Multi-site Investigation of DTI Reproducibility

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Declaration of Conflict of Interest or Relationship

Speaker Name: Karl G. Helmer

I have no conflicts of interest to disclose with regard to the subject matter of this presentation.

Materials and Methods

Similar protocol parameters used at all five sites.
Five local subjects scanned at each site

10 scans of Jones30 diffusion-weighted directions (DWDs)
+ 5 b=0 scans = 1 Scan Time Unit (STU)

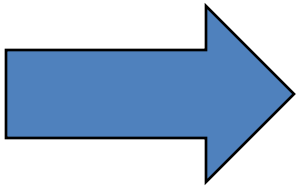
GE 3.0T

Siemens 3.0T

Siemens 3.0T

Philips 3.0T

Philips 1.5T



Central Data Processing

Materials and Methods (2)

Other Parameters:

- b = 1000 s/mm^2
- acquired matrix size: 96 x 96 (**GE and Philips 3.0T interpolated to 256 x 256**)
- full k-space coverage, FOV: 240 x 240 mm
- 25 slices with 2.5 mm^3 isotropic voxels
- parallel imaging: SENSE (p = 2) for Philips and GRAPPA for Siemens
- 1 average
- TR/TE (ms) were: Siemens = 4000/98 (MGH), 3800/98 (UCI); GE = 5200/**69.8** (Duke); Philips = 4000/101.19, (Dallas), 4000/100.00 (JHU).

Data Processing (1)

- Separate runs were concatenated:

  1, 1+2, 1+2+3, … 1+2+3+…+9+10

  creating data sets with increasing ‘SNR’.
- Each concatenated data set was registered to the first run using a 12 degree-of-freedom registration code (FSL).
- Tensors and tensor metrics were calculated using in-house code written in C.
- Skull-stripping was performed using BET (FSL) and in-house code written in IDL.

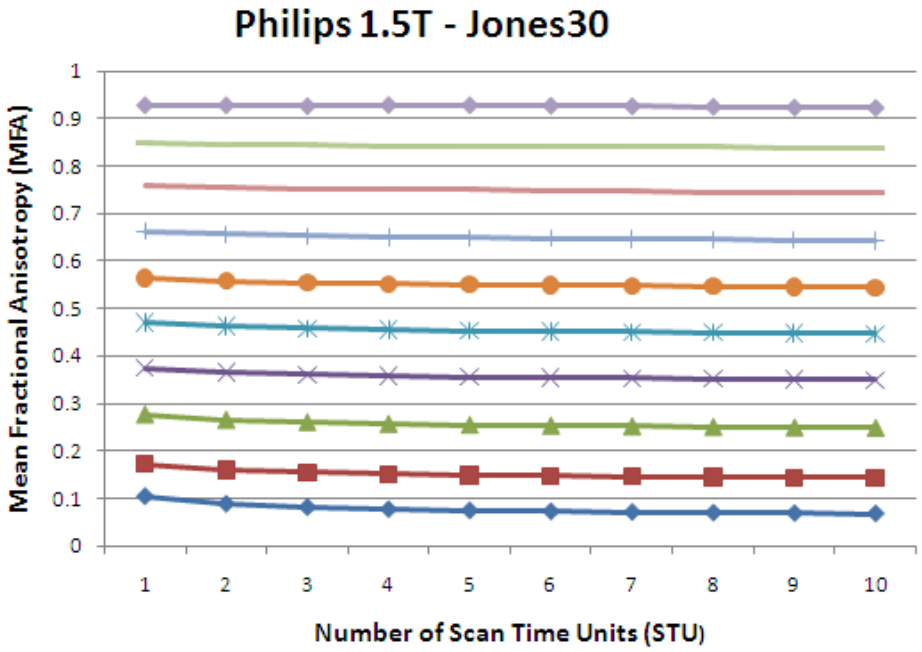
Data Processing (2)

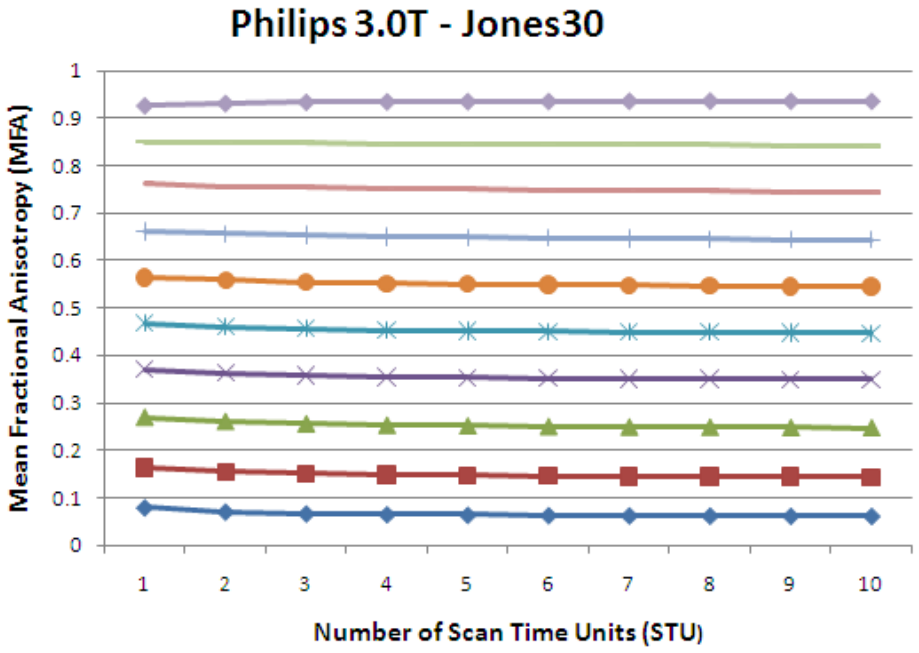
- Two types of FA analysis were performed:
    1. whole brain (bin analysis)
    2. region-of-interest
- Bins were defined in 0.1 increments
- Means of ROIs and bin members were plotted versus STU number.
- ***Analysis explores how much data is needed to accurately characterize structures of a given FA value and whether differences in vendor/site are significant.***

Data Processing (3)

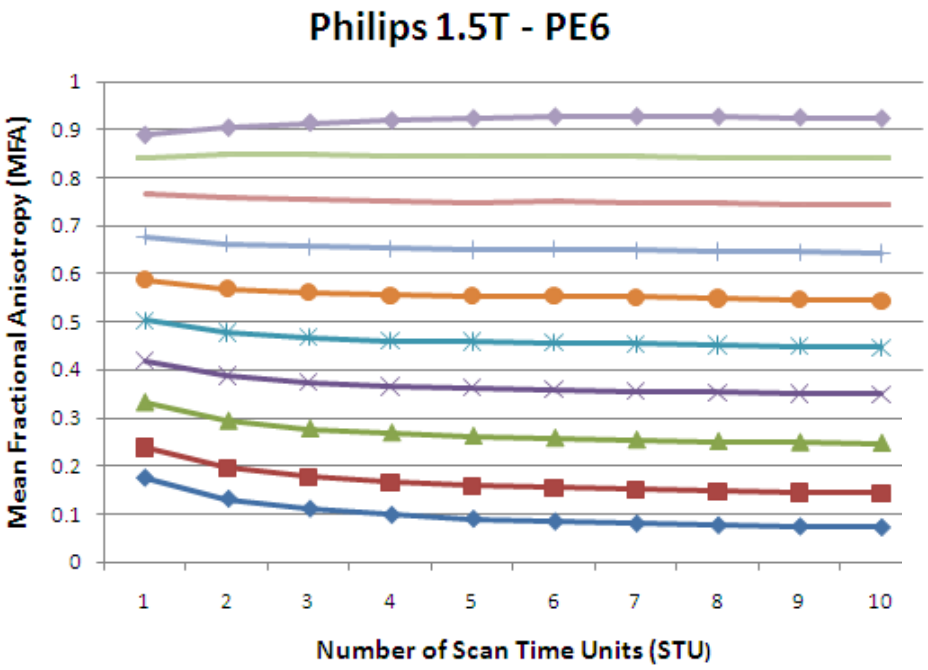
- The STU=10 data set was used as a “gold standard” and to identify the bin-range membership of each brain voxel.
- The corresponding bin means were then calculated at each STU value using those voxels identified as belonging in a given bin for the STU=10 data.
- The data sets were then sub-sampled to 6, 10, 15 (electrostatic model) direction sets and the analysis repeated.

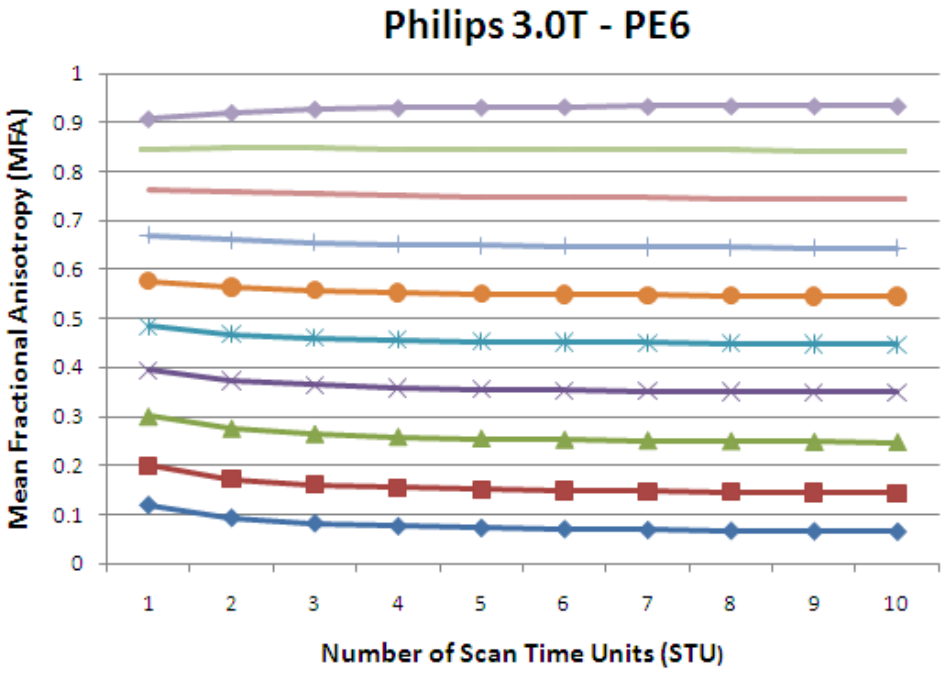
Sample Results - Jones30
Philips 1.5T vs. 3.0T





Sample Results – PE15
Philips 1.5T vs. 3.0T





Statistical Analysis (1)

- Comparisons were made between:
  - *Siemens 3.0T vs. Siemens 3.0T*
  - *Philips 3.0T vs. Philips 1.5T*
  - *GE 3.0T vs. Siemens 3.0T*
  - *GE 3.0T vs. Philips 3.0T*
  - *Siemens 3.0T vs. Philips 3.0T*

The F-statistic/p-value were calculated for each comparison at each bin/STU combination and the number of statistically significant differences was recorded.

Statistical Analysis (2)

Ex. Comparison between Philips 3.0T vs. Philips 1.5T

100 Total comparisons
F Statistic and p-values calculated from 5 subjects / site

(Colored cells denote $p < 0.05$)

Low FA, Low STU

Bin/STU	1	2	3	4	5	6	7	8	9	10
0.1	0	9.54E-07	2.26E-06	8.29E-06	3.21E-05	8.96E-05	0.000154316	0.000242651	0.000406742	0.000778317
0.2	0	3.22E-06	5.05E-05	0.000368178	0.00195944	0.00655711	0.0224515	0.0798988	0.293991	0.508273
0.3	5.36E-06	9.37E-05	9.79E-05	0.00160998	0.00243467	0.00492287	0.021911	0.146898	0.438298	0.379259
0.4	1.80E-05	0.00142992	0.0023815	0.00682247	0.00733173	0.0121752	0.00906277	0.00644761	0.0102204	0.83285
0.5	7.92E-05	0.00709277	0.0273395	0.108074	0.0237196	0.018902	0.0247695	0.0355365	0.055523	0.760126
0.6	0.00807184	0.130207	0.122224	0.355942	0.117805	0.0329333	0.0329406	0.0463014	0.0591979	0.420084
0.7	0.0527408	0.447169	0.613591	0.828653	0.793377	0.163872	0.0891116	0.0718021	0.299285	0.436027
0.8	0.572527	0.491481	0.777909	0.878502	0.867671	0.348857	0.394813	0.399482	0.411898	0.692038
0.9	0.228009	0.805941	0.88447	0.938602	0.877891	0.989134	0.923779	0.321186	0.240206	0.0631192
1	7.96E-05	0.00795323	0.00423664	0.000175297	0.00104731	0.0203058	0.035708	0.0190884	0.0208411	0.0175568

High FA, but few pixels in bin

Results - # of Significant Differences in Bin Mean vs. STU

Gradient scheme / comparison	Jones30	PE15	PE10	PE6	Mean +/- std. dev. (max=100)
Siemens 3.0T vs 3.0T	1	0	3	4	2 ± 2
Philips 3.0T vs 1.5T	19	30	34	54	34 ± 15
GE 3.0T vs Siemens 3.0T	25	29	28	24	26 ± 2
Siemens 3.0T vs Philips 3.0T	25	23	24	19	23 ± 3
GE 3.0T vs Philips 3.0T	59	63	66	64	63 ± 3

Effect of TE

- GE has minimum TE shorter than other vendors for same b-value (but longer min TR).
- Scanned one subject with same protocol, but with TE = 99.5 ms. (other sites ~100 ms)
- Determine if bin mean FA values for single subject @ TE=99.5 ms, is within the 95% confidence level for other sites.

Does GE Long TE Data Fall Within 95% Confidence Levels?

Gradient scheme / comparison	Jones30 (% yes)	PE15 (% yes)	PE10 (% yes)	PE6 (% yes)	Mean +/- std. dev. (max=100)
GE 3.0T (short TE)	43	39	47	38	42 ± 4
Philips 1.5T	32	33	32	30	32 ± 1
Siemens 3.0T (1)	73	76	75	79	76 ± 3
Siemens 3.0T (2)	70	73	60	51	64 ± 10
Philips 3.0T	51	54	49	47	50 ± 3

Effect of Zero Filling

- Two sites (GE 3.0T and Philips 3.0T) zero-filled data matrix to 256 x 256 (vendor default).
- Simulations show that this has only a slight effect at the lowest STU value.

Results Whole Brain Summary

- Within same vendor and all other parameters the same: few significant differences.
- Effect of field strength: increases the number of significant differences as the number of gradient directions decreases.
- Vendor difference and zero filling/filtering is a constant effect.
- Some vendors have more significant differences to other vendors. Baseline is significant differences in ~ 25% of bin mean/STU combinations.

ROI Analysis

- Check to see if specific structures with a range of FA values can be used to identify scanner differences.

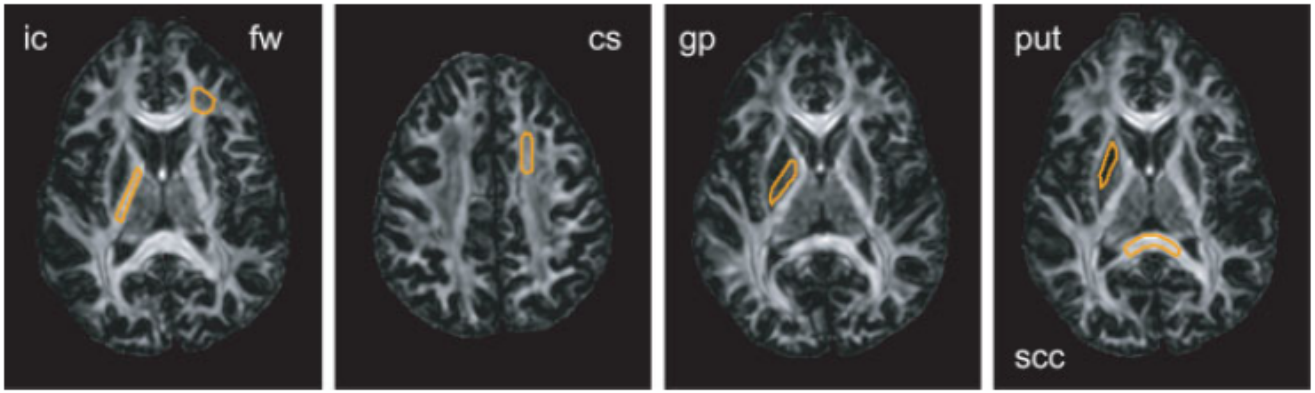
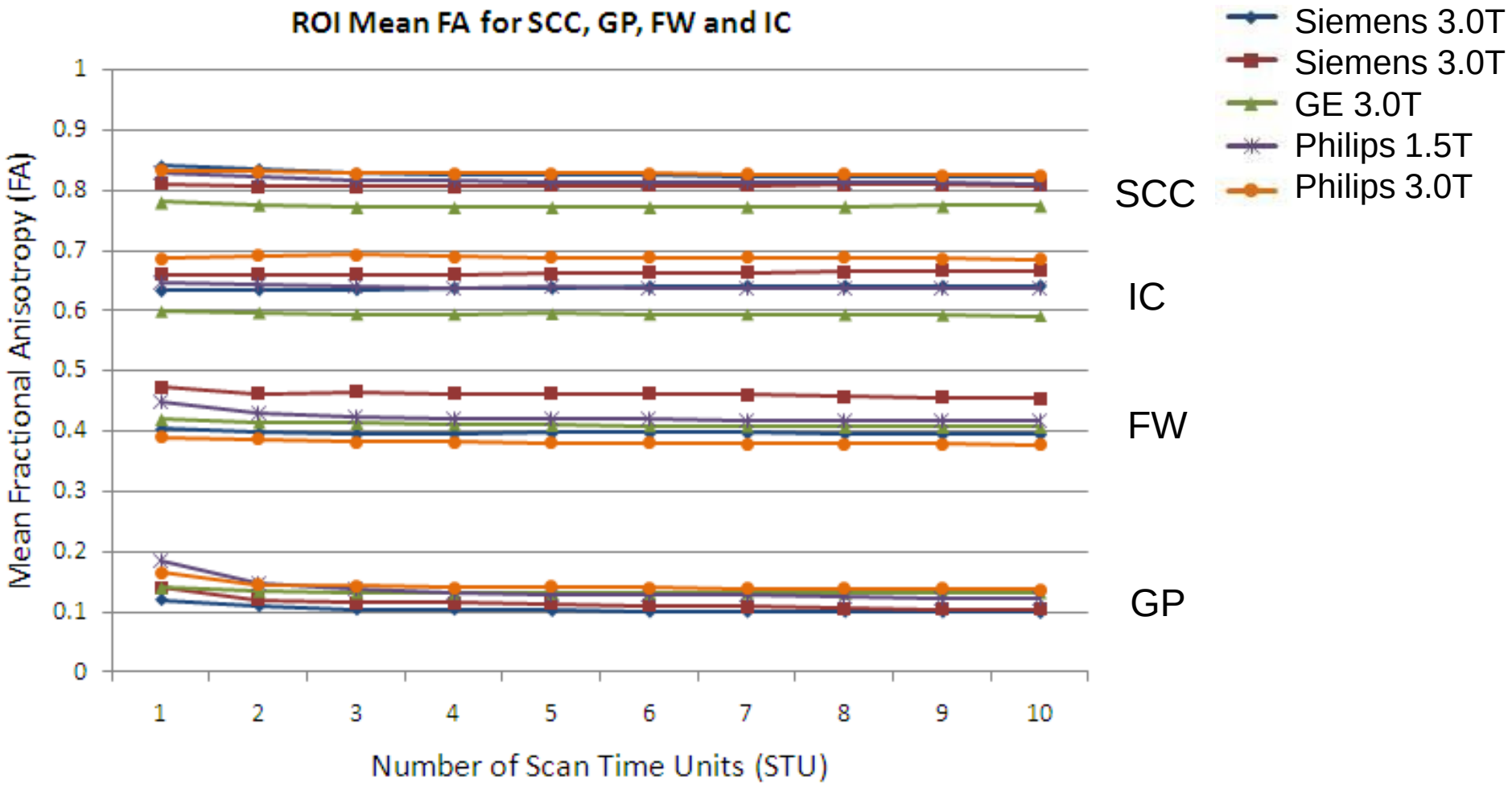


Figure 3. Locations of ROIs at four slice levels used for ROI-based analyses. These include internal capsule (ic), frontal white matter (fw), centrum semiovale (cs), globus pallidus (gp), putamen (put), and splenium of the corpus callosum (scc).

Landman et al., Journal of Magnetic Resonance Imaging 26:756–767 (2007)

Site Mean ROI FA vs. STU - Jones30 data



Results ROI Analysis – Differences Across STU

ROI/ comparison	Internal Capsule	Frontal White Matter	Centrum Semiovale	Globus Pallidus	Put-amen	Splenium of the Corpus Callosum	Mean +/- std. dev. (max=10)
Siemens 3.0T vs. 3.0T	9	9	10	0	0	0	5 ± 5
Philips 3.0T vs. 1.5T	9	0	9	0	0	0	3 ± 5
GE 3.0T vs. Siemens 3.0T	10	0	7	10	0	10	6 ± 5
GE 3.0T vs. Philips 3.0T	10	0	9	0	0	10	5 ± 5
Siemens 3.0T vs. Philips 3.0T	10	0	10	10	0	0	5 ± 6

Conclusions

- Whole-brain analysis is sensitive to field strength, vendor, and TE. Zero filling of data matrix has (minimal) effect at low STU.
- ROI mean FA vs. STU data shows difficulty in using ROI data to identify scanner differences.
- Sub-sampling bin analysis allows for determination of needed STU level for a given structure.
- Method can be used to ‘calibrate’ scanners used in multisite studies.