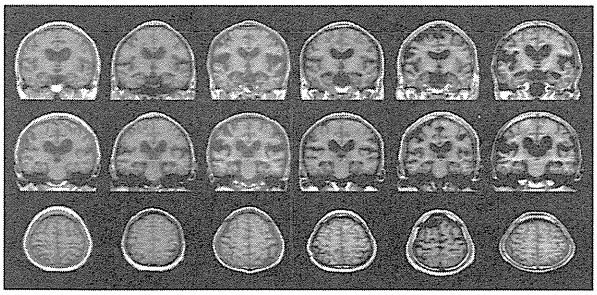
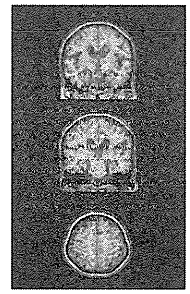
結果



82才 女性　74才 男性　81才 男性　71才 男性　82才 男性　71才 男性

9

結果

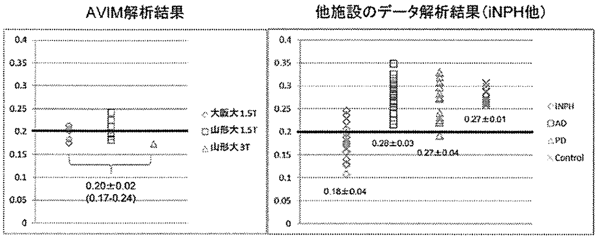


63才 女性
3T

10

結果 - 高位正中・円蓋部(HCM)

AVIM解析結果　　他施設のデータ解析結果(iNPH他)



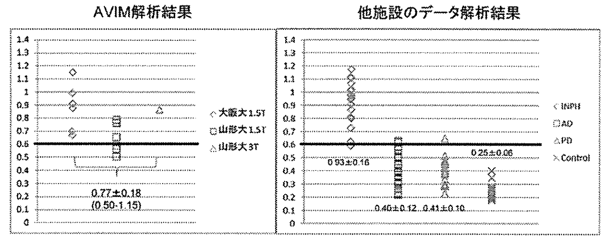
カットオフ：0．20

P < 0.001; AVIM vs AD, PD, Control
(Steel test)

11

結果 - 脳室・シルビウス裂領域(VS)

AVIM解析結果　　他施設のデータ解析結果



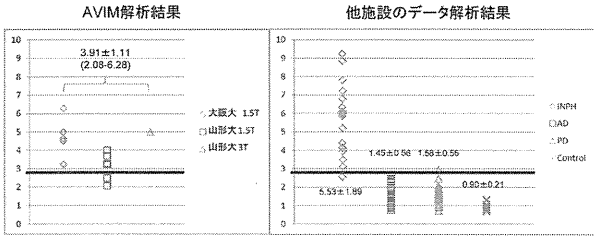
カットオフ：0．61

P < 0.001; AVIM vs AD, PD, Control
(Steel test)

12

結果 - VS/HCM

AVIM解析結果　　他施設のデータ解析結果

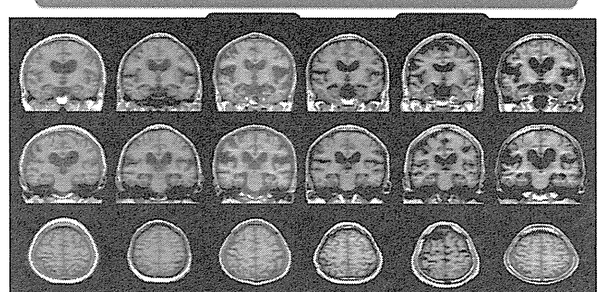


カットオフ：2．81

P < 0.001; AVIM vs AD, PD, Control
P = 0.05; AVIM vs iNPH (n.s.)
(Steel test)

13

カットオフを下回った正常寄りの2例



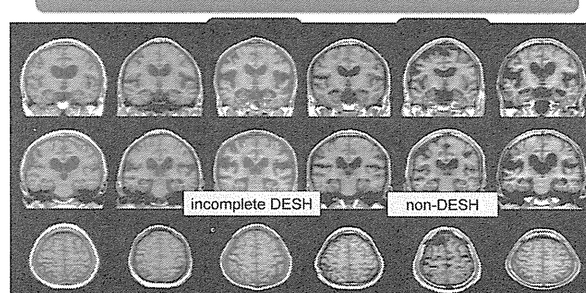
	82才 女性	74才 男性	81才 男性	71才 男性	82才 男性	71才 男性
HCM	0.21	0.18	0.23	0.20	0.24	0.19
VS	0.79	0.59	0.57	0.65	0.50	0.76
VS/HCM	3.70	3.23	2.51	3.30	2.08	4.01

DESH Consensus Meeting判定基準(案)

- DESH　aが3項目
- incomplete DESH　aが2項目、bが1項目
- non-DESH　上記以外

脳室	高位円蓋部・正中部くも膜下腔	Sylvius裂
a.脳室拡大(EI>0.3) b.脳室拡大(EI≤0.3) c.脳室拡大無し	a.狭小化 b.狭小化・拡大無し c.拡大	a.拡大 b.拡大・狭小化無し c.狭小化

カットオフを下回った正常寄りの2例



	82才 女性	74才 男性	81才 男性	71才 男性	82才 男性	71才 男性
HCM	0.21	0.18	0.23	0.20	0.24	0.19
VS	0.79	0.59	0.57	0.65	0.50	0.76
VS/HCM	3.70	3.23	2.51	3.30	2.08	4.01

まとめ

- CSF領域のVBM手法を用いてAVIMのCSF容積解析を行った。
- AVIM13例の頭部サイズ正規化後の高位正中・円蓋部(HCM)のCSF容積は平均±標準偏差0.20±0.02、脳室・シルビウス裂領域(VS)のCSF容積は0.77±0.18であった。これらの比(VS/HCM)は範囲2.08–6.28、平均±標準偏差3.91±1.11で、13例中11例(84.6%)でカットオフ値(2.81)を上回った。また、カットオフ値を下回った2例は視覚的にも完全なDESHではなかった。
- AVIMの画像所見はCSF-VBM手法による自動ROI解析で定量化可能で、客観的評価法として使用できる可能性が示された。

17

特発性水頭症における 脳脊髄液ダイナミクスの観察
ーtime-SLIP法による観察ー 多施設共同試験計画

および、time-SLIP法の新たな研究開発の報告

山田晋也1)、宮嶋雅一2)、新井一2)、橋本正明3)、二宮敬4)

1) 東芝林間病院、脳神経外科, 2) 順天堂大学付属順天堂医院 脳神経外科 3)公立能登総合病院、脳神経外科 4)八千代病院、リハビリテーション科

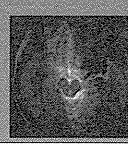
目的:

Definitive iNPH における脳脊髄液ダイナミクスの変化を捉え、病態理解と診断精度の向上を目指す。

Material and Method

MRI Time-Spatial Labeling Inversion Pulse (Time-Slip) technique (CSF dynamics imaging) was used in this study. (TOSHIBA EXCELART /VANTAGE/TITAN)

MRI visualization of cerebrospinal fluid movement with spin labeling: Preliminary results in normal and pathophysiological conditions. Radiology 249:644-652, 2008. Yamada S, et.al



Material and Method

Definitive iNPHにおけるMRI time-SLIP法を用いた観察。
多施設共同試験 Started 2012 April

東芝林間病院
Internal Review Board 2013 April

参加施設

東芝林間病院
公立能登病院
順天堂大学付属順天堂医院
八千代総合病院

Clinical Criteria:

diagnosis of iNPH was made according to Japanese iNPH guideline

- *60 years of age or older*
- *Clinical symptoms of progressive dementia, ataxia and urinary incontinence*
- *MRI findings of ventriculomegaly (Evan's index of <0.3) and disproportionately enlarged subarachnoid spaces (DESH)*
- *10% improvement in ambulation and mini-mental testing following lumbar puncture with removal of 30 ml of CSF*

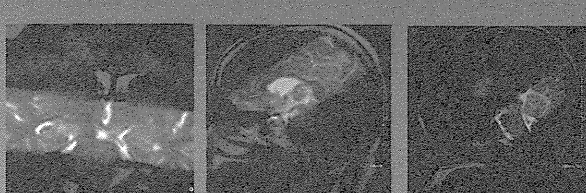
Definition of Definitive iNPH

Improvement following CSF diversion

One or more points of improvement on the modified Rankin Scale

観察部位

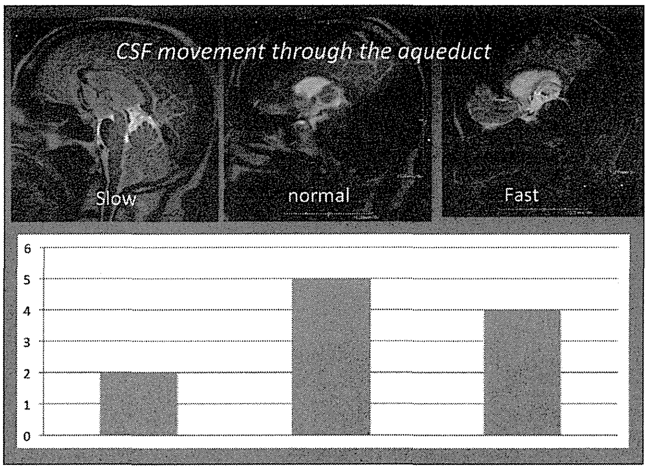
CSF movement were studied at

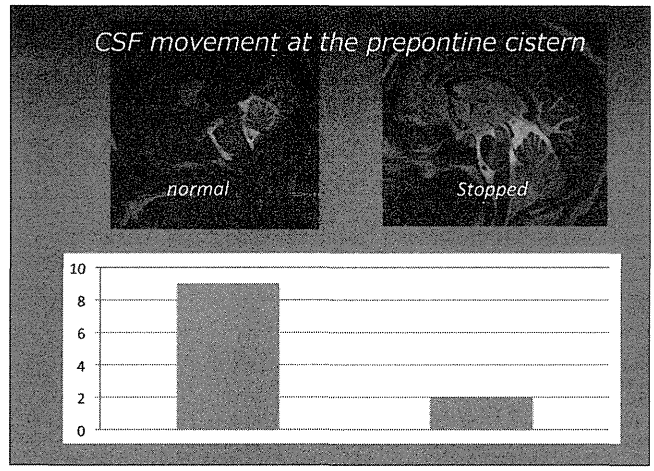


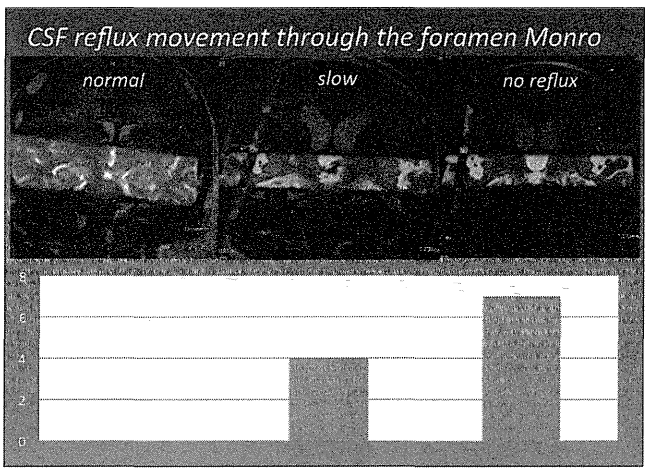
foramina of Monro　*the aqueduct*　*the pre-pontine cistern*

Semi-automatic CSF speed measurement
CSF Dynatracer soft ware (Toshiba Corp)

Automated Flow Quantification for Spin Labeling MR Imaging: Taichiro Shiodera Shuhei Nitta Tomoyuki Takeguchi Masao Yui Yuichi Yamashita Takao Yamamoto, Shinya Yamada: Magnetic Resonance Materials in Physics, Biology and Medicine IN PRESS



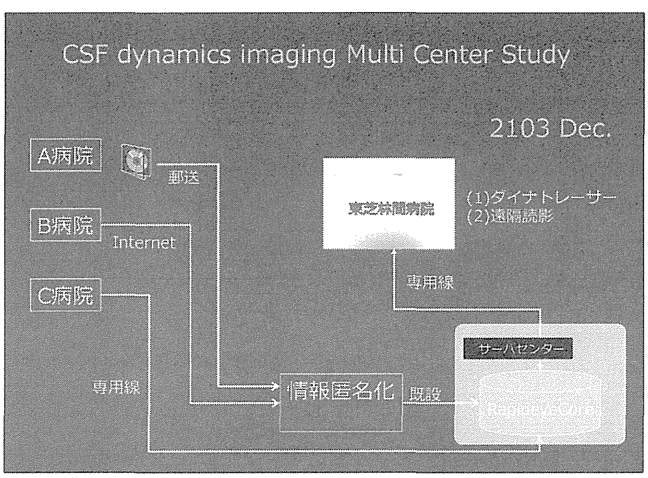


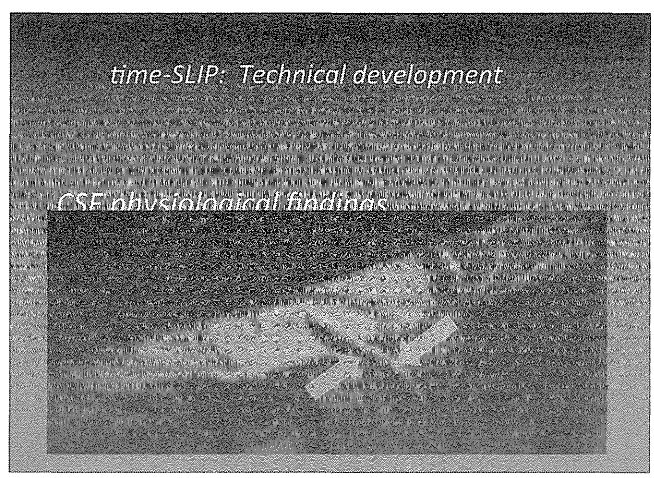


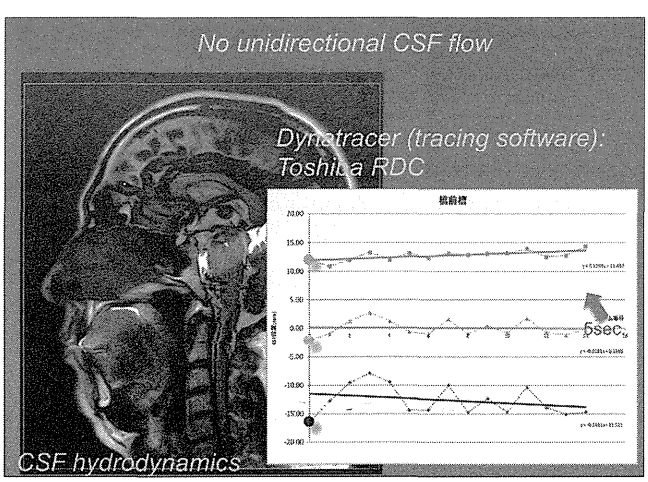
Conclusion and future direction

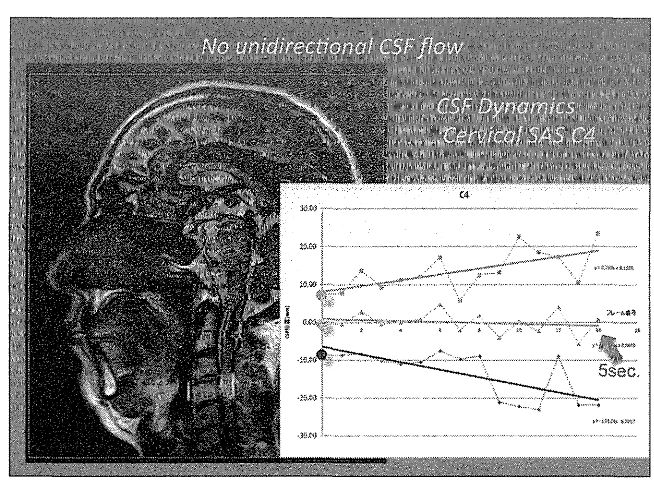
A non-invasive MRI time-SLIP technique demonstrated alteration of CSF movement pattern in definitive iNPH patients before the surgery.

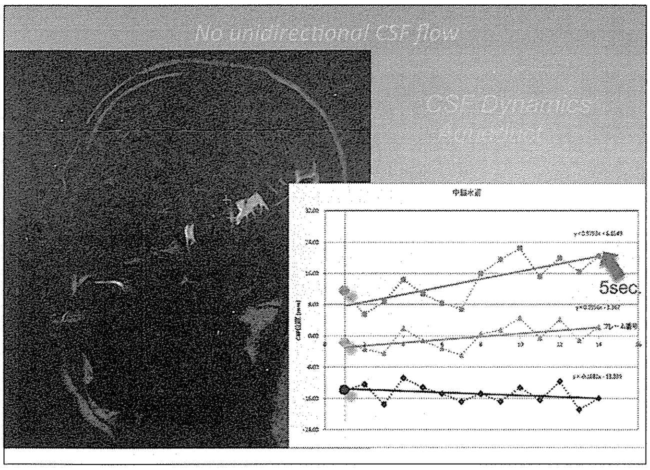
This technique may help to diagnose to those patients with suspected iNPH who would benefit from CSF diversion.

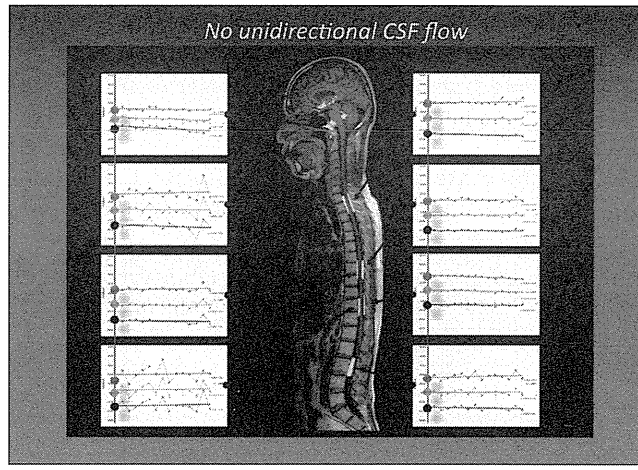


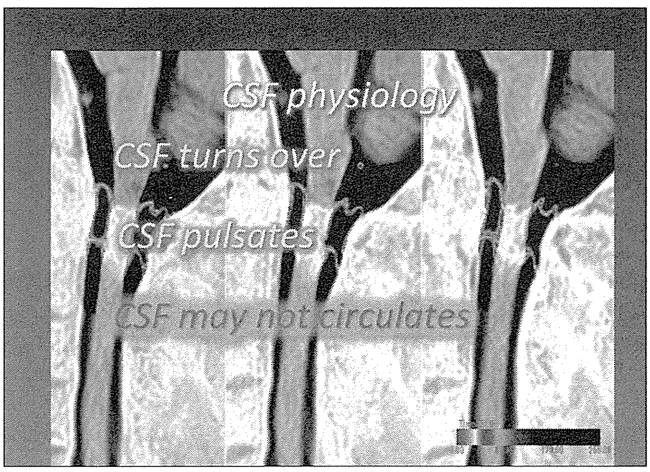


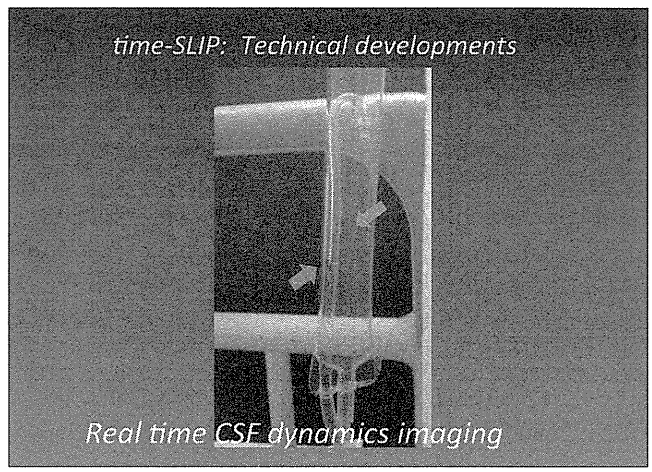


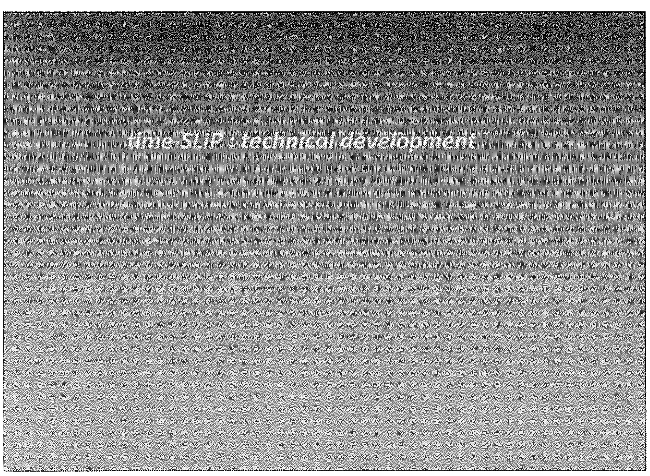


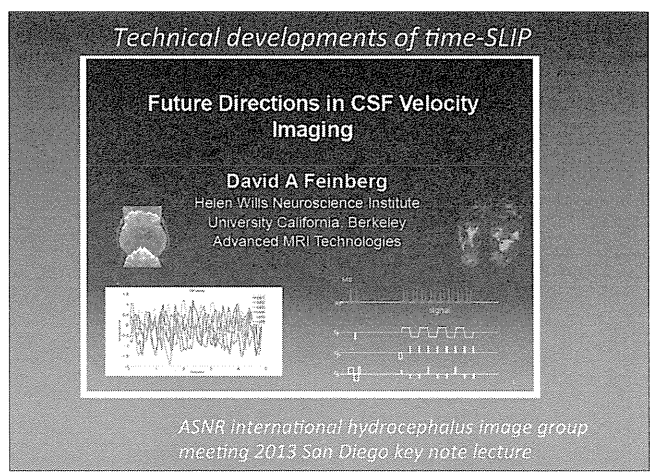

No unidirectional CSF flow
CSF Dynamics
Aqueduct
中脳水道
5sec.

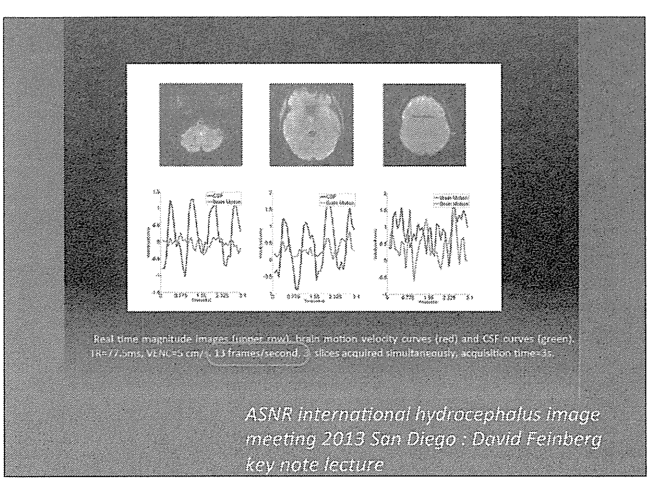

No unidirectional CSF flow

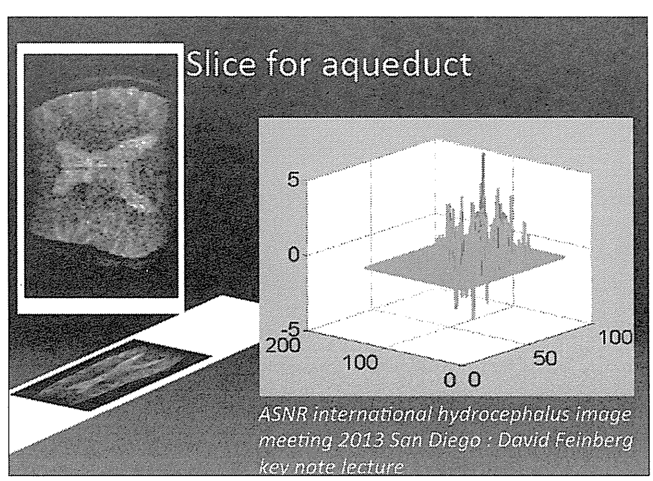

CSF physiology
CSF turns over
CSF pulsates
CSF may not circulates

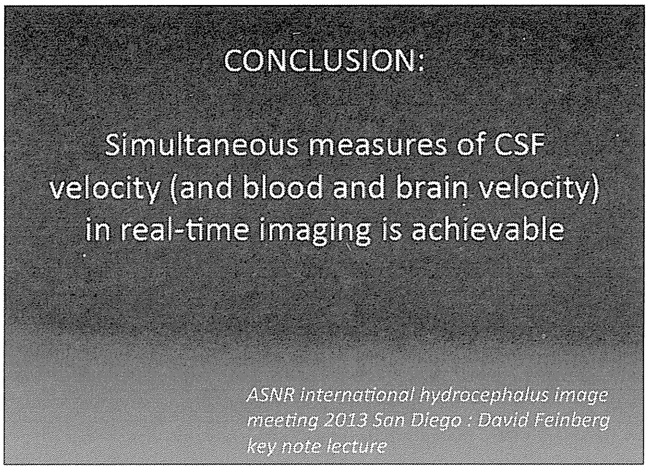

time-SLIP: Technical developments
Real time CSF dynamics imaging

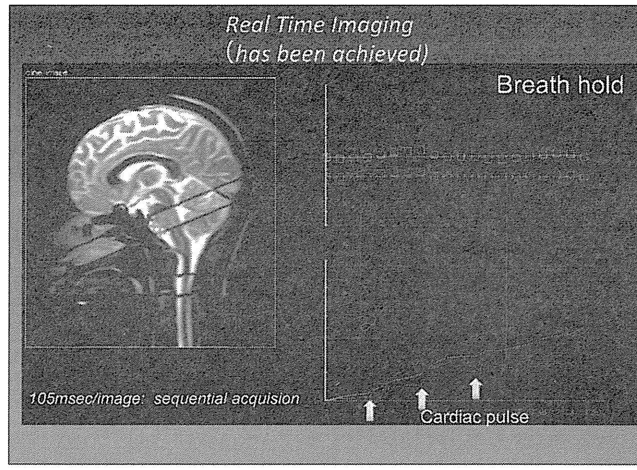

time-SLIP : technical development
Real time CSF dynamics imaging

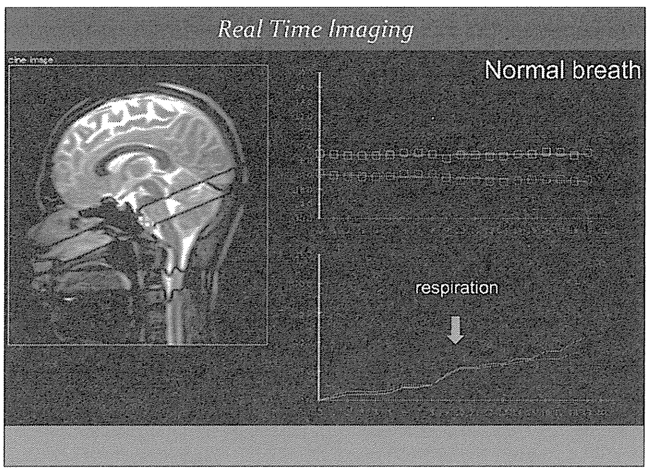

Technical developments of time-SLIP
Future Directions in CSF Velocity Imaging
David A Feinberg
Helen Wills Neuroscience Institute
University California, Berkeley
Advanced MRI Technologies
ASNR international hydrocephalus image group meeting 2013 San Diego key note lecture

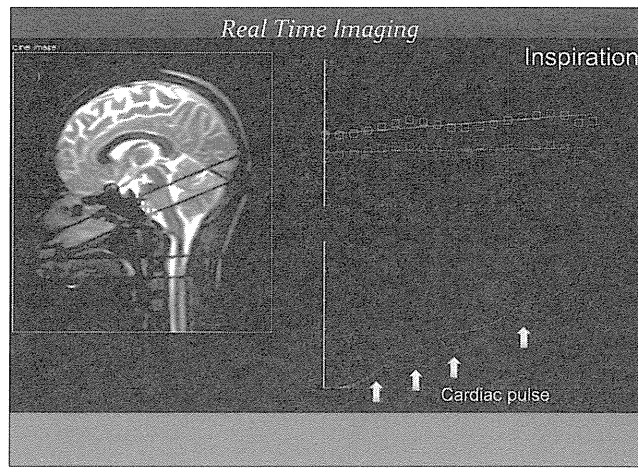

Real time magnitude images (upper row), brain motion velocity curves (red) and CSF curves (green). TR=77.5ms, VENC=5 cm/s, 13 frames/second, 3 slices acquired simultaneously, acquisition time=3s.
ASNR international hydrocephalus image meeting 2013 San Diego : David Feinberg key note lecture

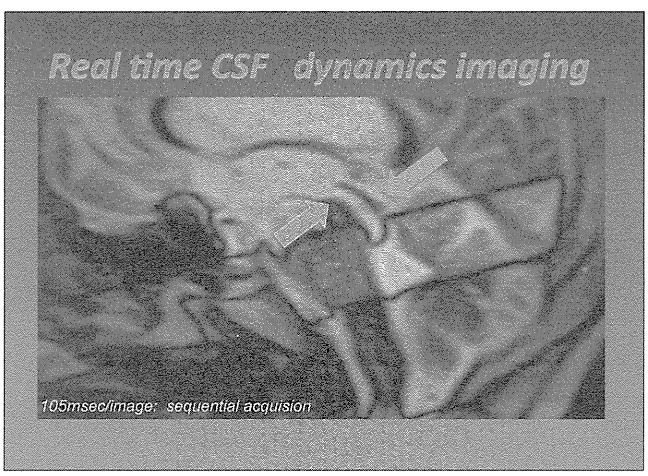

Slice for aqueduct
5
0
-5
200
100
0 0
50
100
ASNR international hydrocephalus image meeting 2013 San Diego : David Feinberg key note lecture


CONCLUSION:
Simultaneous measures of CSF velocity (and blood and brain velocity) in real-time imaging is achievable
ASNR international hydrocephalus image meeting 2013 San Diego : David Feinberg key note lecture

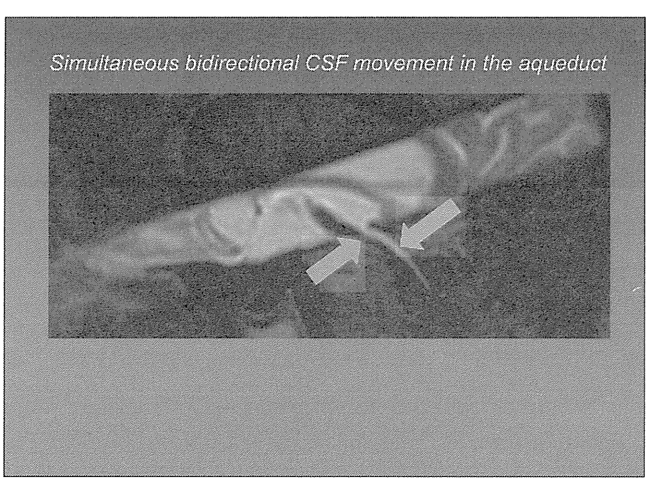

Real Time Imaging
(has been achieved)
Breath hold
105msec/image: sequential acquision
Cardiac pulse


Real Time Imaging
Normal breath
respiration

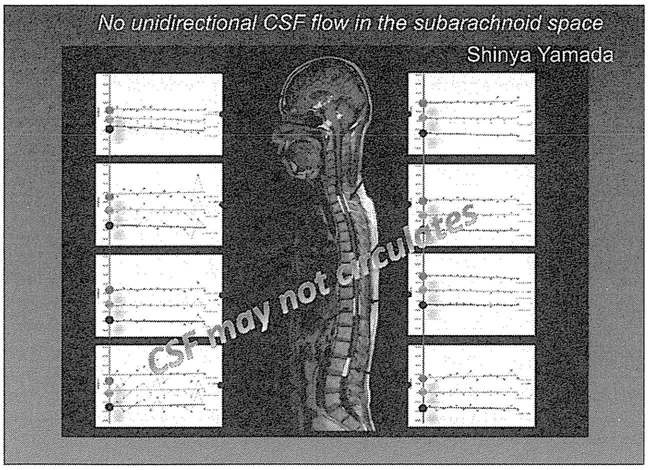

Real Time Imaging
Inspiration
Cardiac pulse

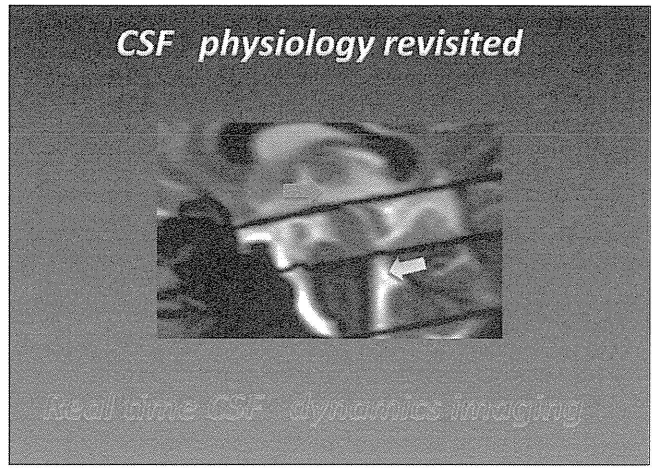

Real time CSF dynamics imaging
105msec/image: sequential acquision


Simultaneous bidirectional CSF movement in the aqueduct
Real time CSF dynamics imaging


Simultaneous bidirectional CSF movement in the aqueduct


Simultaneous bidirectional CSF movement in the aqueduct
Real time CSF dynamics imaging


No unidirectional CSF flow in the subarachnoid space
Shinya Yamada
CSF may not circulates


CSF physiology revisited
Real time CSF dynamics imaging

Prospective estimation of mean axon diameter and extra-axonal space of the posterior limb of internal capsule in patients with idiopathic normal pressure hydrocephalus before and after lumboperitoneal shunt by using q-space diffusion analysis

Hori M[1], Kamiya K[1], Nakanishi A[1], Fukunaga I[1, 2], Miyajima M[3], Suzuki M[1], Suzuki Y[4], Kamagata K[1], Yoshida M[1], Arai H[3], Aoki S[1]

[1]Department of Radiology, Juntendo University School of Medicine
[2]Department of Health Science, Graduate School of Human Health Sciences, Tokyo Metropolitan University
[3]The department of Neurosurgery, Juntendo University School of Medicine
[4]Philips Electronics Japan, Ltd.

INTRODUCTION

✓Improvement of gait disturbance is seen in patients with idiopathic normal pressure hydrocephalus (iNPH) after shunt surgery.

✓However, it is so often that no apparent changes of ventricular size are observed on conventional MRI, despite obvious clinical improvement after the surgery.

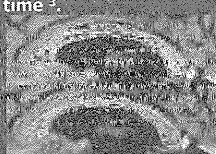
✓The pathogenesis of gait disturbance in iNPH is not completely understood. One possible explanation is compression and/or deformation of the corticospinal tract, as supported by recent DTI and DKI studies [1-3].

1, Relkin N, et al. Neurosurgery. 2005;57(3 Suppl):S4-16
2, Hattori T, et al. AJNR Am J Neuroradiol. 2012;33(1):97-103.
3, Nakanishi A, et al. Neuroradiology. 2013;55(8):971-6.

INTRODUCTION

✓Measurements of axon diameter and/or axon density by diffusion MRI have been proposed for investigation of brain microstructural changes [1, 2]. However, they usually require high-gradient amplitude and long scanning time, not clinically applicable.

✓Recently, two-component low-q fit method was introduced as a method to measure axonal diameter using q-space diffusion MRI, with less demands in terms of hardware and scanning time [3].



Example of axon diameter map (above) and axon density map (below) of corpus callosum obtained by using two-component low-q fit of q-space imaging (scan time = 776 sec)

1, Assaf Y et al. Magn Reson Med. 2008;59(6):1347-54.
2, Alexander DC, et al. Neuroimage. 2010;52(4):1374-89.
3, Ong HH, Wehrli FW. Neuroimage. 2010;51(4):1360-6.

PURPOSE

The purpose of this study is to investigate changes in mean axon diameter and extra-axonal space of the posterior limb of internal capsule (PLIC) in patients with iNPH before and after lumbo-peritoneal (LP) shunt by using q-space diffusion analysis.

MATERIALS AND METHODS

✓10 consecutive patients with known iNPH

3 males and 7 females; mean age 75 y (67 - 82 y)

✓All patients underwent MR exam before and after the surgery

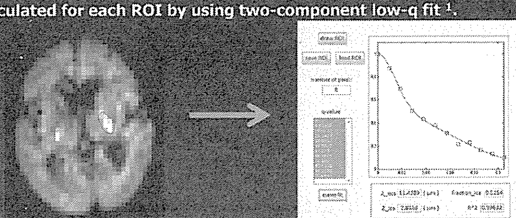
q-space imaging parameters:

MR system	Philips Achieva 3T
TR / TE	8000 / 96 msec
Voxel size	4 x 4 x 4 mm^3
δ/Δ	37.8 / 47.3 msec
b values	0, 124, 496, 1116, 1983, 3099, 4463, 6074, 7934, 10041, 12397, and 15000 s/mm^2
MPG	1 axis (applied in A-P direction within x-y plane)
NEX	1
Scanning time	552 sec

MATERIALS AND METHODS

✓ROI was drawn manually on the PLIC on each side.

✓Root mean square displacement (RMSD) of diffusing water molecules in intra-axonal (= mean axon diameter) and extra-axonal spaces were calculated for each ROI by using two-component low-q fit [1].



$$E(q) = (1 - f_I)\exp(-2\pi^2 q^2 Z_E^2) + f_I \exp(-2\pi^2 q^2 Z_I^2)$$

f_I : the relaxation-weighted intra-axonal space volume fractions
Z_E and Z_I : RMSDs of diffusing molecules in the extra- and intra-axonal space

1, Ong HH, Wehrli FW. Neuroimage. 2010;51(4):1360-6.

RESULTS

In all patients, the gait disturbance ameliorated after LP shunt.

Excellent fitting was obtained in all ROIs ($R^2 > 0.96$).

Significant increase of the extra-axonal space RMSD was observed after shunt surgery, whereas no change in the intra-axonal space (axon diameter) was observed.

	Intra-axonal RMSD (axon diameter)	Extra-axonal RMSD
Before LP shunt	1.86 ± 0.50	7.31 ± 1.27*
After LP shunt	1.97 ± 0.55	8.09 ± 1.67*

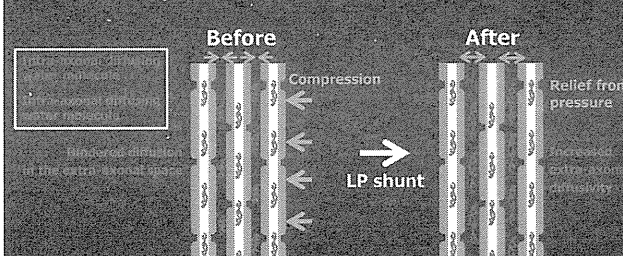
$P = 0.009$*

*Wilcoxon signed rank tests with Bonferroni correction

DISCUSSION

✓Our study suggested that diffusion of water molecules in the extra-axonal space is increased after LP shunt surgery, whereas intra-axonal space is not altered.

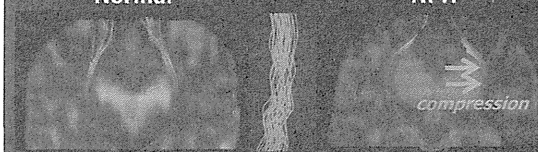
✓These results supports the idea that patients with iNPH do not suffer from irreversible axonal damage of corticospinal tract but compression of the tract.



DISCUSSION

✓The present results are also consistent with previous DTI studies that demonstrated increased FA and λ1 in iNPH, presumably due to mechanical pressure due to ventricular enlargement [1,2].

Normal NPH



Stretched, straightened

→ FA↑ λ1↑

1, Hattori T, et al. AJNR Am J Neuroradiol. 2012;33(1):97-103.
2, Nakanishi A, et al. Neuroradiology. 2013;55(8):971-6.

DISCUSSION

limitations

Insufficient optimization for q-space imaging parameters
→ Values and numbers of q-values and voxel size

Small number of the patients
→ to establish clinical usefulness, more patients with clinico-image correlation will be needed

Meaning the "extra-axonal" RMSD value remains unclear.
→ What actually hinders water diffusion ?
→ axon density measurement might be better, and easy to interpret

CONCLUSION

✓Our study showed feasibility of two-component low-q fit method for estimation of mean axon diameter and extra-axonal space in patients with iNPH.

✓Axon diameter and extra-axonal space might be biomarkers of recovery after shunt surgery in iNPH. The clinical value of these measures, such as monitoring the effect of surgery or pre-operative prediction of response to surgery, needs to be further investigated.

平成25年度
厚生労働科学研究費補助金難治性疾患克服研究事業
「正常圧水頭症の疫学・病態と治療に関する研究」班会議
研究代表者　順天堂大学脳神経外科　新井　一教授

MRIを用いた髄液循環動態解析の意味

発表　東海大学脳神経外科
平山 晃大
分担研究者　東海大学脳神経外科
松前 光紀

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目的

MRI Phase Contrast法を用いて立体構造に分布する脳脊髄液の運動を広範囲で捉える為に、3方向のデータ収集に基づく解析をし、さらに時間軸を加えた4次元の解析方法の開発を目的として、本研究を行なった。

我々はPC法によって得られた速度情報に基づいて、速度・回転・圧勾配をベクトルならびに色差を用いて広範囲にて可視化し、中脳水道における各パラメーターの定量を行い、健常者・iNPH患者で比較。

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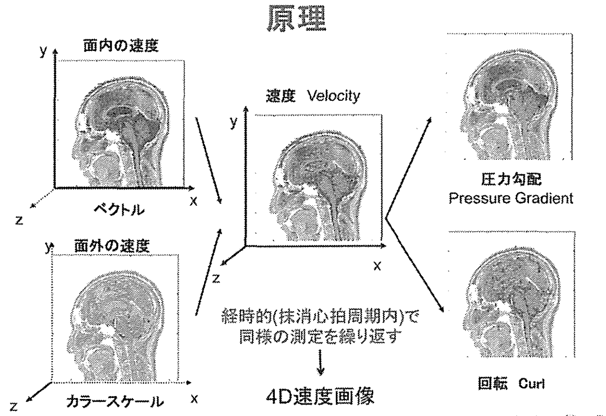
原理



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Curl

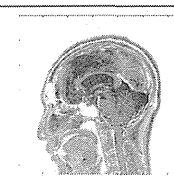
ベクトル場のある点の周辺において、場が回転しようとする傾向を表すベクトル

Helmholtz's theorem

$$curl\, v = \nabla \times v$$

$$P_{xy} = \frac{\sum_{k=1}^{N}(R_k-\bar{R})\sum_{k=1}^{N}(V_{xyk}-\overline{V_{xy}})}{\sqrt{\sum_{k=1}^{N}(R_k-\bar{R})^2\sum_{k=1}^{N}(V_{xyk}-\overline{V_{xy}})^2}}$$

Pressure Gradient



Navier-Stokes equation

$$\nabla P = -\rho\left(\frac{\partial v}{\partial t} + (v\cdot\nabla)v\right) + \mu\cdot\nabla^2 v$$

P: 圧力, v: 速度ベクトル
ρ :流体密度, μ: 流体粘度
(CSF ρ=1.0007g/cm³, μ=1.1cPç)

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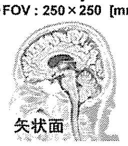
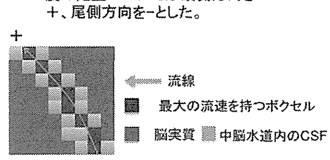
撮像方法と中脳水道の定量方法

撮像条件
・健常ボランティア42名（男性21名　女性21名）
・年齢：21-80歳
・iNPH患者7名
矢状面　冠状面
・1.5T MRI
・3D - Q flow ・SENSE factor：2
・マトリックス：256×256
・空間分解能：2 [mm]
・スラブ厚：50～140 [mm]
・TR：16.1～16.6 [msec]
・TE：6.6～6.7 [msec] ・FA：20°
・VENC：5 [cm/sec]
・FOV：250×250 [mm²]



中脳水道の定量方法
中脳水道におけるCSFの流れをを層流と仮定し，画像の行毎の最大流速を持つボクセル座標に多項式を当てはめて得た曲線を流線とし流速を定量。RL方向の速度は十分に小さいとみなし，速度ベクトルを流線に正射影した。得られた流線上のボクセルの平均速度・圧力勾配・回転を算出した。なお速度の定量については頭側方向を＋、尾側方向を－とした。



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(1) Volunteer Study

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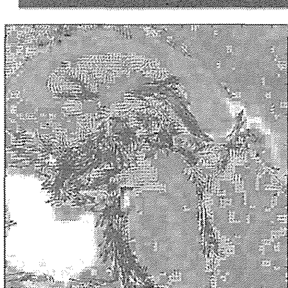
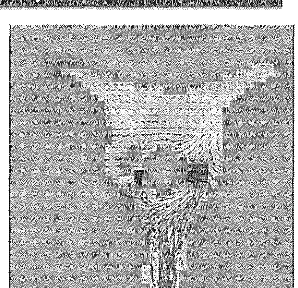
Volunteer CSF motion MR imaging (PC) Velocity



Midline sagittal image(Ventricle)



Coronal image (foramen of Monro)

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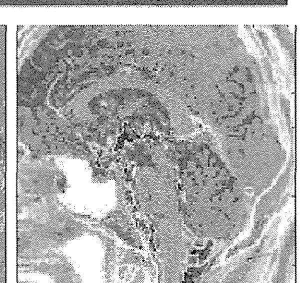
Volunteer CSF motion MR imaging (PC) Curl & Pressure Gradient

Midline sagittal image(Curl)



Midline sagittal image(Pressure Gradienl)

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