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White matter integrity in kleptomania: A pilot study

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Abstract

This study's goal was to examine microstructural organization of frontal white matter in kleptomania. Ten females with DSM-IV kleptomania and 10 female controls underwent diffusion tensor imaging. Inferior frontal white matter was the a priori region of interest. Trace and fractional anisotropy (FA) were also calculated for frontal and posterior cortical regions in both subject groups. Kleptomania subjects had significantly higher mean frontal Trace, and significantly lower mean frontal FA than control subjects. Group differences remained significant when right and left frontal Trace and FA were analyzed. Groups did not differ significantly in posterior Trace or FA. Kleptomania may be associated with decreased white matter microstructural integrity in inferior frontal brain regions.

Keywords

Impulse control disorders; Imaging; White matter

1. Introduction

Kleptomania is characterized by the impulse to steal objects not needed for personal use or their monetary value and the inability to control that impulse (McElroy et al., 1991). Although there have been no brain-imaging studies of kleptomania, the literature suggests that damage to orbitofrontal–subcortical circuits may result in kleptomania (Nyffeler and Regard, 2001). Diffusion tensor imaging (DTI) is an MRI technique that measures the self-diffusion of water in brain tissue. DTI data can be visualized in a variety of ways such as image maps of scalar parameters including Trace, a measure of the magnitude of water diffusion in each image fractional; and fractional anisotropy (FA), a measure of the extent to which water diffusion in each voxel is directionally restricted. Typically, in damaged white matter, Trace values are higher and FA values lower than in normal white matter presumably owing to axonal degeneration (Beaulieu et al., 1996). Studies of white matter microstructure in impulsive schizophrenia patients using DTI showed that lower FA (i.e., axonal disorganization) in the right inferior frontal area was associated with greater impulsivity (Hoptman et al., 2002, 2004). Because frontal brain circuits, particularly the orbitofrontal circuit, are important in behavioral regulation (Mega and Cummings, 1994), we hypothesized that kleptomania subjects would show compromised white matter integrity (i.e., increased Trace and decreased FA) in inferior frontal regions compared with a healthy comparison group.

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2. Materials and methods

2.1. Subjects

Ten female subjects (mean age=34.9±18.0; range 18–60; all right-handed) with DSM-IV kleptomania were recruited from an outpatient clinic. The diagnosis was confirmed by the Structured Clinical Interview for Kleptomania, a valid and reliable instrument (Grant et al., in press). Inclusion criteria were 1) kleptomania as the primary Axis I disorder; 2) shoplifting at least one time per week; and 3) urges to steal at least one time per week. The sample was limited to females as early evidence suggests that the majority of individuals suffering from kleptomania are female (Grant, 2005), and there is some suggestion that males with kleptomania may be a more heterogeneous sample (Grant, 2005). Ten healthy, nonpsychiatric female subjects (mean age=32.8±9.5; range 21–49; all right-handed) matched to the kleptomania group on key demographic variables were recruited from the community.

Exclusion criteria for all subjects included: 1) current DSM-IV Axis I disorder based on the Structured Clinical Interview for DSM-IV (SCID) (First et al., 1995); 2) lifetime history of bipolar I or II, psychotic, or obsessive-compulsive disorders based on the SCID, attention deficit hyperactivity disorder based on clinical interview, personality disorder based on the Structured Clinical Interview for DSM-IV Personality Disorders (First et al., 1997), or history of another DSM-IV impulse control disorder not elsewhere classified based on SCID-compatible modules; 3) history of head injury or neurological disorder; 4) psychotropic medication use during the 3 months prior to imaging; and 5) positive urine pregnancy test.

Butler Hospital's Institutional Review Board approved the study and the informed consent. After complete description of the study, subjects provided written informed consent.

2.2. Procedures

MRI scans were obtained on a 1.5-T Siemens Symphony scanner using a volume head coil. A standard localizer was obtained followed by a 3D T1 MPRAGE (one acquisition, sagittal) as follows: 0.85-mm slices, no gap, 176 slices, 256×256 matrix, 21.7×21.7 cm FOV, TR=1900, TE=4.31 ms, TI=1100, NEX=1, and flip angle=15; acquisition time=8.08 min. Co-registered sagittal double spin-echo, echo-planar diffusion-weighted images were collected based on Siemens' MDDW protocol as follows: 3 acquisitions with offset in slice direction by 0.0, 1.7 and 3.4, 5-mm thick slices, 0.1-mm inter-slice spacing, 30 slices per acquisition, 128×128 matrix, 21.7×21.7 cm FOV (interleaving during postprocessing provides true 1.7-mm³ resolution images), TR=7200, TE=156. Bipolar diffusion gradients were applied in 12 non-collinear diffusion directions with 2 b magnitudes: 0, 1000 mm/s², NEX=3. A double-echo sequence was used that effectively cancels the effects of eddy currents (Reese et al., 2003). There were no partial echoes. The entire brain was imaged. Time per acquisition=4:48 min. We used a vacu-pillow and head cushions to minimize subject movement during scanning.

All three offset diffusion scans were up-sampled to 0.85-mm³ isotropic voxels for analysis. Scalar maps of Trace and FA were produced using custom software (Basser et al., 1994). An additional T2-weighted image (I0) without diffusion encoding (*b*=0) inherently co-registered with the Trace and FA images was also produced.

2.3. Data analysis

Experienced raters (SC and TBK), blind to group assignment, analyzed images using Analyze AVW software (v. 5.0 and 6.0) (Robb and Hanson, 1990). The MPRAGE images were manually corrected for head rotation and re-sliced along the AC-PC line. The transform matrix was applied to the DTI FA map volumes with manual adjustment, and then this new adjusted matrix was applied strictly to the remaining DTI maps (Trace and *b*=0). Four standard sized

square (5×5 mm voxel) regions of interest (ROIs) were placed bilaterally in anterior and posterior white matter on each of four axial slices based on a previously published method (Lim et al., 1999) for a total of 16 regions per subject (Fig. 1). The most inferior slice was identified in the sagittal view and was located at the inferior border of the rostrum of the corpus callosum. The remaining three slices were those falling three, six, and nine slices superior to the first. A pre-specified coordinate-based algorithm was designed to guide ROI placement such that anterior ROIs would be placed anterior and slightly lateral to the anterior horns of the lateral ventricles on the three superior slices and anterior and medial to the Sylvian fissure on the most inferior slice, and posterior ROIs would be placed lateral to the posterior horns of the lateral ventricles. Adjustments in final ROI placement were made to accommodate individual differences in brain anatomy. All ROIs were placed on the $b=0$ image without reference to the Trace and FA images and transferred without further adjustment to the inherently co-registered Trace and FA images for measurement.

Across the 16 regions, inter-rater reliability, measured as the intraclass correlation coefficient (ICC) between two raters, ranged from 0.69 to 0.97 for Trace with only two regions falling below 0.80; and from 0.51 to 0.92 for FA with only two regions falling below 0.70. For both Trace and FA, the lowest ICC values were in posterior regions. The lower ICC values for FA likely reflect greater heterogeneity of this parameter in white matter compared with Trace (Basser and Jones, 2002; Pierpaoli et al., 1996). Given identical placement of Trace and FA ROIs for each subject, the higher ICCs for Trace likely reflect greater homogeneity of this parameter across the white matter relative to FA. The 16 regions of interest were placed by each rater on each of the 17 brain volumes, for a total of 17 measurements per ROI per rater. To optimize measurement reliability we omitted those individual FA and Trace measurements that differed more than 10% between the raters. The groups did not differ significantly in the number of individual Trace or FA measurements removed from the analysis. For FA, 33% of the measurements were omitted from the control group and 26% for the kleptomania group ($\chi^2 = 1.47$, $P = 0.25$); for Trace, 13% of the individual ROIs were removed in the control group and 10% in the kleptomania group ($\chi^2 = 0.75$, $P = 0.38$). There was no significant difference in the number of measurements removed from left vs. right hemisphere in either group. In the control group only, significantly more anterior vs. posterior individual Trace measurements were removed ($\chi^2 = 9.31$, $P = 0.002$) and there was a trend toward more anterior FA measurements being removed ($\chi^2 = 3.27$, $P = 0.07$). After removal of these individual measurements, ICC improved to 0.80 or greater for all regions for both FA and Trace. To further improve reliability, we used the mean of the two raters' values for FA and Trace for each of the 16 regions in the analysis. For the group analysis, the 16 ROIs were summed across slices so that each subject had four Trace and four FA measurements (i.e., right and left anterior and right and left posterior). Group differences were compared using Student's *t*-test and analysis of covariance (ANCOVA) using age as the covariate.

3. Results

The 10 kleptomania subjects reported a mean age of symptom onset of 18.0 ± 4.3 years (range 13–25). The mean duration of illness was 16.9 ± 10.3 years (range 4–39). Kleptomania subjects reported urges to shoplift 4.3 ± 2.6 times per week and shoplifting 1.7 ± 0.9 times per week. All subjects reported an inability to resist the urge to shoplift. Six (60.0%) subjects had histories of arrest, although no subject had been arrested within the last year.

DTI data on three control subjects could not be analyzed due to motion artifact. Accordingly, the final sample included 10 subjects with kleptomania and 7 controls. The mean $\pm$ S.D. age in the kleptomania group was 34.9 ± 11.6 years (range: 18 to 60 years) and 32.8 ± 9.5 years (range: 21 to 49 years) in the controls. This difference was not statistically significant ($t = -0.443$, $P = 0.663$). However, given that prior studies have demonstrated an association between

increasing age and decreased white matter integrity on DTI (Pfefferbaum et al., 2000), group differences in anterior and posterior Trace and FA were tested in a single ANCOVA with age as the covariate (Table 1). Right and left ROIs were combined in the analysis as right – left differences in anterior or posterior Trace or FA were not significant.

The kleptomania group had higher mean anterior Trace [$F(1, 14)=22.50, P < 0.001$] and lower mean anterior FA [$F(1, 14)=13.28, P=0.003$] than the control subjects. Effect sizes (partial η^2) were moderate (0.616 for Trace, 0.487 for FA). The groups did not differ significantly in posterior Trace ($P=0.500$) or FA ($P=0.320$). Repeating this analysis using all individual ROI measurements (mean of the two raters) had no appreciable impact on the pattern or magnitude of significant results or effect sizes demonstrating that the removal of individual ROIs to maximize measurement reliability did not bias our results. Individual data points for each group are presented (Fig. 2).

4. Discussion

These findings of compromised white matter microstructure in the inferior frontal regions using DTI are consistent with results reported previously in other impulsive behaviors (Hoptman et al., 2002) and with the hypothesis that the inferior frontal brain region is involved in impulsive behaviors that involve poor decision-making, such as stealing unnecessary items (Bechara et al., 2000). Kleptomania patients score high on tests of impulsivity (McElroy et al., 1991; Grant and Kim, 2002), and shoplifting may reflect an inability to balance the desire for immediate reward with punishment, an activity thought to involve prefrontal cortical function (Bechara et al., 2000). These DTI findings in the inferior frontal regions may therefore reflect impaired connectivity in the tracts running from the limbic region to the thalamus and to the prefrontal region.

These findings may also have clinical and forensic implications. Clinically, psychotherapies that improve decision-making (for example, cognitive behavioral therapy) and pharmacotherapies that decrease impulsivity may be recommended in patients with kleptomania (Hollander, 1998). Forensically, an understanding of whether shoplifting has a neurobiological basis may result in different recommendations to courts when repeat shoplifting is involved. For example, sentencing recommendations for individuals with kleptomania that include psychopharmacological and psychosocial treatments that possibly alter the underlying neurobiology may be more helpful in preventing recidivism than just incarceration.

This is a preliminary analysis, and the findings should be interpreted cautiously. First, although our acquisition protocols control for eddy current and susceptibility artifacts, such effects may have affected our measurements, particularly in anterior regions where such artifacts tend to be greater. However, it is unlikely that such effects would have interacted systematically with subject group to produce a bias favoring our hypothesis. Second, motion artifact, which could have affected the accuracy of our measurements, is unlikely to have produced a systematic bias between the groups. Third, although the groups did not differ significantly by age, the age range was broad, particularly in the kleptomania group. Accordingly, we controlled for age statistically in our main analysis; we recognize that this approach is not as powerful as tight matching of age during recruitment. Fourth, the sample size was small, and therefore replication in a larger sample with tight age matching is warranted. Finally, the sample was limited to kleptomania subjects who were female and without comorbidity. These findings, therefore, may not generalize to all female kleptomania subjects or to men with kleptomania.

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Fig. 1.
Anterior and posterior region of interest placement on the fractional anisotropy map.

Fig. 2.

Anterior and posterior trace and fractional anisotropy (FA) by subject (mean $\pm$ S.D.). Individual data points are ordered by age: leftmost data points represent the youngest subject in each group, and rightmost data points represent the oldest subject in each group.

White matter trace and fractional anisotropy in kleptomania subjects compared with controls (means±S.D. by group; controlled for age)

DTI measures	Kleptomania subjects (n=10)	Control subjects (n=7)	F-value ^a	P-value	Effect size ^b
<i>Anterior</i>					
Trace (mm ² s ⁻¹ ×10 ⁻³)	0.8251±0.0889	0.5781±0.1215	22.50	<0.001	0.616
Fractional anisotropy	0.4784±0.0302	0.6053±0.0988	13.28	0.003	0.487
<i>Posterior</i>					
Trace (mm ² s ⁻¹ ×10 ⁻³)	0.8231±0.0772	0.7952±0.0280	0.48	0.500	0.033
Fractional anisotropy	0.4795±0.0648	0.4577±0.0853	1.06	0.320	0.070

DTI=diffusion tensor imaging.

^a *df*=1, 14.

^b Partial eta squared.