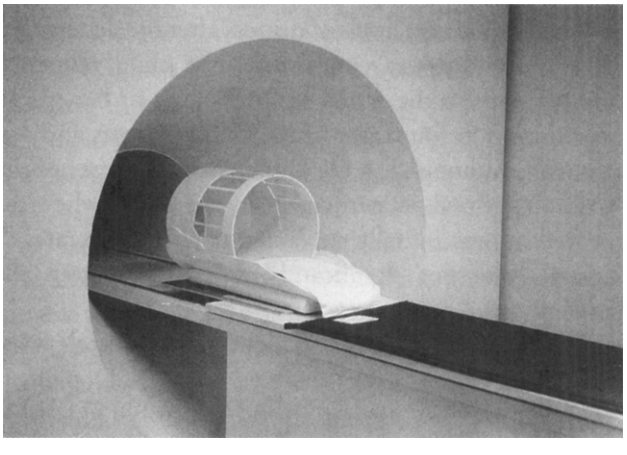

Fig. 1 Simulated scanner that mimics the actual scanning environment. The simulated radiofrequency coil is shown just outside the bore of the simulated magnet. The patient table is manually pushed into the bore.

The subjects sat on the moveable patient table positioned outside of the simulated scanner and had their subjective and objective levels of distress measured. As earplugs are used in the real scanner to reduce scanner noise levels, the subject was given earplugs. For two subjects, a parent modeled the placement of the earplugs in his or her own ears for the child. The children repeated this procedure on themselves. After insertion of the earplugs, the child was asked to lie down on the patient table and again anxiety was measured. The head radiofrequency coil was then moved over the subject's head. The subject was allowed to adjust to this sensation (approximately 2 minutes) while still outside the scanner bore. Distress was measured during this period. The nurse made a game of this by telling the subject that he or she would be wearing a kind of space helmet like astronauts wear. When comfortable having his or her head in the head coil, the child was informed that the table would be moving him or her slowly closer and closer to "go into the tunnel." This involved two "checkpoints," after which the subject was asked to rate his or her level of distress while having pulse, blood pressure (for ages 12 and older), and percutaneous oxygen saturation monitored. For a child with high distress, he or she was instructed to close his or her eyes and keep them closed until the table stopped moving and his or her head was in the bore of the magnet. The child was also informed that the head coil was designed with a mirror that would enable him or her to see out of the bore of the simulated magnet. Once inside, the child was instructed to slowly open his or her eyes while monitoring his or her level of distress. For 20 of the 32 subjects, after the child had adjusted successfully to being in the bore, the rhythmic sounds from the MR procedure were played over a high-fidelity audio system, while the remaining 12 were taken to the actual scanner after completing the first component of the simulation. The sounds of each sequence of the MRI procedure, including conventional and echo-planar imaging, were played for the 20 subjects with close monitoring of subjective and objective levels of distress. The entire training session lasted from 15 to 30 minutes.

The objective was to gradually introduce subjects to the potentially overwhelming scanner environment so that they could "master" each stage with increasing confidence after each success and become familiar with the scanning environment. Once the child was familiar with the environment, the importance of keeping the head stationary was emphasized. We found that encouraging the child to try to stay "as still as a statue" was effective in obtaining his or her cooperation.

For subjects younger than 12 years of age (n = 12), an additional behavioral program was implemented in which the child received reinforcement rewards such as stickers and treats at the end of the simulation trial. We also gave these children stickers and treats just for coming in to try the procedure and emphasized that they were already "stars" for coming in and helping us make the procedure more comfortable for persons requiring MRI scans.

Actual MRI Procedures

Imaging was performed at the MR Research Center of the University of Pittsburgh Medical Center immediately after the simulation training session (a bathroom break was offered to all subjects) on a 1.5-Tesla Signa System (General Electric Medical Systems, Milwaukee, WI) equipped with echo-planar capabilities (Advanced NMR Systems, Inc., Wilmington, MA). Subjects were provided with earplugs to reduce noise. The head was positioned comfortably in the commercial quadrature radiofrequency head coil (General Electric Medical Systems) with foam cushioning to maintain head stability. The audio link was used for subjective monitoring of anxiety. As during the simulation procedure, the need to remain as still as possible during imaging was reiterated. The time in the actual scanner was made as comfortable as possible by adjustment of air flow through the magnet and by the use of the standard mirror system of the head coil for visualization of the outside of the scanner.

MRI Protocol

The brain was located by scout sagittal spin echo images (TR = 400 msec/TE = 18 msec, number of averages = 1, matrix = 256 × 192, 5 mm thick, 1 mm gap, acquisition time = 2:47 minutes) from which the axial images were graphically prescribed. Multislice images covering the entire brain were then obtained using an axial fast spin echo pulse sequence (TR = 2,500 msec/effective TE = 102 msec, number of averages = 1, matrix = 256 × 192, 5 mm thick, 1 mm gap, expiratory threshold load = 8, acquisition time = 2:20 minutes, FOV = 40 × 20 cm). A high-resolution three-dimensional gradient echo data set was then acquired in the coronal plane (TR = 25, TE = 5 msec, nutation angle = 40°, matrix = 256 × 192, 1.5 mm thickness, no gap, acquisition time = 7:44 minutes). Coronal echo-planar gradient echo images (TR = 3 sec/TE = 50 msec, matrix = 128 × 64, 5 mm thickness, 1 mm gap) were also obtained.

Signal-to-Noise Ratio Analysis

We also compared signal-to-noise ratio (SNR) measurements in subjects who were trained in the simulation scanner versus 10 controls who were not trained in the simulator to determine whether subjects trained in the simulation scanner would have higher-quality MRI studies with higher SNRs than subjects not trained in the simulator. To calculate SNR, a 6 x 6 pixel (0.56 cm x 0.56 cm x 0.15 cm) area was selected in the gray matter just above the left lateral ventricle in the first anterior slice in which this structure was clearly visible. The mean and standard deviation of the signal in this area were calculated. An area the same size was then selected outside the brain, to the left of the head. This area had the same y coordinates as the area within the brain. The mean and standard deviation were then calculated for this area. SNR was then calculated by dividing the mean of the selected gray matter by the standard deviation of the area selected outside the brain.

Data Analysis

The primary data analyses involved use of two-way (time by subject group) analyses of variance. Two-tailed significance tests comparing subjects who experienced the sound component of the simulation procedure versus those who did not were also performed. Paired t tests were used to compare heart rate and self-reported distress in case-matched OCD–control pairs. Two-tailed, unpaired t tests were performed to compare SNR measurements in subjects who were trained in the simulator versus those who were not trained in the simulator. Finally, correlations between subjective and objective anxiety measures and age and sex were performed.

RESULTS

All 32 subjects who underwent the simulation scanning experience (with or without the sound component) completed the actual MRI procedure. As no significant difference in desensitization to the MR procedure was observed in subjects who experienced the sound component versus those who did not as measured by both heart rate ($F[1,30] = 0.34$, $p > .10$) and subjective distress ($F[1,29] = 0.99$, $p > .10$), we pooled their data to enhance our power in determining the efficacy of the simulation procedure with and without the sound component. A significant decrease in heart rate ($F[3,93] = 11.54$, $p < .001$) and subjective distress ($F[3,90] = 5.03$, $p < .01$) was observed in all (n = 32) pediatric subjects from the start of the simulator experience to the end of the training session after the subjects had been habituated to the environment. At the end of the training session in the simulator, subjects had essentially desensitized to a state that was maintained throughout the remainder of the actual scanning session. Some subjects, however, still had significant levels of distress after the desensitization procedure was completed. The child requested the presence in the actual scanner of his or her parent or clinician in four cases (three OCD patients and one control). Although five OCD patients and three healthy controls refused to participate in the study when the procedure was initially explained to them, the rates of refusal were not significantly different between the two groups.

When pediatric OCD patients and controls were compared (Fig. 2), we observed that OCD patients ($F[3,42] = 3.32$, $p < .05$) and controls ($F[3,45] = 4.56$, $p < .01$) exhibited a significant decrease in subjective distress by the end of the simulator experience. This reduction was then maintained during the

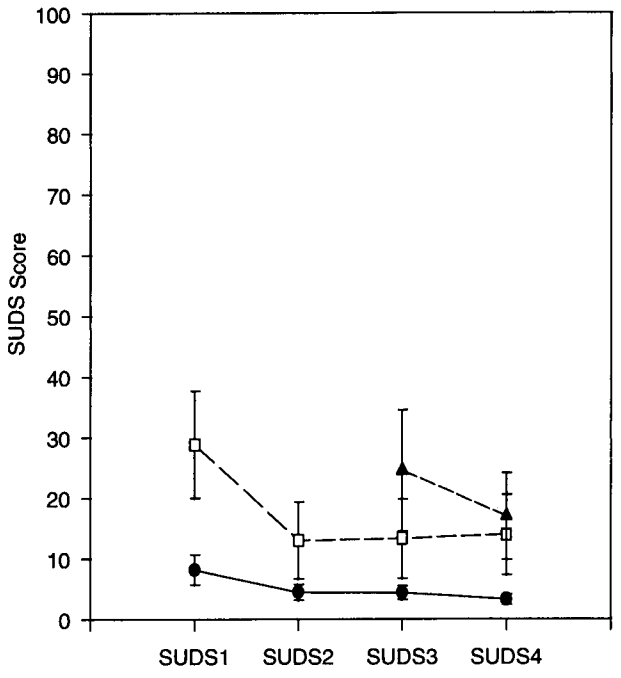

Fig. 2 Subjective distress ratings in 16 patients with obsessive-compulsive disorder (□) and 16 controls who were trained in the simulation scanner (●) versus 9 controls who were not trained in the simulation scanner (▲). SUDS = Subjective Units of Discomfort Scale; SUDS1 = distress rating at beginning of simulator; SUDS2 = distress rating at end of simulator; SUDS3 = distress rating at beginning of actual scanner; SUDS4 = distress rating at end of actual scanner. Error bars indicate standard error of the mean.

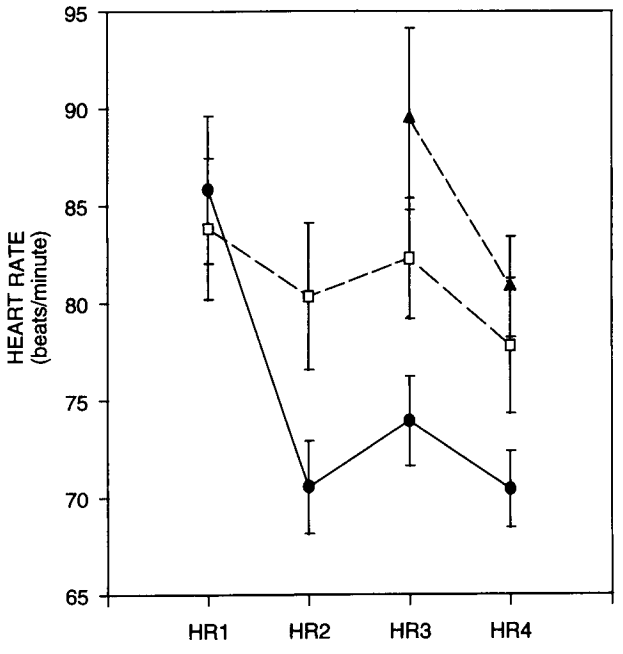

Fig. 3 Heart rate measures in 16 patients with obsessive-compulsive disorder (□) and 16 controls who were trained in the simulation scanner (●) versus 9 controls who were not trained in the simulation scanner (▲). HR1 = heart rate at beginning of simulator; HR2 = heart rate at end of simulator; HR3 = heart rate at beginning of actual scanner; HR4 = heart rate at end of actual scanner. Error bars indicate standard error of the mean.

actual scanning experience. The decrease in self-reported distress was more marked in the OCD patients than in the controls. However, OCD patients did have significantly greater levels of self-reported distress at the beginning of the simulation experience than did controls ($t[14] = 2.22$, $p < .05$) (Fig. 2). Controls ($F[3,45] = 13.89$, $p < .001$) but not OCD patients ($F[3,45] = 2.01$, $p > .10$) also experienced a significant decrease in heart rate from the beginning to the end of the simulation procedure (Fig. 3). In addition, when we looked at specific individuals, the most striking desensitizations were observed in specific OCD cases. For example, one 11-year-old subject with a severe overanxious disorder and OCD had previously been unable to complete a routine clinical MRI study ordered by her physician to rule out an organic cause of her psychiatric symptoms. Her initial SUDS rating was 100, and her heart rate was greater than 120 beats per minute. After simulation, she completed the MRI study without difficulty with a SUDS rating of 0 and a heart rate of 78. There were no significant correlations between age or sex and any physiological or subjective measurement of distress in the entire group or when OCD and control subjects were considered separately.

One (10%) of the 10 subjects who were not trained in the simulation scanner suffered a severe claustrophobic reaction to being placed in the actual scanner and was unable to complete the study. The control subjects who completed the actual scanning procedure but did not undergo the simulation scanning procedure had significantly higher initial heart rates ($t[39] = 2.22$, $p < .05$) and self-reported distress ($t[38] = 2.25$, $p < .05$) and a trend for higher heart rates at the end of the actual scanning procedure ($t[39] = 2.03$, $p < .06$) (Fig. 3). Although subjects who were trained in the simulator appeared to have lower self-reported distress ratings at the end of the actual scanning procedure than subjects who had not been trained in the simulation scanner, this difference was not significant at $p < .05$ (Fig. 2).

It should be noted that the controls who were not trained in the simulator did have significant decreases in heart rate and subjective distress levels (Figs. 2 and 3) from the beginning to the end of the actual scanning

experience. However, these measures were higher than those observed in subjects who were trained in the simulator, and measures in these subjects at the end of the actual scanning procedure were comparable with those observed in simulator-trained subjects at the end of the simulation procedure (Figs. 2 and 3). Although subjects who were not trained in the simulation scanner (mean ± SD = 116.06 ± 46.37) appeared to have lower SNRs than subjects who were trained in the simulator (mean ± SD = 152.74 ± 36.48), this difference was not statistically significant, perhaps reflecting the small sample size of subjects who were not trained in the simulator.

DISCUSSION

Our data indicate that simulation of the scanner environment for subjects in the pediatric age range can result in an amelioration of anxiety and successful completion of the actual MRI examination without sedation. Specifically, children with OCD and healthy controls as young as 6 years of age successfully completed the MRI studies. All children benefited from decreased distress, although psychiatrically ill patients appeared to benefit to a greater extent than did controls. It is interesting that no obvious benefit of the sound component of the simulation procedure was evident. Specifically, both desensitization procedures were equally effective in decreasing heart rate and subjective distress, resulting in better subject cooperation.

Healthy comparison subjects who were not trained in the simulation scanner had baseline anxiety scores comparable with baseline scores observed in OCD patients and significantly higher anxiety ratings than healthy controls who were trained in the simulator. The disparity between baseline anxiety scores in the two control groups might be due to children and their families feeling more reassured by knowing they would have a practice session to get used to the MRI procedure. Both parents and their children often experienced substantial reduction in their concerns about the MRI procedure when the utilization of the simulator was mentioned. In fact, for some subjects and their families, just knowing about the availability of the simulator proved decisive in their participation in the study. It is also possible that OCD patients may have had even higher baseline anxiety levels had they not been made aware of the availability of the simulator. An OCD control group not trained in the simulator was not assessed in this study. Further study of larger samples of controls and psychiatrically ill children who are trained in the simulation scanner versus those who are not are critical to determining the ultimate role of simulation scanners in pediatric populations.

It should be noted that construction and use of a simulation scanner is not a convenient or inexpensive undertaking, Our simulation scanner cost approximately $10,000 to build and occupies a 9 × 12-foot room. The expense may in part be balanced if the simulator's use results in more efficient use of expensive actual scanner time and if pharmacological sedation is made unnecessary.

Our results suggest that pharmacological sedation can be avoided for research MRI examinations in children. Simulation with subjects in the pediatric age range may increase the likelihood of obtaining a diagnostically useful MRI scan in a time-efficient manner. This may become especially critical for functional MRI studies in which drugs may affect performance of neurobehavioral paradigms.

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