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Original Article

Pilot Study of Efficacy of Tongue and Body Acupuncture in Children With Visual Impairment

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ABSTRACT

We studied the efficacy of tongue and body acupuncture in affecting visual recovery in children with central and peripheral visual disorders. Twelve children (five boys, seven girls) (age range 18 months to 14.5 years) with visual disorder with static functional visual ability for at least 12 months were recruited for the study. The causes of cortical visual impairment (10) included severe perinatal asphyxia (4), postencephalitis (1), traumatic brain injury (1), hydrocephalus (1), and increased intracranial pressure (3). Peripheral causes (2) were due to congenital optic atrophy. We used the following assessment tools: clinical visual improvement, defined as improvement of vision by one grade in one or both eyes with measurement of visual acuity; the functional visual outcome scale of 0 to 5, with positive outcome defined as improvement in one level on a functional scale; visual evoked potential, with positive improvement defined as 10% improvement in P100 latency of one or both eyes; [^{18}F]-fluorodeoxyglucose (FDG) positron emission tomography (PET) of the brain, with positive improvement defined as a 10% increase in glucose metabolism in one or both occipital lobes; and the Clinical Global Impression Scale (parental report). Tongue and body acupuncture consisted of 60 sessions, with 5 sessions per week. Four children showed clinical or functional improvement (33%). Of nine children with abnormal visual evoked potentials, five had improvement (56%). Of seven children who underwent PET, six had improvement in glucose metabolism in the visual cortex (86%). Seven parents (58%) reported improvement (three children had 75% improvement; four children had 25% improvement). There was a significant correlation between the interval of onset of visual impairment and starting treatment with clinical or functional outcome, with a longer interval resulting in a better outcome ($P = .0282$). However, there was no correlation between cause, severity, or clinical or functional visual outcome with improvement in the visual evoked potential or PET. We demonstrated that tongue and body acupuncture can improve the visual status of children with visual disorders, both peripheral and central in origin. As children with chronic visual impairment also showed some visual recovery, more studies should be done to assess the full potential of acupuncture as an adjunct to Western medicine in neuroplasticity. (*J Child Neurol* 2006;21:462–473; DOI 10.2310/7010.2006.00105).

Children with visual disorders, especially cortical visual impairment, had to go through the natural course of visual recovery with a visual rehabilitation program. There is no medication or surgical procedure to alleviate partial or complete blindness. The prognosis of visual recovery is unpredictable, and some studies have shown that recovery of function can still occur during the normal developmental process of a child and that the process can take up to 3 years.[1–5]

For children with visual loss owing to traumatic or hypoxic brain injury, the prediction of visual outcome is often difficult. The window of visual recovery is unknown. While waiting for regeneration of visual fibers with an unexpected or even prolonged recovery in any child with sudden visual loss, we wanted to investigate whether alternative therapies have a role as an adjunctive treatment to the Western model of visual rehabilitation.

In traditional Chinese acupuncture, 400 acupoints on the body surface are linked through 14 meridians to various organs of the human body. The approach in traditional Chinese medicine, in sharp contrast to the Western medical concept, is a "holistic" approach, with a philosophical background of balancing the "yin and yang." The main objective of traditional Chinese medicine is to improve the health of the body and the mind. The pathophysiologic basis of traditional Chinese medicine aims to improve "energy" or "body flow" (*de-qui* in Chinese). The effect of acupuncture was proven in animal and human studies to be due to direct neural stimulation, changes in neurotransmitters such as endorphins, and immunologic or endocrine signals. Thus, acupuncture is effective in chronic disorders, especially in neurologic disorders.[6]

Tongue and body acupuncture is an acupuncture technique with acupoints on the tongue and body. With our experience of using tongue and body acupuncture in treating chronic neurologic disorders in adults and children,[7–29] we hoped to undertake the first pilot project to integrate traditional Chinese medicine with Western medicine in visual neuroscience and to determine whether traditional Chinese medicine is useful in affecting visual recovery in children with central and peripheral visual disorders owing to various causes.

METHODOLOGY

We started a research program integrating traditional Chinese medicine with Western medicine in the comprehensive management of children with various neurologic disabilities in March 1999 at The University of Hong Kong. Twelve patients with a central or peripheral visual disorder with a lack of clinical visual recovery for at least 12 months were recruited for the study. All children had a comprehensive neurologic and visual evaluation. Each patient had a baseline visual evaluation and objective assessment before, during, and after treatment. The following assessment tools were used:

1. Clinical visual improvement: improvement of vision by one grade in one or both eyes with measurement of visual acuity using the standard visual charts for children. This is performed only for children who are cooperative and have normal intelligence.
2. Functional visual outcome: a positive outcome defined as improvement of one level on a functional scale:
   - Level 1: light perception only
   - Level 2: occasional fixation on large objects, faces, or movement
   - Level 3: occasional fixation on small object (ie, pennies or stickers) or reliable fixation on faces
   - Level 4: reliable visual acuity not better than 20/50 (both eyes open)
   - Level 5: completely normal vision
3. Visual evoked potential: positive improvement was defined as 10% improvement in the P100 latency of one or both eyes. Children need oral sedation to perform this procedure.
4. [^{18}F]-fluorodeoxyglucose (FDG) brain positron emission tomography (PET): positive improvement means a 10% increase in glucose metabolism in one or both occipital lobes.
5. Clinical Global Impression Scale (CGIS) (parental report): a measure on a Likert scale of 0 to 7. Zero means not assessed, 1 means very much improved (75%), 2 means much improved (50%), 3 means minimally improved (25%), 4 means no change, 5 means minimally worse (–25%), 6 means much worse (–50%), and 7 means very much worse (–75%). The chief caretaker, usually the mother, was asked to fill in a standardized questionnaire about the final score of 1 to 7. This scale has been validated as an assessment tool for global impression after treatment.[30]

The clinical and functional assessments (ie, items 1 and 2) were performed by an optometrist, who had experience in handling disabled children, after getting the cooperation of the visually impaired children. Items 1 to 3 were performed after each course (ie, 20 sessions, 40 sessions, and 60 sessions). Item 4 (brain PET) was performed only if the parents agreed to this procedure. This was performed after completion of two courses of therapy. Item 5 was performed after completion of three courses (ie, 60 sessions).

Tongue and Body Acupuncture Method

This was performed by the second author. As this was a pilot study, with our experience in other neurologic disorders for children, we performed three courses for each patient (total of 60 sessions). This project was preliminarily considered unsuccessful in an individual case if no clinical or functional visual improvement (items 1 and 2) or objective improvement (items 3 and 4) was seen after three courses were tried.

Each course of tongue and body acupuncture consisted of 20 sessions for each course, with 5 sessions performed on a daily basis per week. This lasted for 4 weeks. A rest period of 1 week without acupuncture followed. Visual assessment was performed after the end of the course. Repeated courses were applied until three courses were obtained for each case. Thus, the total duration of treatment for each patient (including the 2-week rest between the first and second courses and the second and third courses) lasted for 6 months.

Tongue and body acupuncture was applied daily to specific acupoints on the tongue and body in the meridian related to visual function of the traditional Chinese medicine concept using a sterile disposable acupuncture needle. Based on the clinical experience of the acupuncturist, three acupoints were used on the tongue: (1) midline between the tip and root of the left lateral surface of the tongue, (2) midline between the tip and root of

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Table 1. Demographic Data of 12 Cases With Visual Impairment

Case	Sex	Age (y, m)	Causes of Blindness (N = 12)	Neurologic Deficit	Mental Retardation	Age at Blindness (y, m)	Interval Between Onset of Visual Impairment and Acupuncture (y, m)
1	F	4, 9	Hydrocephalus, cerebellar hemorrhage	Mild ataxia	Mild	Birth	4, 9
2*	M	6, 8	R optic atrophy, congenital	No	No	Birth	6, 8
3	F	4, 9	Hypoxic-ischemic encephalopathy	No	Mild	3, 7	1, 2
4	F	8, 0	Severe perinatal hypoxic-ischemic encephalopathy	Spastic tetraplegia	Severe	Birth	8, 0
5*	F	14, 7	Bilateral optic atrophy, congenital cytomegalovirus, infection	No	No	Birth	14, 7
6	M	11, 8	Traumatic brain injury	Spastic tetraplegia	Mild	6, 7	5, 1
7	M	11, 6	Hypochondroplasia, hydrocephalus with increased ICP	No	No	7, 2	4, 4
8	F	13, 8	Medulloblastoma, hydrocephalus with increased ICP	No	No	10, 9	2, 11
9	F	1, 6	Post–acute encephalitis	Spastic tetraplegia	Severe	0, 5	1, 1
10	M	11, 8	Congenital hydrocephalus with increased ICP	No	Mild	4, 3	7, 5
11	F	4, 0	Severe perinatal hypoxic-ischemic encephalopathy	Spastic tetraplegia	Severe	Birth	4, 0
12	M	1, 10	Severe perinatal hypoxic-ischemic encephalopathy	Spastic tetraplegia	Severe	Birth	1, 10

ICP = intracranial pressure.
*Peripheral cause of blindness ($n = 2$).

the right lateral surface of the tongue, and (3) midline of the tongue base. Both acupoints 1 and 2 were punctured obliquely at 45 degrees at a depth of 0.3 to 0.5 cm, and acupoint 3 was punctured perpendicularly at a depth of 0.3 to 0.5 cm. For body acupuncture, scalp acupoints near both visual cortices and other body points were punctured. We did not follow the traditional acupuncture method of leaving the acupuncture needles on the scalp or tongue because we found that our disabled children could not tolerate having the needles left on the body for 20 to 30 minutes.

The children attended our acupuncture clinic on an ambulatory basis. The total acupuncture procedure lasted for < 15 seconds for each session. No sedation was required. The child just sat on the mother's lap with the head tilted around 45 degrees upward. Sterile gauze was used to pick up and station the tongue with the examiner's left hand. The child was encouraged to open his or her mouth. Quick and accurate insertion into acupoints was performed with the examiner's right hand. Most children tolerated the procedure well.

Side Effects

The children were monitored for side effects, and the parents were asked to report on any change. A questionnaire on side effects was administered after the course of tongue and body acupuncture treatment. Because this is a pilot research project, the parents were requested to report subtle changes in any behavior or any side effect daily by filling in a standardized diary of clinical response.

Cerebral FDG Metabolism by PET

The subjects were placed in a quiet room with ambient light for 15 minutes before radionuclide injection. FDG per 1.73 m^2 body surface area with dose correction for blood glucose normalized to 5 mmol/L was injected quietly, without disturbing the child. Such an approach tends to minimize the variability caused by glucose level and body size. If necessary, sedation with a lytic cocktail was given 25 minutes later, approximately 20 minutes prior to PET. A three-dimensional brain PET scan was obtained using Siemen's ECAT Exact Scanner (Long Island PET Imaging, New York, NY), acquiring 120 million counts for emission and 50 million/5 minutes counts for transmission. The PET scan was reconstructed using order subset estimation for maximum likelihood in 1 iteration and 30 subsets. The zoom factor was 2.5. Quality control was obtained for reproducibility of baseline and a second scan in terms of blood glucose, mCi dose of FDG injected, the time of performing FDG PET, and the time of sedation to minimize variation in the same patient. The scans were interpreted by the third author.

Altogether, 22 regions of interest for each side of the brain were drawn by expert interaction on the FDG PET scan with the assistance of a template on the transverse slice images of the brain at different levels. The region of interest includes superior, middle, and inferior frontal gyri; precentral and postcentral gyri; superior and inferior parietal lobules; anterior and posterior cingulate gyri; Broca's area; angular gyri; auditory temporal cortex; associative auditory temporal cortex; precuneus; cuneus; lingual gyri; hippocampus; cerebellum; pons; caudate head; lentiform nucleus; and thalamus.

The standardized uptake value maximum and standardized uptake value average of each region were obtained. An increase of 10% between the baseline and post-treatment standardized uptake value (maximum) or standardized uptake value (average) in one or both occipital lobes was considered a significant response.

Statistical Analysis

P values for all statistical tests using the Fisher exact test and unpaired Student's *t*-test were two-tailed and were considered significant if < .05.

Ethical Approval

This study was approved by the Institutional Review Board of the Faculty of Medicine of The University of Hong Kong. The parents were informed about the methodology, and written consent was obtained.

RESULTS

Altogether, 12 cases (5 males, 7 females), aged 18 months to 14.5 years (mean age 7 years 11 months; median 7 years 4 months), were recruited (Table 1). The causes of cortical visual impairment (10) included severe perinatal asphyxia (4), postencephalitis (1), traumatic brain injury (1), hydrocephalus (1), and increased intracranial pressure (3). The peripheral causes (2) were due to congenital optic atrophy, one of which was due to congenital cytomegalovirus infection. The interval between onset of visual impairment and starting tongue and body acupuncture treatment ranged from 13 months to 14 years 7 months. The mean interval was 62 months, and the median was 55 months.

Clinical or Functional Improvement

Three children (cases 1, 2, and 10) showed clinical functional improvement of one level (25%) (Table 2). One case (case 5) had improvement in visual acuity in both eyes without visual functional improvement. Thus, there were four cases with clinical improvement (33%).

Visual Evoked Potential

Of nine children with an abnormal visual evoked potential at baseline, five cases (cases 1, 6, 7, 10, and 11) showed more than 10% improvement in either eye (56%) (Table 3). One case (case 8) with an absent visual evoked potential before treatment failed to achieve any resignaling after treatment.

FDG PET Brain Scan

Brain PET was performed for seven children (Figures 1 and 2 and Tables 4 and 5). Six cases (86%) (cases 2, 4, 5, 6, 7, and 12) showed more than 10% improvement in PET glucose metabolism in one or both occipital lobes.

Illustrative Cases

Cases Without Any Clinical or Functional Visual Improvement (N = 8) (Cases 3, 4, 6, 7, 8, 9, 11, and 12)

The eight cases without clinical or functional improvement were due to cortical causes only. This included perinatal asphyxia (four), acute encephalitis (one), increased intracranial pressure (two), and traumatic brain injury (one) (Table 6). However, from the parental report of these cases, some improvement occurred, as illustrated by the daily diary recordings below.

Case 3 This child could notice large objects and thick lines, could throw a ball to a net at a close distance, and could chase after his maid while holding a ball.

Case 4 This child had improvement in visual and drooling problems. He could read characters, and there was a decrease in the spasticity of the lower limbs, such that he could abduct his hips better.

Case 6 This child had improved right-hand function and improved balance. He was noticed to have less muscle wasting. However, no improvement in vision or memory was noticed.

Case 7 This child had much improved vision of the left eye and mildly improved vision of the right eye. However, there was no improvement in memory, speech, or emotion.

Case 8 A girl with medulloblastoma and hydrocephalus with severely increased intracranial pressure had improvement in the visual evoked potential and PET glucose metabolism without clinical or functional visual improvement. She had a chronic increased intracranial pressure for 3 months with a ventriculoperitoneal shunt inserted. She was found to be completely blind thereafter. After a trial of tongue and body acupuncture, her mother claimed that she walked faster, improved in memory and tactile sensation, and had improved high-frequency sound hearing. She started to play her piano again, which she failed to recognize before.

Table 2. Outcome of Treatment With Clinical Outcome Measures

	Visual Acuity Tests (only if applicable)						*Functional Visual Outcome**			
	Right Eye			*Left Eye*			*Level (Both Eyes)*			
Case	*Baseline*	*Best (Aided)*	*Positive Response*	*Baseline*	*Best (Aided)*	*Positive Response*	*Baseline*†	*Best*†	*Positive Response*	*Clinical Global Impression Scale*‡ *(Parental Report)*
1	6/12	6/9.5	Yes	6/24	6/9.5	Yes	1	4	Yes	1
2§	Light perception	Hand movement	Yes	6/6	6/6	Normal eye	1	2	Yes	1
3	6/19	6/19	No	6/19	6/19	No	4	4	No	3
4	6/48	6/48	No	Finger count (0.5 m)	Finger count (0.5 m)	No	3	3	No	3
5§	6/180	6/48	Yes	6/90	6/72	Yes	4	4	No	4
6	NA	NA	NA	NA	NA	NA	3	3	No	4
7	Finger count (1 ft)	Hand movement	No	6/12	6/12	No	4	4	No	3
8	NA	NA	NA	NA	NA	NA	1	1	No	3
9	NA	NA	NA	NA	NA	NA	2	2	No	4
10	6/15	6/7.5	Normal eye	6/38	6/48	No	3	4	Yes	1
11	NA	NA	NA	NA	NA	NA	1	1	No	4
12	NA	NA	NA	NA	NA	NA	1	1	No	4

NA = not applicable.

*Positive response is defined as one level of improvement.

†Level 1: light perception only; level 2: occasional fixation on large objects, faces, or movement; level 3: occasional fixation on a small object (ie. pennies or stickers) or reliable fixation on faces; level 4: reliable visual acuity not better than 20/50 (both eyes open); level 5: completely normal vision.

‡Clinical Global Impression Scale rating: 0 = not assessed; 1 = +75% improvement; 2 = +50% improvement; 3 = +25% improvement; 4 = no change; 5 = –25% worsening; 6 = –50% worsening; 7 = –75% worsening.

§Peripheral cause of blindness (n = 2).

Table 3. Outcome of Acupuncture With Neurophysiologic and Neuroradiologic Outcome Measures

	*Visual Evoked Potential**						
	Right Eye			*Left Eye*			*Positron Emission Tomography†*
Case	*Baseline*	*Best*	*Positive*	*Baseline*	*Best*	*Positive*	*Occipital Region*
1	246	194	Yes	230	200	Yes	ND
2‡	141	133	No	97	93	Normal	Positive
3	92	92	Normal	106	92	Normal	ND
4	86	80	Normal	138	142	No	Positive
5‡	91.2	86.4	Normal	90.8	88	Normal	Positive
6	279	220	Yes	274	192	Yes	Positive
7	221	187	Yes	290	137	Yes	Positive
8	Absent visual evoked potential signals		No	Absent visual evoked potential signals		No	Negative
9	125	118	No	126	120	No	ND
10	192	108	Yes	239	128	Yes	ND
11	180.8	137	Yes	163.2	130	Yes	ND
12	236	224	No	247	255	No	Positive

ND = not done.
*10% decrease in latency of P100 (milliseconds) as a positive response.
†10% increase in mean standardized glucose uptake value of one or both occipital lobes as a positive response.
‡Peripheral cause of blindness ($n = 2$).

Case 9 The child with acute encephalitis had a complete loss of consciousness, with no viral etiology identified. She also had an infantile spasm with intractable seizures despite multiple antiepileptic drugs. Her mother failed to notice any visual improvement.

Case 11 Although the mother claimed that there was no improvement in vision, she noted that her child cried louder, vocalized more, and had improved standing.

Case 12 This mother noted improved hearing with more smiling and clapping of hands and increased vocalization.

Cases With Neurophysiologic Improvement Without Clinical Recovery (N = 3) (Cases 6, 7, and 11)

Case 6 This boy sustained severe traumatic brain damage in a car accident with total loss of consciousness for 3 months. His vision stayed at level 1 for at least 5 years before the trial of tongue and body acupuncture was performed. He had improvement in visual evoked potential and PET glucose metabolism, without any clinical or functional visual improvement. The P100 latencies of his right eye decreased from 279 to 220 milliseconds and of his left eye from 274 to 192 milliseconds. His PET scan showed dramatic improvement in glucose metabolism (right = increased by 215%; left = increased by 183%).

Cases Without Clinical or Functional Visual Improvement but a Positive Positron Emission Tomography Response (N = 6) (Cases 4, 5, 6, 7, and 12)

Of seven PET scans performed, six showed positive responses. The PET metabolism also showed improvement of > 10% in other brain regions (five each in the frontal and temporal lobes and cerebellum; four in the thalamus, and three each in the caudate and pons). These correlated with parental reports of improvement in other functions despite a lack of visual recovery (see Tables 4 and 5 and Figures 1 and 2).

Cases With Positive Clinical or Functional Visual Improvement (N = 4) (Cases 1, 2, 5, and 10), of Which Only Two Had a Positive Visual Evoked Potential Response (Cases 1 and 10) and One Had a Positive PET Response (Case 5)

Case 1 Our first case was a girl of 4 years 9 months. She had hemorrhage into both cerebellar hemispheres on day 1 with hydrocephalus. A ventriculoperitoneal shunt was inserted. She had severe delay in development, with ataxia and cortical visual impairment. She had cyclic vomiting syndrome that was unresponsive to conventional antiemetics and was referred to the first author at age of 3 years 9 months. A course of tongue and body acupuncture was performed to treat her vomiting. Her intractable vomiting subsided within 1 week, and she spontaneously reported that she could see shadows, butterflies, and color at a close distance over the course of 2 months. Her visual recovery was steady with a continuous course of tongue and body acupuncture, with improved vision for objects at a distance. She was then prescribed a corrective lens and was ambulatory after 5 months, with much improved vision. Her vision did fluctuate with a decrease in visual acuity after the full course of tongue and body acupuncture was finished. Subsequent repeated tongue and body acupuncture courses improved her vision to a plateau level. Her mother claimed that she could focus better and her eye-hand coordination improved, and she could see at greater distances and finer objects. Her mother noted improvement in both eyes.

Case 2 This boy with congenital right optic atrophy was accidentally noted to have total blindness of his right eye while playing the "peek a boo" game with his mother when his left eye was covered. After a course of treatment, his mother noted that his right eye recognized objects and color at arm distance, and then he started to count fingers with his right eye at 0.5 m.

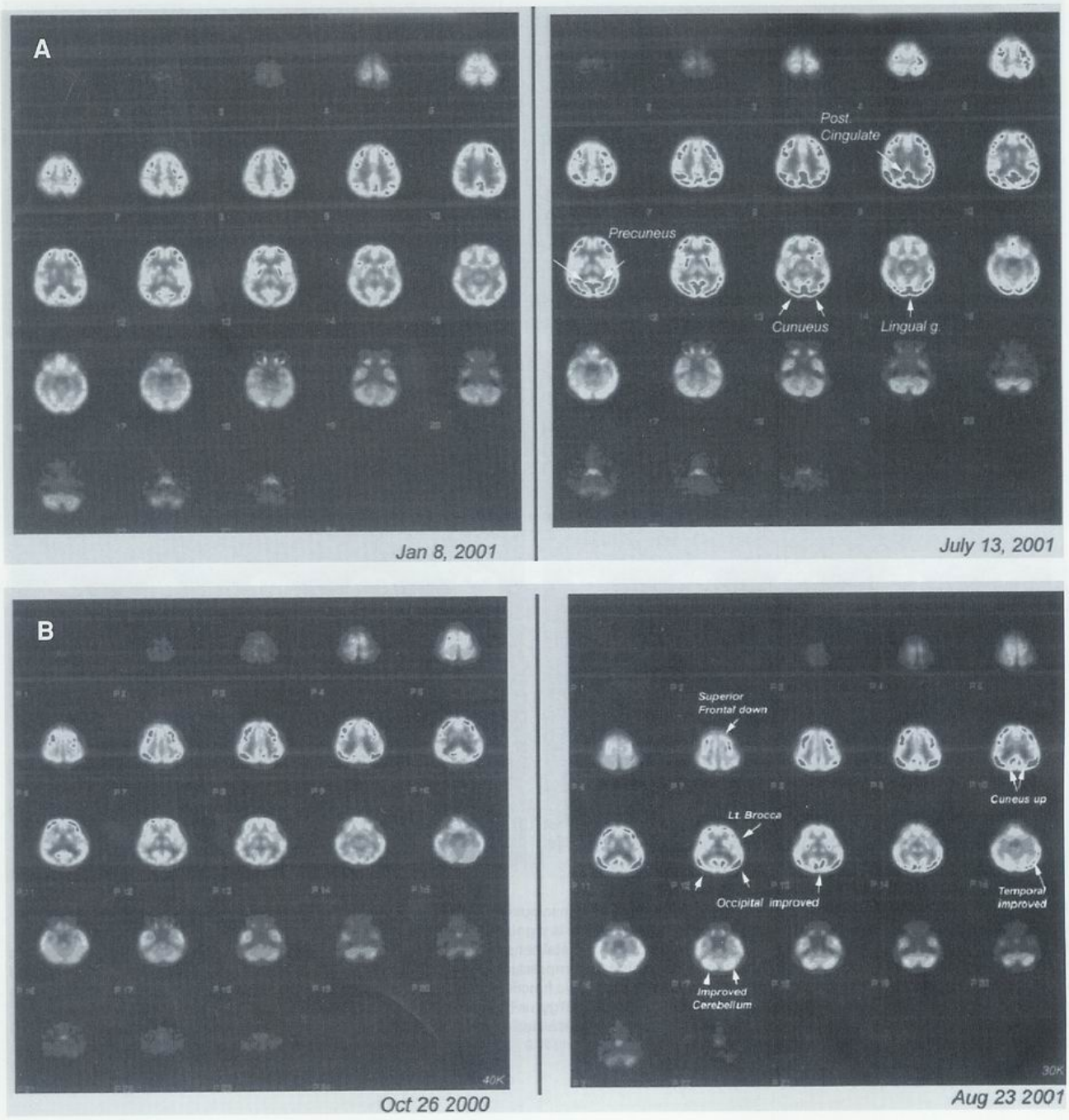

Figure 1. Brain positron emission tomography (PET) of five cases with a positive response. *A,* Case 2: congenital right optic atrophy. There is marked improvement in cerebral metabolism, mostly noted in the cuneus (visual association cortex), which suggests that there is an increase in the processing of visual information (right +97%, left +85.1%). There is also improvement in the visual cortex in the lingual gyrus (right +56.3%, left +57.2%). There is also marked improvement in frontal, parietal, and temporal lobe functions. *B,* Case 4: severe perinatal asphyxia resulting in severe mental retardation and spastic tetraplegia. Overall cerebral cortical metabolism shows no significant interval change. There is a significant improvement in occipital lobe metabolism, which correlates well with the clinical finding of visual impairment. There is also improvement in temporal lobe, basal ganglia, cerebellum, vermis, and pons metabolism. There is mild down-regulation of superior frontal lobe metabolism.

Case 5 This girl had slight improvement in vision, could see objects further away, and improved in English dictation owing to improved memory. Her teacher noted that she understood better.

Case 10 Another boy, age 11 years 8 months, had congenital hydrocephalus with a ventriculoperitoneal shunt inserted at 3 months. He had left optic atrophy, leading to complete blindness of his left eye. His visual recovery with tongue and body acupuncture was first seen after 4 weeks. He had slow but steady improvement in visual acuity of his left eye; he regained his confidence and was fully ambulatory in the community. His mother reported that he could walk downstairs for more than 50 steps and crossed the street

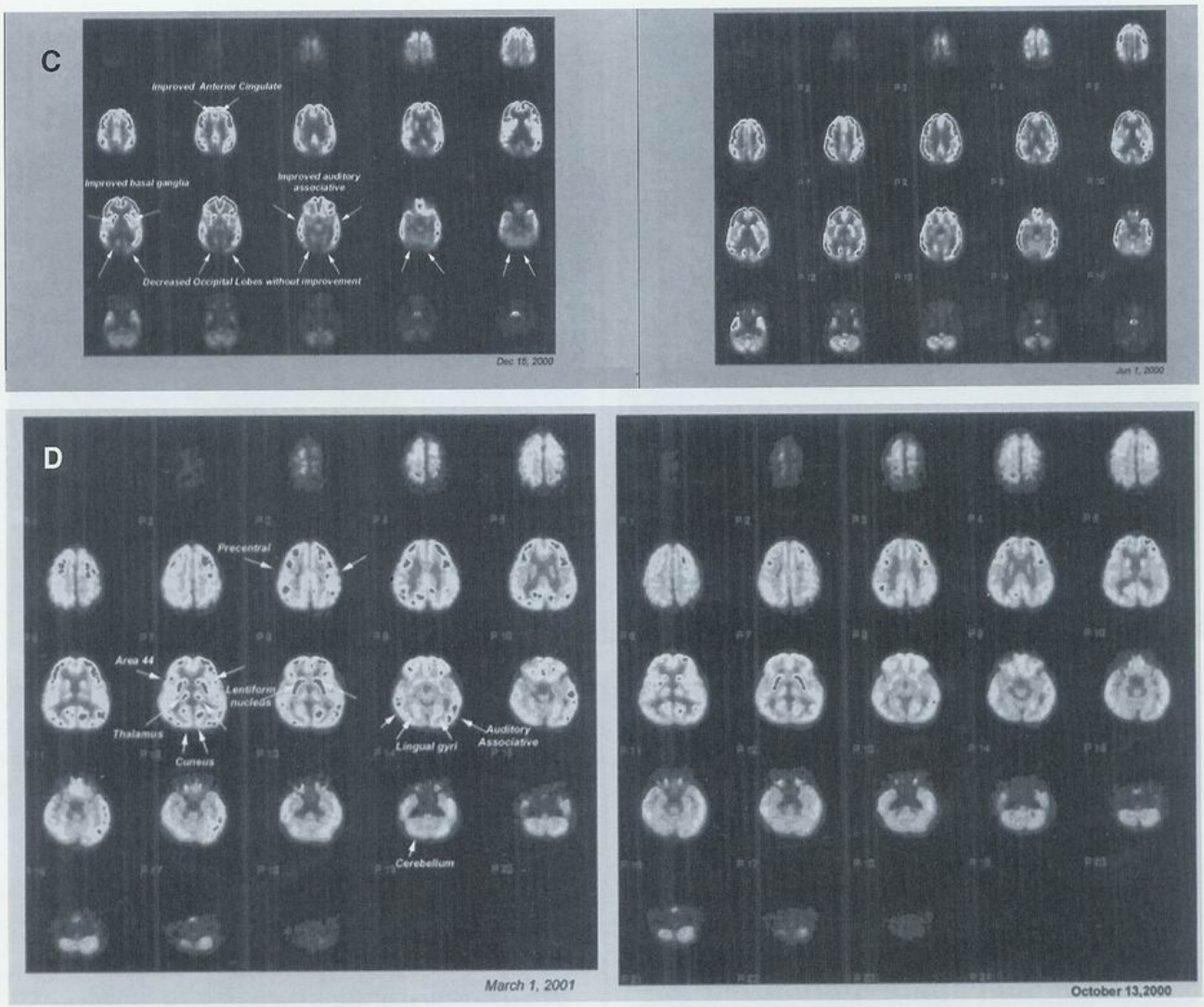

Figure 1. *continued C,* Case 6: traumatic brain injury with loss of consciousness for > 3 months. There is marked improvement in visual associative function, memory, and cerebellar function after treatment. There is significant improvement in the anterior cingulate gyri, basal ganglia, auditory cortex, and auditory associative cortex. The frontal motor and parietal sensory function appeared to be unchanged. *D,* Case 7: hypochondroplasia with hydrocephalus and increased intracranial pressure leading to compression of both optic nerves. There is mild improvement (+12.9%) in global cortical metabolism. There is significant improvement in the metabolic function of the right primary visual lingual gyrus (+18.1%), left lingual gyrus (+17.4%), bilateral cuneus (right +24.4%, left +21.9%), bilateral precentral gyrus (right +17.9%, left +26.9%), bilateral anterior cingulate gyri (right +32.9%, left +27%), bilateral frontal operculum, both thalami, bilateral lentiform nucleus (right +42.2%, left +36%), right auditory cortex, bilateral auditory associative cortex, right cerebellum, and right pontine area.

alone after the full course of tongue and body acupuncture. He had better eye contact, improved comprehension, attention span, and emotion; he would talk and ask more questions, respond to others, and was willing to join activities.

Summary of Outcome Data for 12 Cases

The final outcome of 12 cases is listed in Table 6. It seems that parents noted overall improvement more than the clinical and objective outcome measures.

Correlation Between Onset of Visual Impairment and Acupuncture Treatment With Any Outcome Using the Unpaired Student's t-Test

The mean age of those (n = 4) with improvement in clinical or functional outcome is 100.25 months (95% confidence interval = 18.1–182.4 months; SD = 51.6 months). The mean age of those (n = 8) without improvement in clinical or functional outcome is 42.6 months (95% confidence interval = 19.2–66.0 months; SD = 28.0 months). The difference in the mean age

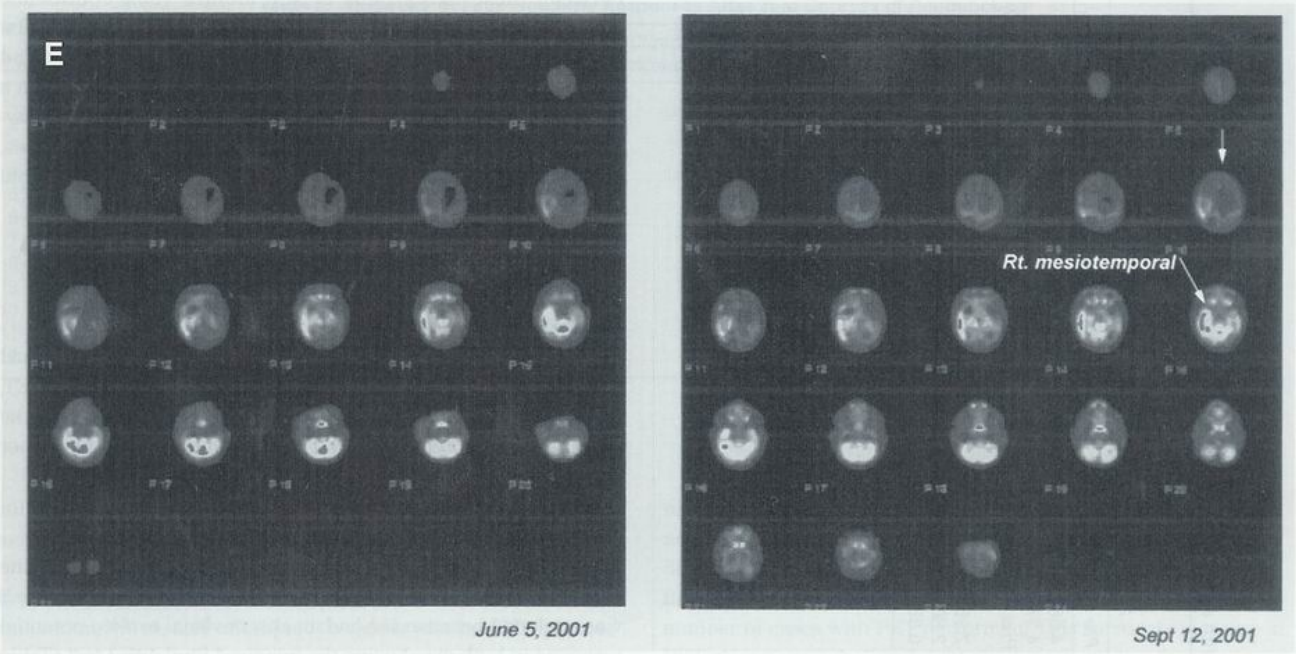

Figure 1. *continued E,* Case 12: severe perinatal asphyxia resulting in severe mental retardation and spastic tetraplegia. There is 19.6% improvement in cerebral cortical standardized uptake value maximum and significant improvement in frontal and parietal lobe metabolism. However, the actual functionality of the cerebral hemisphere in the frontal, parietal, and occipital lobes is still markedly impaired. The right inferior temporal lobe has good metabolism, and this is probably the only area of significant function remaining in the cerebrum. There is some improvement in the mesiotemporal lobe on the right side compared with before treatment. The cerebellum is down-regulated, and the hypermetabolic activity seen in the vermis has now returned to normal. There is no significant interval improvement seen in basal ganglia, thalamus, and pontine function.

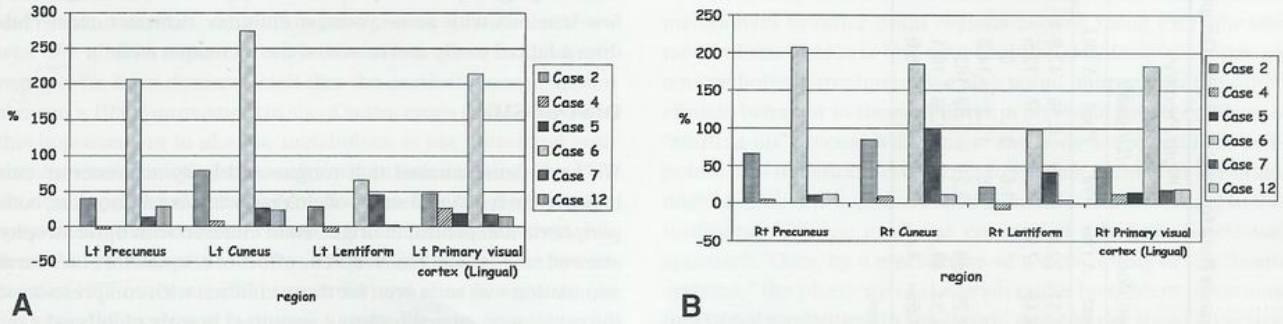

Figure 2. Positron emission tomographic (PET) scan of the brain showing a positive response in six cases. *A,* Percent change in the mean standardized uptake value of glucose in the left occipital lobe. *B,* Percent change in the mean standardized uptake value of glucose in the right occipital lobe.

Table 4. Comparison of Positron Emission Tomography Glucose Response in Six Positive Cases

Case	*Frontal*	*Parietal*	*Temporal*	*Occipital*	*Caudate*	*Thalamus*	*Cerebellum*	*Pons*
2*	+	+	+	+	+	+	+	–
4	+	–	+	+	–	–	+	–
5	–	–	+	+	+	+	+	–
6	+	+	+	+	+	+	+	+
7	+	–	+	+	–	+	+	+
12	+	+	–	+	–	–	–	–

+ = increase by > 10% glucose metabolism in any one region.
*Peripheral cause of blindness (n = 2).

Table 5. Standardized Uptake Value of Glucose Data for Regions in the Occipital Lobe in the Six Cases With a Positive Positron Emission Tomography Response

Case	*Right Precuneus*			*Right Cuneus*			*Right Lentiform*			*Right Primary Visual Cortex (Lingual)*			*Left Precuneus*			*Left Cuneus*			*Left Lentiform*			*Left Primary Visual Cortex (Lingual)*		
	Pre	*Post*	Δ *(%)*	*Pre*	*Post*	Δ *(%)*	*Pre*	*Post*	Δ *(%)*	*Pre*	*Post*	Δ *(%)*	*Pre*	*Post*	Δ *(%)*	*Pre*	*Post*	Δ *(%)*	*Pre*	*Post*	Δ *(%)*	*Pre*	*Post*	Δ *(%)*
2*	5.28	8.77	66.1	5.23	9.78	84.1	5.81	7.11	22.4	5.65	8.35	47.9	6.10	8.51	39.6	4.68	8.39	79.1	5.83	7.45	27.7	5.86	8.60	46.7
4	5.21	5.45	4.8	4.41	4.83	9.5	4.88	4.49	−7.9	4.33	4.87	12.5	5.39	5.22	−3.1	4.37	4.74	8.4	4.76	4.39	−7.7	4.03	5.09	26.2
5*				Pre: 8.7 Post: 8.7Δ: 0†						11.6‡	11.6	0				Pre: 8 Post: 8.6 Δ: 7.5†						10.7‡	10.5	−1.87
										11.5§	13.2	14.8										12.4§	14.7	18.6
6	2.78	8.54	207	3.59	10.25	186	6.20	12.25	98	2.70	7.63	183	2.64	8.10	207	2.95	11.08	276	6.07	10.02	65	3.05	9.60	215
7	3.63	4.03	11.0	2.52	3.42	35.9	3.07	4.34	41.8	2.84	3.36	18.1	4.01	4.55	13.4	2.86	3.61	26.3	3.37	4.86	44.2	3.16	3.71	17.4
12	0.83	0.93	11.5	1.10	1.23	11.6	1.90	1.99	4.6	1.87	2.22	18.6	0.71	0.90	27.6	0.85	1.06	23.9	1.69	1.73	2.3	1.45	1.66	14.2

Pre = before acupuncture; Post = after acupuncture; Δ = change in percentage.
*Peripheral cause of blindness (*n* = 2).
†Data for the visual association cortex.
‡Data for the superior occipital lobe.
§Data for the inferior occipital lobe.

between these two groups is 57.6 months (95% confidence interval =7.5–107.7 months). There was a significant correlation between the interval of onset of visual impairment and starting treatment with clinical or functional outcome, with a longer interval resulting in a better outcome (P = .0282). However, there was no correlation with other outcome measures, such as the visual evoked potential, PET, or the Clinical Global Impression Scale.

Correlation of Cause or Severity of Visual Disorder or Clinical Outcome With Improvement in Visual Evoked Potential or PET of the Brain

There was no correlation between clinical or functional visual outcome and improvement in the visual evoked potential or PET, nor was there any correlation between cause and severity with the visual evoked potential or PET improvement using the Fisher exact test.

Analysis of Visual Evoked Potential Outcome

We analyzed the visual evoked potential outcome of eight of nine cases with abnormal visual evoked potentials at baseline (case 8 was excluded because she had an absent visual evoked potential response in both eyes) using the unpaired Student's t-test (Table 7). The improvement in the visual evoked potential as measured by the mean difference of post- minus pretreatment visual evoked potential of the right eye and the left eye were 37.475 and 51.4 milliseconds, respectively, with corresponding P values of .154 and .088, respectively.

Side Effect

Initial crying for fear and possible minor pain occurred in the first few sessions with some younger children. However, most children adapted easily and tolerated the technique well.

DISCUSSION

We have demonstrated that tongue and body acupuncture can improve the functional status of children with visual disorders, both peripheral and central in origin. Both children with optic atrophy showed some visual recovery. The effect of acupuncture on neural stimulation was seen even for those children with compression of the optic nerve visual pathway sustained in early childhood. Our visual recovery pattern showed that children could still sustain some visual recovery despite more than 10 years of deprivation of vision (ie, case 5; bilateral optic atrophy possibly owing to congenital cytomegalovirus infection). Our results also showed that children need repeated neural stimulation of the visual neural pathway for a stepwise sustained visual response. Their objective visual assessment showed that deterioration occurred in some during the interval between the courses. However, the long-term efficacy of repeated courses of acupuncture in functional visual improvement needs to be further explored.

The usefulness of the visual evoked potential in monitoring visual recovery and predicting prognosis has been quite controversial.[31–33] We have demonstrated that the visual evoked potential is useful in monitoring visual recovery in this cohort because clinical testing with visual acuity or functional level testing might not be sensitive enough to document any subtle improvement after chronic visual deprivation. Of our children with abnormal visual evoked potentials at baseline, 56% showed improvement. There are

Table 6. Summary of Final Outcome Responses After Two Courses of Acupuncture

Case	Blindness (Right/ Left/Bilateral)	Clinical/Functional Outcome	Clinical Global Impression Scale	Visual Evoked Potential	Positron Emission Tomography
1	Bilateral	+	+	+	
2*	Right	+	+		+
3	Bilateral		+		
4	Bilateral		+		+
5*	Bilateral	+			+
6	Bilateral			+	+
7	Bilateral		+	+	+
8	Bilateral		+		
9	Bilateral				
10	Left	+	+	+	
11	Bilateral			+	
12	Bilateral				+

+ = positive response as defined in the Results section.
*Peripheral cause of blindness (n = 2).

still other visual parameters, such as color, perception, depth, and movement, which can be difficult to test in uncooperative children.

With available functional neuroimaging modalities such as PET to show quantitative data with good spatial resolution for visual simulation,[34–39] we also attempted to assess whether PET glucose metabolism can be used as a surrogate marker for visual recovery. We wanted to assess whether PET glucose metabolism is more sensitive than the visual evoked potential and whether these objective parameters can precede clinical recovery in children who are usually not cooperative during clinical visual testing.

We used the standardized uptake value rather than the cerebral metabolic rate for glucose to assess FDG PET images. The standardized uptake value is defined as the ratio of activity in tissue per milliliter to the activity in the injected dose per body weight and is not an absolute value. Thus, we cannot conclude that there was any absolute change in glucose metabolism in the brain regions. We have demonstrated that the cortical glucose uptake showed > 10% improvement in six of seven cases (86%). However, this improvement in glucose metabolism is not correlated with simultaneous clinical visual acuity or functional testing. Our PET data did support a clinical observation noted by the parents, who were usually more observant about any subtle changes in their children. As we wanted to achieve standardization for our assessment of PET outcome, PET was performed after 40 sessions (or 2 courses) of treatment in this pilot study. We postulate that with repeated tongue and body acupuncture, there is stimulation of the neural networking with the visual cortex, although there was a lack of correlation with clinical improvement in some cases for the initial phase of two-course treatment. This might be due to the small number of cases with PET performed. This surrogate increase in PET glucose metabolism might need more studies for confirmation as a useful surrogate marker for visual recovery. The change in glucose metabolism in the PET scan might provide an objective measurement of the observed clinical change. We propose that in future studies, with ethical approval and parental consent, repeated PET scanning after each course of treatment might reveal more useful data for the prediction of visual outcome in vision neuroscience research.

Our study showed that there was improvement in glucose metabolism in other brain regions as well using PET glucose metabolism. This is in line with traditional Chinese medicine as a more holistic treatment. We also noted improvement in other clinical behavior in those children with visual recovery. Thus, a "starting-up" process with tongue and body acupuncture to acupoints rich in neural networking to various regions of the brain might explain the improvement in general status according to the traditional Chinese medicine concept of a holistic functional approach. Thus, by a mechanism of renetworking of the "brain systems," the plasticity of the brain might be evident in various functional modalities. In the future, one can use these objective

Table 7. Comparison of Visual Evoked Potential Response in Eight Cases After Acupuncture Using the Unpaired Student's *t*-Test

	Right		*Left*	
Number of eyes	8		8	
Mean difference of P100 latency	–37.475		–51.4	
95% CI	(–15.9–90.85)		(–8.712–111.51)	
P value	.1543		.088	
	Pre	*Post*	*Pre*	*Post*
Mean P100 latency (ms)	202.6	165.13	213.4	162
SD	52.886	46.44	62.614	48.606
95% CI	158.38–246.82	126.29–203.96	161.04–265.76	121.36–202.64

CI = confidence interval.
A minus sign indicates improvement.
Case 8 was omitted because she had an absent visual evoked potential response at the baseline evaluation.

surrogate markers to confirm any philosophical approach in neuroregeneration and assess for any correlation of corresponding clinical functions, such as attention, memory, cognition, language, and motor and fine motor skills, with brain glucose metabolism.

One limitation of this study is the lack of a control group for comparison. However, we demonstrated in another randomized controlled study that tongue acupuncture can improve function in children with other chronic disabilities, such as cerebral palsy, compared with a control group on the Gross Motor Function Measure.[40] As PET is a very expensive tool to perform twice, it has been difficult for us to recruit subjects in the control group. Moreover, using the ABA approach is also difficult because it meant that at least four PET scans had to be performed for any child in this study. If three courses of acupuncture were used (ie, baseline and after each acupuncture course), parents were quite reluctant to have their children with severe chronic disability subjected to sedation at least three times within 4 months for PET scans, although our Institutional Board of Review had approved such an evaluation for research purposes. Thus, we were left with performing this pilot study to see whether the PET scan can be used as a surrogate marker for improvement. Moreover, with our experience and others, there would not be any major clinical improvement for children with visual impairment that had been static for more than a year with any treatment modalities given for 4 months, as in our study.

With our previous experience of using PET glucose metabolism as a surrogate marker for improvement in brain function in children with autistic spectrum disorder by correlating with clinical improvement, we found that a 10% increase in glucose metabolism, taken arbitrarily, is a suitable value for demonstrating improvement in glucose metabolism on a PET scan.

In the traditional Chinese medicine model, there are 14 meridians and > 400 acupoints in the normal human body. The acupoints in the tongue correspond to various organs and meridians of the human body. These, in turn, are linked to various diseases, according to the "Zung-Fu" concept (or the "organ" concept). If we approach neurologic diseases from a functional point of view, stimulating the acupoints will improve functions in specific aspects, such as visual impairment. This is a new way of looking at cortical visual impairment from the philosophy of traditional Chinese medicine.

The tongue is full of neural networks, and the connection between the tongue and the brain, especially the occipital cortex, with the nearest neural pathway, to other parts of the brain, such as the temporal lobe, can gradually reinnervate another neural pathway with repetitive stimulation. The reinnervation of a neural network might help reestablish the link with any dormant neural networks, thus compensating for the visual loss.

Thus, when approaching cortical visual impairment from the Western medicine model, one should also analyze the possible improvement in children in terms of overall function from the traditional Chinese medicine perspective. Thus, we consider acupuncture an adjunctive treatment program for children with cortical visual impairment.

We have demonstrated that in children with visual impairment, especially those with cortical causes, functional visual recovery can be achieved with repeated neural stimulation with traditional Chinese medicine using acupuncture. With acupuncture, especially when neural stimulation was applied to the tongue, which is closely connected to the visual pathway in the occipital lobes, plasticity of the brain can still occur. Further research is needed with more patients in different subcategories of visual impairment with injury sustained at various ages of life to assess the most critical period for acupuncture application for visual recovery.

Some studies reported that dormant multipurpose neurons can take over function with neural stimulation.[38,39] In future studies, we still need to assess other parameters, such as factors contributing to efficacy, and the intermediate and long-term efficacy of acupuncture in neuroregeneration. We have demonstrated the potential use of PET as a possible surrogate marker to document objectively the efficacy in clinical improvement with regional brain glucose metabolism. We hope that the natural course of children with cortical visual impairment can be evaluated with PET as well to assess the real use for visual recovery.

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