

脳出血患者におけるDTI-FA TBSS 解析の病変マスキング有無の比較：日常臨床での有用性

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はじめに

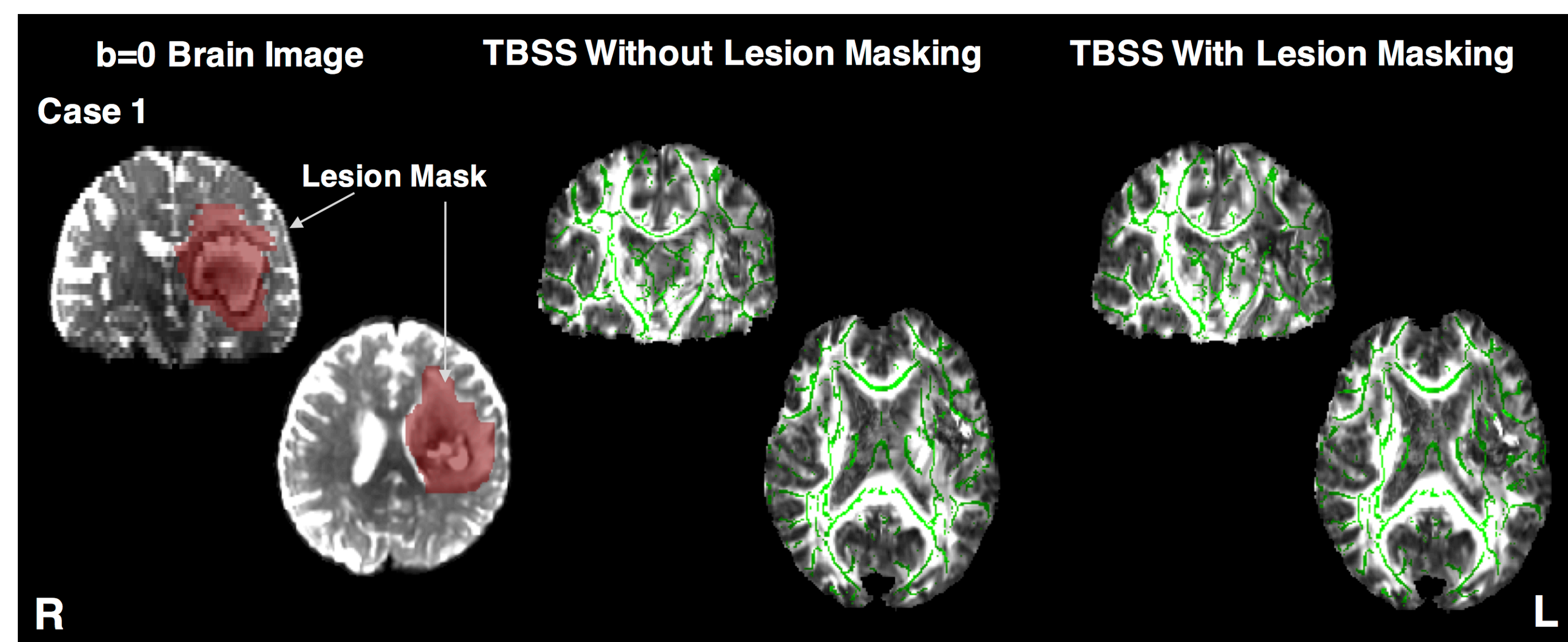
●拡散テンソル法MRI (DTI) のfractional anisotropy (FA) 値は脳卒中後の脳内神経線維損傷の指標とされている。線維損傷の描出のため非線形的標準的脳変換を行うtract-based spatial statistics (TBSS) が頻繁に用いられる。

●神経画像研究での幅広い有用性にもかかわらず、この技術は脳内占拠性病変を縮小する特性がある。その補正のため、病変マスキングが行われる場合がある。しかし、それは時間のかかる手作業で、かつ画像解析の再現性を低下させる。

●そこで今回、病変マスキング無しと有りのTBSS FA値を比較し、臨床的有用性を評価した。

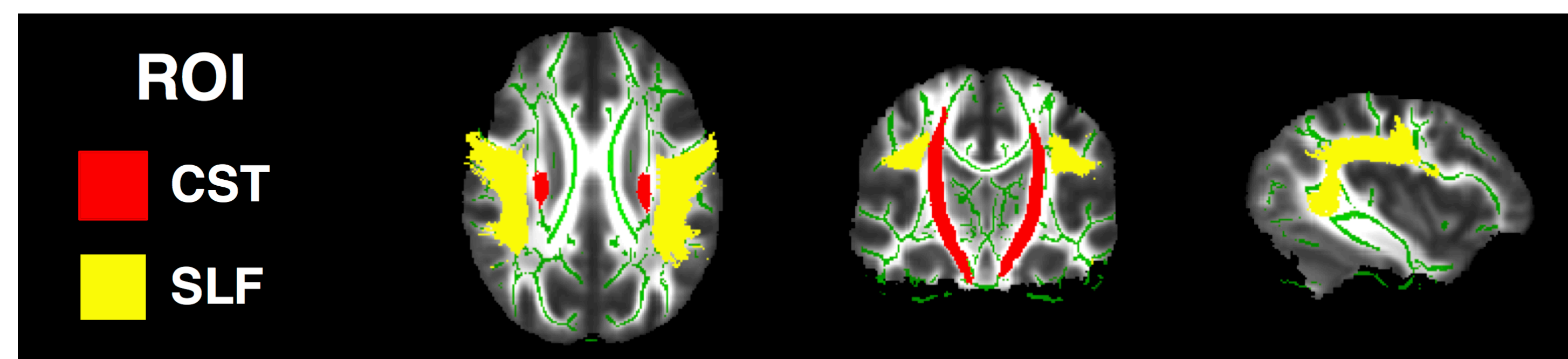
対象と方法

- 脳出血患者40例を用いて解析を行った。発症から14 -21日後、DTI撮像を行い、FA脳画像を生成した。
- 非拡散 (b = 0) 脳画像を参照して病変マスクを作成した。



■ Image acquisition and processing in details
➢ DTI was performed using a 3.0 Tesla MR scanner (Trio; Siemens AG, Erlangen, Germany) with a 32-channel head coil. Employing a single-shot echo-planar imaging sequence, the DTI scheme acquired twelve images with non-collinear diffusion gradients (b = 1000 s/mm²) and one non-diffusion-weighted image (b = 0 s/mm²).
➢ For each patient, 64 axial slices were obtained. The field of view was 230.4 mm×230.4 mm, the acquisition matrix was 128×128, and the slice thickness was 3mm without a gap, which resulted in voxel dimensions of 1.8 mm×1.8 mm×3.0 mm. Echo time was 83 ms and repetition time was 7,000ms.
➢ TBSS analyses were then performed, and spatial transformations and skeletonizations of the FA brain maps were confirmed by visual inspection by using FSLVIEW.

- 次に病変マスキング有りと無しのTBSS解析を行った。
- 個々の患者データで、皮質脊髄路 (CST) および上位縦束 (SLF) のFA平均値を抽出し、さらに病変半球と非病変半球のFA比 (rFA) を求めた。



- 2群のデータの差異を平均二乗和誤差 (RMSE) で評価した。
- 帰結の指標として回復期退院時のBrunnstrom Stage (BRS) とFunctional Independence Measure (FIM) 運動スコアを評価した。
- rFAと帰結の相関 (回帰直線) を評価した。

Brunnstrom Stage (BRS)

1. Flaccid paralysis, hyporeflexic or areflexic
2. Some spastic tone through available range of motion (ROM), no voluntary movement, limb may move in synergistic pattern with facilitation
3. Marked spasticity through full available ROM, voluntary movement with synergistic pattern
4. Diminished spasticity, initial voluntary movement is within synergistic pattern but then able to move out of the pattern
5. Minimal spasticity with slight increased tone, able to initiate movement out of synergies but they are still present
6. Movement patterns near normal, difficulty only with complex and rapid tasks.

Functional Independence Measure (FIM)

Motor Component

- Self-care
 - Eating
 - Grooming
 - Bathing
 - Dressing - Upper
 - Dressing - Lower
 - Toileting
- Sphincter Control
 - Bladder Management
 - Bowel Management
- Transfers
 - Bed, Chair, Wheelchair
 - Toilet
 - Tub, Shower
- Locomotion
 - Walk/Wheelchair
 - Stairs
- Motor: 13 items
Total Score: 13 - 91

Cognition Component

- Communication
 - Comprehension
 - Expression
- Social Cognition
 - Social Interaction
 - Problem solving
 - Memory
- Cognition: 5 items
Total Score: 5 - 35

No Helper
7: Complete Independence (timely, safely)
6: Modified Independence (device)
5: Supervision
4: Minimal Assist (Subject > 75%)
3: Moderate Assist (Subject = 50-75%)
2: Maximal Assist (Subject < 25-50%)
1: Total Assist (Subject < 25%)

●Abbreviations: BRS, Brunnstrom stage; FIM; functional independence measure; H/F, hand/finger; L/E, lower extremity; S/E/F, shoulder/elbow/forearm.

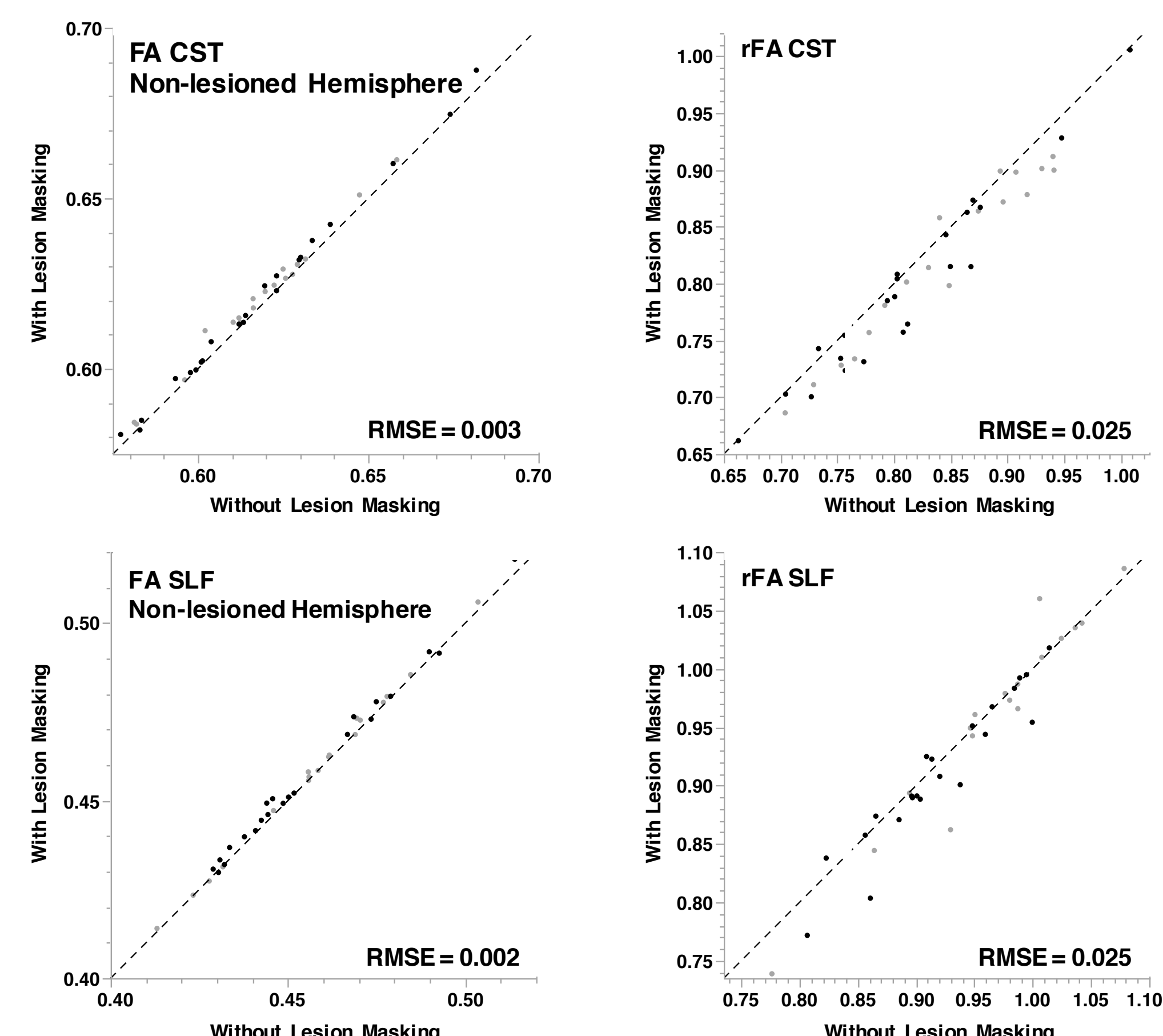
Results

●患者背景 (N = 40)

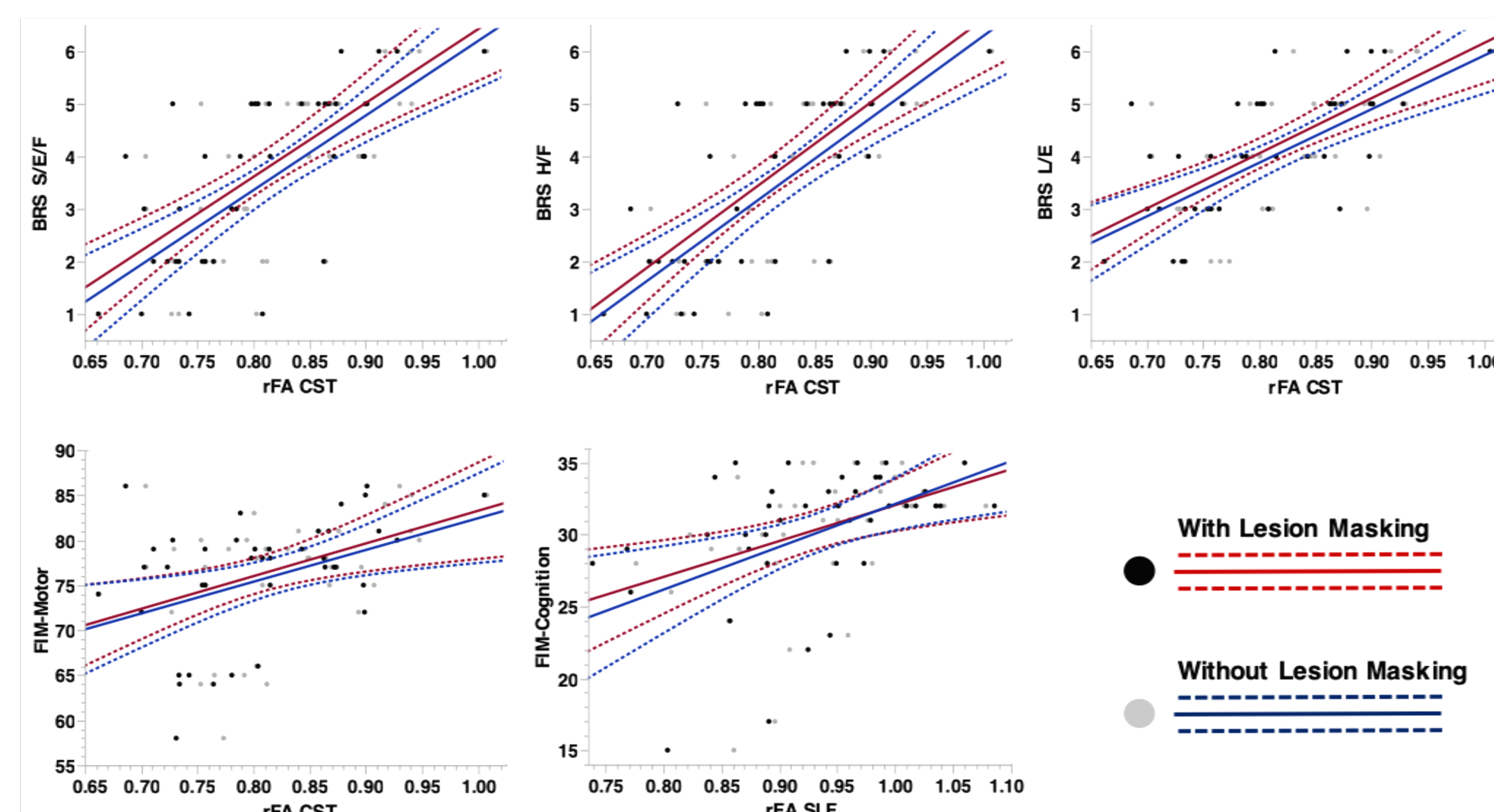
Pt	No.	Age	M/F	Hemorrhage Site / Volume (mL)	Without Lesion Masking				With Lesion Masking				BRS			FIM		LOS	
					FA CST	FA SLF	rFA CST	rFA SLF	FA CST	FA SLF	rFA CST	rFA SLF	S/E/F	H/F	L/E	Mot	Cog		
1	73	M	L	Put	47.1	0.682	0.663	0.469	0.823	0.688	0.662	0.474	0.838	1	1	2	74	30	18
2	59	M	R	Put	24.6	0.616	0.704	0.456	0.864	0.621	0.686	0.458	0.844	4	3	5	86	34	19
3	55	M	L	Put	32.7	0.639	0.705	0.446	0.904	0.642	0.703	0.451	0.888	3	2	4	77	30	16
4	31	F	L	Put	29.7	0.634	0.727	0.475	0.938	0.638	0.700	0.478	0.901	1	1	3	72	31	22
5	44	M	R	Put	43.5	0.625	0.729	0.470	0.841	0.629	0.711	0.473	0.769	2	2	3	79	29	17
6	69	M	L	Put	62.8	0.630	0.734	0.434	0.856	0.632	0.743	0.437	0.858	1	1	3	65	24	21
7	74	M	L	Put	17.5	0.620	0.753	0.467	0.865	0.624	0.734	0.469	0.874	3	2	3	64	29	20
8	71	M	R	Thal	6.4	0.620	0.753	0.461	0.950	0.623	0.728	0.462	0.961	5	5	4	80	31	10
9	50	M	L	Put	62.3	0.604	0.757	0.442	0.861	0.608	0.755	0.444	0.804	2	2	3	75	15	21
10	46	F	L	Thal/Put	53.8	0.614	0.757	0.444	0.807	0.616	0.723	0.449	0.772	2	2	2	77	26	22
11	64	M	R	Put	49.4	0.616	0.765	0.478	0.987	0.618	0.734	0.479	0.966	2	2	2	65	33	19
12	62	F	L	Thal	8.7	0.583	0.773	0.431	0.959	0.582	0.731	0.433	0.944	2	1	2	58	23	20
13	62	M	R	Thal/Put	3	0.629	0.778	0.413	0.987	0.631	0.757	0.414	0.987	4	4	4	79	34	20
14	77	F	R	Thal/Put	2.8	0.581	0.792	0.423	0.947	0.584	0.781	0.423	0.949	3	3	5	65	28	18
15	57	M	L	Put	6.1	0.623	0.794	0.450	1.014	0.623	0.785	0.451	1.018	3	2	4	80	32	20
16	56	M	L	Put	5.6	0.613	0.801	0.430	0.989	0.614	0.788	0.430	0.992	4	5	4	83	35	16
17	80	M	L	Thal	10.5	0.601	0.803	0.432	0.948	0.602	0.804	0.432	0.951	5	5	5	66	32	20
18	39	F	L	Put	27.8	0.630	0.803	0.441	1.000	0.633	0.808	0.442	0.954	1	1	3	78	34	18
19	72	M	L	Put	7.6	0.657	0.808	0.514	0.885	0.660	0.757	0.518	0.871	2	2	3	75	30	19
20	51	M	R	Thal	17.7	0.582	0.811	0.432	0.976	0.584	0.801	0.431	0.979	5	5	5	79	31	13
21	57	M	L	Put	26.9	0.623	0.812	0.490	0.896	0.627	0.764	0.492	0.891	2	2	3	64	17	16
22	62	F	R	Put	9.7	0.622	0.830	0.446	1.006	0.626	0.814	0.447	1.060	5	4	6	79	35	19
23	50	M	R	Put	20.4	0.602	0.840	0.469	0.776	0.611	0.858	0.473	0.739	5	5	4	81	28	12
24	89	M	L	Thal/Put	3.8	0.674	0.846	0.493	0.965	0.675	0.843	0.492	0.967	5	5	4	79	35	16
25	73	M	R	Thal	6.4	0.628	0.849	0.462	1.036	0.628	0.798	0.463	1.035	5	5	5	78	32	14
26	61	M	L	Put	15.2	0.577	0.850	0.444	0.914	0.581	0.815	0.446	0.923	4	2	4	78	32	20
27	61	F	L	Put	20.1	0.593	0.864	0.429	0.897	0.597	0.863	0.431	0.890	2	2	5	78	28	11
28	83	M	L	Put	3.9	0.612	0.868	0.479	0.920	0.613	0.815	0.479	0.908	4	4	4	75	35	19
29	49	M	L	Thal	13.5	0.583	0.870	0.449	0.909	0.585	0.873	0.449	0.925	5	5	5	77	22	6
30	76	M	R	Put	25	0.610	0.874	0.456	0.894	0.614	0.864	0.457	0.894	5	5	5	77	33	6
31	69	F	L	Put	18.3	0.598	0.876	0.438	0.901	0.599	0.867	0.440	0.891	5	5	5	81	32	12
32	77	F	R	Thal	4.1	0.626	0.894	0.469	1.042	0.627	0.899	0.469	1.039	4	6	5	72	32	18
33	68	M	R	Thal	7.8	0.632	0.896	0.459	1.008	0.632	0.872	0.458	1.010	4	4	3	77	32	10
34	73	M	R	Thal	12.6	0.596	0.908	0.428	1.078	0.597	0.898	0.427	1.086	4	4	4	75	32	17
35	53	M	R	Put	23.8	0.658	0.917	0.504	0.948	0.661	0.878	0.506	0.943	6	6	6	84	33	4
36	64	M	R	Thal	7.4	0.612	0.930	0.456	1.025	0.614	0.901	0.456	1.026	5	5	5	86	33	8
37	48	F	R	Thal/Put	4.5	0.647	0.940	0.485	0.980	0.651	0.912	0.485	0.973	6	6	6	81	28	8
38	43	F	R	Put	11.2	0.612	0.941	0.477	0.930	0.615	0.900	0.478	0.862	5	5	6	85	35	6
39	69	M	L	Thal	4.5	0.601	0.948	0.452	0.995	0.602	0.928	0.452	0.995	6	5	5	80	32	3
40	55	M	L	Thal	2.8	0.599	1.008	0.473	0.984	0.600	1.006	0.473	0.983	6	6	6	85	34	3

Patients are listed in order of increasing rFA of the CST from regular TBSS without lesion masking. Eight patients underwent surgical evacuation of hematomas; open surgical removal was performed in 6 cases (Nos. 4, 5, 6, 9, 10 and 11) and stereotactic aspiration was performed in 2 cases (Nos. 18 and 21). Abbreviations: BRS, Brunnstrom stage; Cog, cognition; CST, corticospinal tract; F, female; FA, fractional anisotropy; H/F, hand and fingers; L, left; L/E, lower extremity; LOS, length of total hospital stay from admission to acute medical service to discharge from long-term rehabilitation facility; M, male; Mot, motor; Pt, patient; Put, putamen; R, right; rFA, ratio between FA values in affected and unaffected hemispheres; S/E/F, shoulder, elbow, and forearm; SLF, superior longitudinal fasciculus; Thal, thalamus.

●病変マスクなし (横軸) と病変マスクあり (縦軸) データの散布図



●rFAと帰結の回帰直線



まとめ

- 病変マスキング有りのTBSSから得られたrFA値は、病変マスキング無しのTBSSから得られたものより僅かに小さい傾向があったが、RMSEはCSTとSLFの双方で0.025であった。
- 病変マスキング有りと無しのTBSSのrFAの差異は小さかった。病変マスク作成の労力を考えると、病変マスキング無しの通常のTBSSは日常臨床診療に応用可能と考えられる。

【この資料は以下論文の日本語解説である】

Koyama T., Uchiyama Y., Domen K., Comparison of fractional anisotropy from tract-based spatial statistics with and without lesion masking in patients with intracerebral Hemorrhage: a technical note, *J. Stroke Cerebrovasc. Dis.*, 28, 104376, 2019
<https://doi.org/10.1016/j.jstrokecerebrovasdis.2019.104376>