SNR and CNR Measurements in the fBIRN Multicenter Study

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Background

Multi-center trials and studies are becoming ever more prevalent in the medical imaging field. These studies have many benefits including a more heterogeneous sample, larger samples, and the ability to acquire data in a shorter period of time. For the BIRN (Biomedical Informatics Research Network) initiative, an additional goal is to have each site contribute value added research back to the partner sites in addition to the data collected as part of the multi-center study. One major complication in these studies is the comparability of data acquired across sites. The study proposed by the First BIRN (fBIRN) consortium allows several variables to vary across site including scanner manufacturer, field strength, RF coil design, the fMR cognitive paradigm manipulandum and visual presentation system. The goal of this project is to develop the tools (both image processing and databases) required to perform multi-center studies. The challenge in the realm of image acquisition and image analysis is to equate the data acquired using various scanner hardware and field strengths and to then apply these methods to a sample of patients with schizophrenia collected across each of the sites performing a common set of fMR paradigms.

Table 1. fBIRN Sites and Hardware

Site	Manufacturer	Field/ Scanner	Coil*
Iowa	GE	1.5T - CV/I	TR quadrature head
New Mexico	Siemens	1.5T - Sonata	RO quadrature head
Minnesota	Siemens	3.0T - Trio	TR quadrature head
MGH	Siemens	3.0T - Trio	TR quadrature head
Duke/UNC	GE	4.0T – Nvi	TR quadrature head
Duke/UNC	GE	1.5T - NVi	
Brigham and Womens	GE	3.0T	GE Research Coil
UCSD	Siemens	1.5T - Symphony	RO quadrature head
UCI	Phillips/Picker	1.5T	28 cm circular volume coil with quadrature detection, birdcage type
Stanford	GE	3.0 T - CV/NVi	Elliptical quadrature
UCLA	Siemens	3.0 T - Allegro	Phased array head

*TR=transmit/receive; RO=receive only

Methods

In a pilot study five normal subjects were scanned at each of the ten centers on eleven scanners (Table 1). Separate informed consent was collected at each of the sites. These subjects were scanned twice on each scanner within a 48 hour time period. The imaging protocol acquired a three plane localizer, an oblique T2 aligned along the AC-PC line, 10 fMR studies including a sensory motor task, a resting state scan, a breath-hold task, either a Sternberg or mismatch negativity task, and an optional 3D T1 weighted volume. The parameters for the oblique AC-PC aligned T2 weighted scans were: TE=70, TR=4000, NEX=1, Echo Train length =12 (GE, Picker) and 13 (Siemens), FOV=240, Matrix=256x192. We evaluated the T2 weighted scans for signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) on six scanners across three field strengths (1.5, 3, and 4T). The SNR measurements were obtained for grey matter, while the CNR measurements were evaluated for grey matter/white matter differentiation. A manual rater on the first scan collected at the University of Iowa for each subject defined an ROI in the grey matter, white matter, CSF, and air. The ROIs were chosen such that the ROI was not placed near the border or edge of one of these tissues. The grey matter definition included samples in both the right and left caudate and putamen. The white matter included regions from the left and right frontal and posterior temporal regions. CSF was defined in the lateral ventricles and air was defined in the superior aspect of the brain avoiding motion artifacts from the eyes. The first scan obtained at the University of Iowa was then co-registered to all of the other scans obtained for this subject at all of the other sites. The ITK multi-resolution mutual information registration algorithm was used for the co-registration. The mask based representation of the defined ROIs were mapped using the resulting affine transformation used to co-register the T2 weighted scans. The co-registered masks were used to obtain measurements of the mean and standard deviation signal intensity in each of the T2 weighted scans. Separate measurements were obtained for both scanning sessions. SNR was computed as $\mathrm{Mean}_{GM}/(\mathrm{Standard\ Deviation})_{Air}$, while the CNR measurements were defined as $(\mathrm{Mean}_{GM}-\mathrm{Mean}_{WM})/(\mathrm{Standard\ Deviation})_{Air}$.

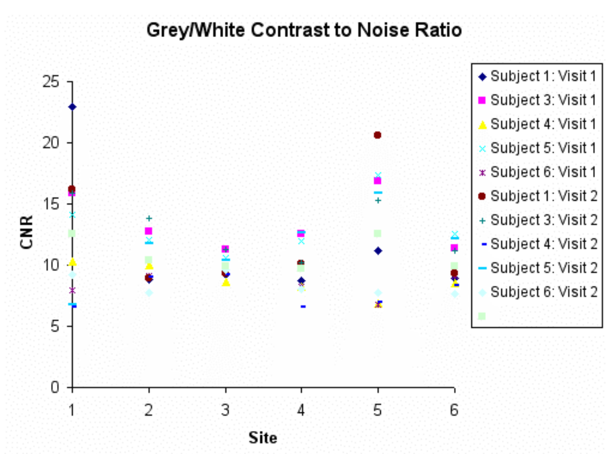

Figure 1. CNR measurements for six fBIRN sites. 1=Duke/UNC 4T, 2=New Mexico, 3=UCSD, 4=Duke/UNC 1.5T, 5=Minnesota, 6= Iowa

Results

The results for SNR were very stable across 1.5T scanners with values ranging from 41.3 to 43.3. There was an increase in the SNR at higher fields with measurements of 50.7 at 3T and 50.8 at 4T. The SNR measurements were more variable as well. An ANOVA analysis revealed that there was a site effect ($F=5.23$, $p=0.006$), no visit effect ($F=.65$, $p=.424$), a field effect (low vs high) ($F=22.67$, $p=0.001$), and no manufacturer effect($F=1.76$, $p=0.1899$) and a trend towards a manufacturer by field interaction ($F=2.86$, $p=0.0968$). CNR measurements were similar again across 1.5 T scanners ranging from 9.5 to 10.2 with an increase at higher fields (13.2 at 3T and 10.9 at 4 T). The CNR results are summarized in Figure 1.

Discussion

The measured SNR and CNR across vendors and coils were fairly constant across the same field strength. This held true even though both receive only and transmit/receive head coils were used. Higher field scanners significantly improved the SNR using the same imaging parameters. The increase in SNR and CNR at higher field strengths is a potential source of a site bias in studies acquired across field strengths. The field strength should be included as a covariate in analyses that utilize data acquired across different field strengths.