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Asian Pacific Journal of Tropical Medicine

journal homepage:www.elsevier.com/locate/apjtm

Document heading doi:

MRS and diffusion tensor image in mild traumatic brain injuries

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ARTICLE INFO

Article history:
Received 20 November 2011
Received in revised form 15 December 2011
Accepted 5 January 2012
Available online 20 January 2012

Keywords:
Mild trauma brain injures
Magnetic resonance spectroscopy
Diffusion tensor image
Fractional anisotropic mapping

ABSTRACT

Objective: To analyze characters of magnetic r[illegible]ance [illegible]oscopy ([illegible]) and diffusion tensor imaging (DTI) in the diagnosis of mild trauma[illegible]in injurie[illegible]TBI) i[illegible]ntal lobe and to compare with conventional magnetic resonance i[illegible]g (MRI). **Me[illegible]** [illegible] total of 21 patients were selected, who all aged 12–51 years ol[illegible]d h[illegible]jury within [illegible] hours. Computer tomography (CT) and the Glasgow Coma Scale were used t[illegible]luate the degree of injury. All patients were diagnosed as MTBI, and 1[illegible] conventiona[illegible] MRS and DTI. The major parameters of MRS were Probe–P sequenc[illegible] = 1[illegible]4 or 35 ms, and b[illegible] single voxel spectrum and chemical shift imging were included. The ma[illegible]parameters of DTI were diffusion directions =15, b value = 1 000 s/mm^2. Frational anisotropic (FA) [illegible] and avera[illegible]ADC map were obtained to evaluate DTI result. Positive detetion ratio was o[illegible]ved and th[illegible]maging changes were compared between injured side and normal side. **Result[illegible]** [illegible] 21 p[illegible]ts had CT scan and Glasgow scale. A total of 19 patients had c[illegible]nal MRI, [illegible] MRS. Results of CT and conventional MRI showed no significant a[illegible]lobe, and Glasgow scale showed mild type. MRS result showed significant decre[illegible] in N[illegible]spartate (NAA) and NAA/creatine (Cr) in 13 cases (68.4%) (P<0.001), and inc[illegible]lactic acid (Lac) in 7 cases (36.8%). FA mapping of the frontal lobe dis[illegible]gnifican[illegible]anges in 7 cases (36.8%), with 5 out of the 7 cases having increase in FA [illegible]e. An[illegible]ere was [illegible]significant difference in average ADC. **Conclusions:** MRS and DTI might [illegible] more [illegible]sible than [illegible]er methods, such as CT and conventional MRI in diagnosis of MTBI. The [illegible]re reduced NAA and increased Lac for MRS, and increased FA values for D[illegible]

1. Introduction

Mild traumatic [illegible]juries ([illegible]TBI) is main cause for cognitive d[illegible]it. It [illegible]haract[illegible]ed as traumatic axonal injury, [illegible]s ca[illegible]th, diability etc. It is still diffic[illegible]o fin[illegible]ut a non[illegible]asive and special method for diag[illegible] of M[illegible]

Comp[illegible]omography (CT), magnetic resonance imaging (MRI) inclu[illegible] T2 weighted image (T2WI), T2 star weighted image (T2*W[illegible]nd diffusion weighted image (DWI) have been used to evaluate hemorrhage, edema, and ischemia[2]. As a primary imaging technique, CT is sensitive in detection of intracranial hemorrhage, and is the main method for evaluation of head injury. It can provide important evidence for treatment of emergency neurosurgery diseases[2]. With the rapid development of new techniques and improvement of image quality, MRI has become one of the most important method for diagnosis of MTBI. Magnetic resonance spectroscopy (MRS) can provide information about local neurons metabolism, and is helpful in prognosis of clinical outcome and selection of treatment strategy[2] This study aims to analyze characters of diffusion tensor imaging (DTI) and MRS, and to compare with conventional MRI (T1, T2, FLAIR).

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Foundation project: This work was supported by the Science Foundation of Haikou Health Bureau (2010-SWY-13-058) and Haikou Science Technology Information Bureu (2009-049-1).

2. Materials and methods

2.1. Subjects

A total of 21 cases with head injury admitted from February 1st to August 30th, 2011 were selected. All recruited subjects signed informed consent agreements. All patients had consciousness loss within 30 min, coma within 24 h, slight headache, no obvisou abnormality in physical examination of neurological system, and had language reaction. All patients had Glasgow scale and CT. The standard of scale was as following (Table 1), and the result indicated mild type.

Two cases were excluded from further examination, because one patient had metallic artifacts and the another refused.

2.2. Checking methods

MRI was performed by a 3.0 Tesla Signa HDx medical MRI scanner (General Electric Co., USA) with twinspeed gradients (maximum gradient strengths of up to Gmax = 50 mT/m; slew rates 150 mT/m/ms, General Electric Co.). The standard 8 channel high resolution brain coil (HRBRAIN, General Electric Co.) was used as the receiver coils. Main parameters were listed in Table 2.

MRS was performed by PROSE–PRESS method. Multiple voxel spectroscopy (SVS) and chemical shift imaging (CSI) were used. Both were localized at the thalamus level, with the largest slice position at lobus frontalis. Main parameters of SVS were TE=35, 20 mm^2 ×20 mm^2 ×20 mm^2, and NEX=8. Main parameters of CSI were TE=144, 10 mm^2×10 mm^2 ×10 mm^2, and NEX=8.

DTI was conducted by standard DW–SE–EPI sequences (TE=85, b=1 000, diffusion gradient direction=6, NEX=16, 128 ×128, and slice=19).

T1/T2/FLAIR/GRE was conducted by standard fast spin echo sequences (TE=10/105/125/25, IR=2 500, NEX=2, 256×256, and SL=19).

The image results of DTI (FA mapping and ADC mapping) and MRS (SVS and CSI) were analyzed by Spectroscopy Evaluation Software (Advance Workstation version 4.4, General Electric Co.).

Region of interest (ROI) was selected manually under double–blind conditions. References were based on o[illegible] images of T2WI and T1WI with symmetry position, avo[illegible]ng large vessels, cerebral spinal fluid, bleeding sites and b[illegible]d skull at the thalamus level of lobus frontal[illegible] CSI ma[illegible] was no less than 10×10, while the voxel [illegible]d its F[illegible] mapping were 12 ± 3.

2.3. Statistical analysis

The data were analyzed by [illegible]test method[illegible] SPSS16.0 software (SPSS, Chicago, III). P [illegible].05 w[illegible]nsided as significance.

3. Results

CT scanning showed no significant abnormalities, without fracture or hemorrhage. Glasgow score was higher than 13.

Results of conventional MRI (including T1, T2, FLAIR, T2* GRE) showed subcutaeous soft tissue swelling (89.5%), skull fracture (10.5%) and extracranial hemorrhage (15.8%), and no intracerebral hemorrhage (Figure 1 A–D, Table 3).

Results of DTI showed 7 cases had change in factional anisotropic (FA) (Table 3). FA value of injured side (0.48± 0.15) was significantly higher than that of control side(0.32 ±0.13) (P<0.05). There was no significant difference in ADC value (0.78 ± 0.09 *vs*. 0.72 ± 0.12, P=0.12)(Fi[illegible]re 2A,B).

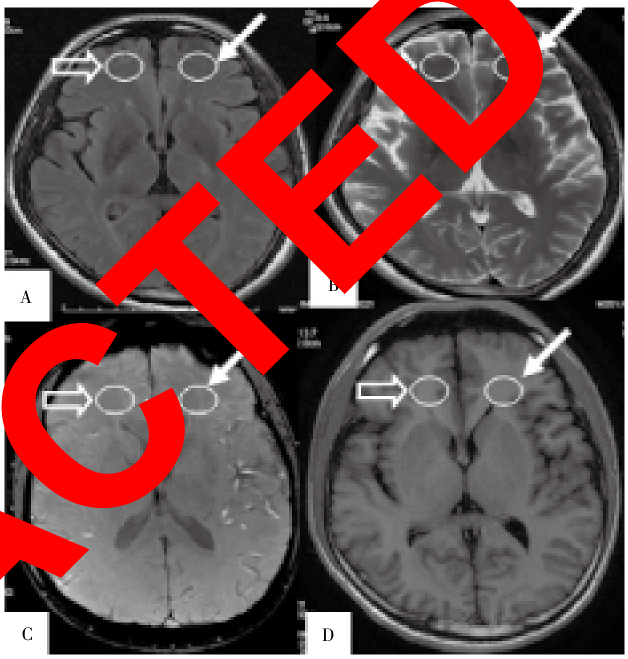

Figure 1. Result of conventional MRI.
A, B, C, D were high resolution FLAIR, T2WI, T1WI and T2* GRE, at lobus frontalis level. ↑ : injured side, ⇑ : control side.

Table 1
Standard of Glasgow[illegible]e.

Points	E[illegible]se	Verbal response	Motor response
1	Not o[illegible]eyes	No sounds	No movements
2	Open in[illegible]e to the painful stimuli	Incompressible sounds	Extension to painful stimuli
3	Open eyes i[illegible] response to the voice	Utter inappropriate words	Flexion/Withdrawal to painful stimuli
4	[illegible]s spontaneously	Confused	Localize painful stimuli
5	N/A	Oriented, converses normally	Localize painful stimuli
6	N/A	N/A	Obey commands

Table 2
Main parameters of conventional MRI, DTI and MRS.

Sequence		TE(ms)	NEX	Matrix	FOV (mm)	Thickness (mm)	Acquisition time(sec)
T1 FSE		14.7	2	256×256	220×220	5	150
T2 FSE		120	2	256×256	220×220	5	100
T2 FLAIR		125	2	256×256	220×220	5	165
T2* GRE		25	2	256×256	220×220	5	145
DTI(DW–SE–EPI)		Min	2	128×128	220×220	5	109
MRS(PROSE–PRESS)	SVS	35	8	1×1	20×20	20	215
	CSI	144	8	18×18	180×180	10	445

DTI diffusion directions= 6; b value=1 000 sec/mm^2.

Table 3
Results of conventional MRI, MRS and DTI (n=19).

Methods	Positive characters	Control side(n)	Traumatic side(n)	Ratio of positive characters (%)
Conventional MRI	Skull fracture	0	2	10.5
	Extracranial hemorrhage	1	3	15.8
	Intracerebral hemorrhage	0	0	0.0
	Subcutaneous soft tissue swelling	2	17	89.5
MRS	NAA/Cr decrease	0	13	68.4
	Cho/Cr increase	1	3	15.8
	Lac/Cr increase	0	7	36.8
DTI	FA value increase	0	5	[illegible]
	FA value decrease	0	2	10.5
	ADC value decrease	0	4	21.1

NAA: N-acetylasparate, Cho: choline, Cr: creatine, Lac: lactic acid.

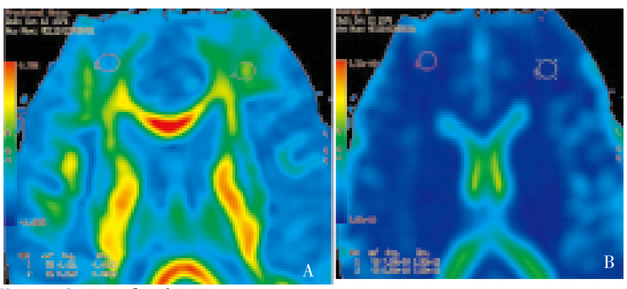

Figure 2. Result of DTI.
A and B were separately high resolution FA mapping and ADC mapping, at the lobus frontalis level.

Results of MRS showed reduced N-acetylasparate/crea[illegible]e (NAA/Cr) at injured side in 13 cases, incr[illegible] choli[illegible] creatine (Cho/Cr) in 3 cases, increased la[illegible] a[illegible] creatin[illegible] (Lac/Cr) in 7 cases (Figure 3 & Table 3)[illegible]A of w[illegible]e matte[illegible] in lobus fontalis was significantly de[illegible]d (P[illegible] L[illegible] significantly increased (P<0.05)[illegible]ho h[illegible] significant change (P=0.02)(Table 4).

Table 4
Results of MRS (n=19).

	NAA/Cr	NAA/Cho	Cho/[illegible]	Lac/Cr
Control side	1.40±[illegible]	1.0[illegible].26	1.32±0.19	0.09±0.05
Injured side	1.07±[illegible]	[illegible]±0.28*	1.33±0.24	0.31±0.25*

*: P<0.05 *vs.* [illegible]ol.

4. Discussion

MTBI is one [illegible]he m[illegible] cause[illegible]r post-traumatic complication[illegible] head inj[illegible]uding brain function failure, ps[illegible]os[illegible]nd mental [illegible]ness[1,2]. Generally MTBI can't be detected [illegible] conventional imaging methods[3], posi[illegible]tection rate[illegible]onventional MRI and CT are low. I[illegible]mergency situations, CT is used as a primary detection m[illegible]hod. Howe[illegible], it is limited in range and degree during ev[illegible]tion of [illegible]l axonal injuries, and repeated CT scans mig[illegible]dioactive injuries. It is needful to develop non-radioactive and highly sensitive tools. Until now, MRI [illegible]ost suitable candidate imaging method for diagnosis [illegible]f acute mild brain trauma, because it has high spatial resolution, high contrast to noise ratio, signal-to-noise ratio, and multiple contrast imaging capacity[2].

With the rapid progress of medical imaging technology especially MRS and DTI, chemical components and composition structure of white matter can be furtherly analyzed, and it is possible to make accurate diagnosis, select suitable treatment and make monitoring[4,5]. In this study, in addition to CT and conventional MRI, DTI and MRS were also used to evaluate the sensitivity and characters of main metabolic peak of MRS and FA values of DTI.

The primary results implied that there was no significant

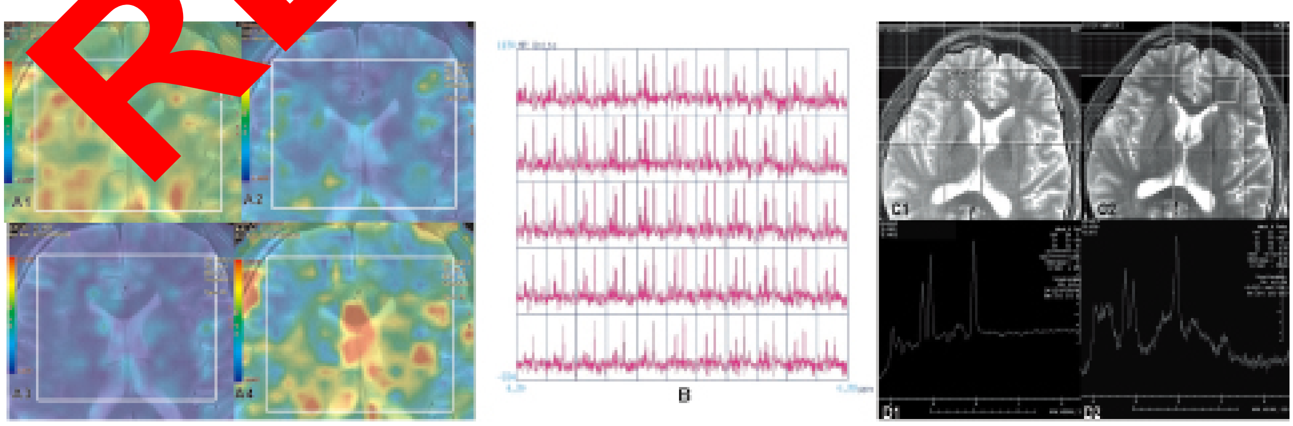

Figure 3. Results of MRS.
A1–4: chemical shift image of NAA/Cr, NAA/Cho, Cho/Cr and Lac/Cr; B: the spectroscopy matrix at same position of A; C1, C2 showed the axial positional mapping of single volume spectroscopy; D1, D2: spectroscopy of white matter at deep lobus fontalis.

difference between CT and conventional MRI, and there was no positive result of T2*GRE. It suggests more sensitive method is needed, Susceptibility weighted imaging can improve the sensitivity of MRI in detection of micro hemorrhagic focus, and has advantage in detection of diffusive axonal injury[6]. It is useful in diagnosis of micro hemorrhage in MTBI. However, this technique is not included in our study due to technical limitations.

It is reported that DWI is more advantageous in detection of range and degree than T2WI and FLAIR. ADC value of white matter is significantly decreased in patients with serious brain trauma. DTI, which was developed from DWI, can measure diffusion abilities in specific direction quantitatively, including rate of isotropy and anisotropy. FA value is a widely used indicator of anisotropic diffusion, with values varying between 0 and 1. The FA value of 0 indicates absolutely isotropic diffusion, like in cerebral spinal fluid, and an FA value of 1 indicates maximum anisotropic diffusion, such as white matter fasciculus. Patients with serious axonal injury have decreased FA due to injury and fracture of nerve fiber. It has been proven that DTI is more sensitive than conventional MRI in evaluation of white matter fasciculus injuries, and it is correlated with Glasgow scores positively[7]. In our study, DTI result showed the 36.8% patients had abnormal FA value, while no change occurred in conventional MRI and CT result. Interestingly, this study indicated that FA value increased rather than decreased. This finding is in agreement with Wildes *et al*. The[illegible] found increased FA, and it may be due to transitory cyt[illegible] brain edema[8].

1H–magnetic resonance spectroscopy [illegible]MRS) i[illegible] non–invasive, and focuses on quantit[illegible]lysis [illegible] main neurometabolites, including NA[illegible]r and [illegible]ho. NAA is regarded as a main marker of ne[illegible]al [illegible] integrity; Cr is a marker of ener[illegible]etabo[illegible]; and Cho is a marker of cell membrane [illegible]rsion. Cho [illegible] increase while NAA will decrease [illegible] to [illegible] of local [illegible]urons. In addition, 1H–MRS can [illegible]asure the [illegible] of Lac, which is a marker of anaerobic [illegible]abolism and m[illegible]e increased due to ischemia or in[illegible]mati[illegible] A lot of researches indicate that neurometab[illegible] d[illegible]urbance is predictive of long–term cogniti[illegible] defe[illegible]d beh[illegible]ral defect of MITB[9,10]. Gasparo[illegible] foun[illegible]o of gray matter in frontal lobe [illegible] correl[illegible]d with s[illegible]al competence and behavioral probl[illegible][11].

In our [illegible], NAA significantly decreased in 68.4% cases within 24 h[illegible]ost MTBI. and Lac increased in 36.8% cases. Cho was seldo[illegible]ltered, only in 21.1% cases. It is deduced that the main pathological changes are loss of neurons or local anaerobic metabolism indicating cell anoxia. Cell membranes were integrated at the early stage of MTBI. But these resumptions still need further investigation.

In conclusion, MRS is the most sensitive method to evaluate MTBI patients, with the reduced NAA peak and increased Lac at local lobus frontalis. DTI is also sensitive to MTBI and more useful than conventional MRI or CT. FA mapping can partially find nerve fiber injuries, and the characteristic change of FA is increase, not decrease during the first 24 hours of MTBI.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgements

This work was supported by the Science Foundation of Haikou Health Bureau (2010–SWY–13–058) and Haikou Science Technology Information Bureu (2009–049–1).

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