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Is it possible to restore function with two percent surviving neural tissue?

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† In memoriam

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ABSTRACT

How much surviving normal neural tissue is required for functional reorganization after a lesion? Clinical and experimental studies suggest that at little as two percent remaining tissue may be sufficient, at least in some cases, for functional reorganization. Recent sensory substitution studies with person who have been diagnosed with total vestibular loss (e.g., due to an ototoxic reaction to an antibiotic) suggest that the persisting function after removal of the substitution system may be related to the survival of a small amount of vestibular tissue.

KEY WORDS: *Brain plasticity, functional reorganization, stroke, vestibular loss, brain damage.*

RESUMEN

¿Cuánto de tejido nervioso sobreviviente normal se requiere para la reorganización funcional después de una lesión? Los estudios clínicos y experimentales sugieren que puede ser tan pequeña cantidad como un dos por ciento del tejido restante, por lo menos en algunos casos, para la reorganización funcional y mantener actividades de la vida diaria. Los estudios recientes de substitución sensorial muestran cómo una persona que ha sido diagnosticada con una pérdida vestibular total (la función que queda después de perder el sistema sensorial del equilibrio, por ejemplo, debido a una reacción ototóxica a un antibiótico), al aplicar un sistema de substitución sensorial y mejorar dicha función, puede relacionarse a la supervivencia de una cantidad pequeña de tejido vestibular.

PALABRAS CLAVE: Plasticidad cerebral, la reorganización funcional, golpe, pérdida vestibular, daño del cerebro.

INTRODUCTION

A recent study[1] demonstrated persisting function after a period of use of a vestibular substitution device. The therapeutic effect demonstrated by research subjects strongly suggests the persistence of a small amount of surviving vestibular sensory tissue. This re-opens a question regarding the percentage of neural tissue required to restore function after brain or neural tract damage. Previous studies suggest that as little as 2 percent of surviving neural tissue in a system can serve as the basis for functional reorganization.

"It is evident from Glees' studies on hemispherectomy[2] that reorganization of function can occur after a great amount of brain has been lost. Animal studies reveal that as little as 2% of remaining neural tissue in a particular system can mediate a high degree of function: Galambos et al[3] destroyed up to 98.5% of the optic track fibers in the cat and a few weeks after the lesions, they found almost normal visual behavior. Pattern discrimination was present and visual evoked potentials had approximately the same amplitude as pre-operatively. Previously, Lashley[4] had demonstrated that complex visual discrimination and visual behavior could be maintained in the rat if only 2% of the visual cortex remained".

Some unusual cases of recovery have been reported in the past, hut in the century 2 (from approximately 1860 to 1960) in which concepts of brain plasticity were not within the conceptual substance of the neurosciences,[5] clinicians and investigators were reluctant to report such findings. Almost 30 years ago,[6] had reported the following:

"Rasmussen (personal communication) discussed the unpublished case of a man who became paraplegic following an automobile accident, hut gradually regained complete function and was able to enlist in the U.S. Navy. He served three enlistment periods with no physical limitations. He died in a second automobile accident. Autopsy revealed that a complete (approximately 1 cm) separation of the spi-

nal cord at the level of T7 had resulted from the first accident. However, microscopic study revealed (approximately 1 cm) cylinders embedded in the fibrous tissue separating the two portions of the spinal cord. Thus, it is likely that recovery was obtained by the functional reorganization of the input to the cell bodies of the 150 remaining fibers, as well as the possible redirection of the axon terminals".

A comparable case was published by Aguilar:[7] it was a case that "...offered an unusual opportunity to relate brain plasticity to recovery of function following a stroke. Due to the conjunction of various factors: a cerebral vascular accident to a previously intact elderly person; an intensive therapy program; a high degree of motivation and family involvement; an excellent recovery over a period of several years; a post-mortem examination following death seven years after the cerebral vascular accident, from an unrelated cause".

PATIENTS AND METHODS

The patient was a 65 year old college professor who returned to full time work 3 years after the event and continued to he employed until his death. He led an active life and died at age 72 of a myocardial infarction which occurred during a mountain hiking trip at an altitude of 9,000 feet. An extensive home rehabilitation program led to significant motor recovery over a 5–year period. After extensive brain damage, the functional rehabilitation apparently unmasked previously existing pathways that, prior to injury, had not had the same relationship to the recovered functions. The damage included the destruction of the pyramidal tract, verified at autopsy 7 years later, which contained only approximately 3% of normal appearing axons scattered throughout the scar tissue, which may have been a morphological base of the functional reorganization. His home program emphasized very high patient participation in the continuing rehabilitation process.

RESULTS

In one extensively studied vestibular substitution subject who demonstrated residual benefits, the persistence of a sensing system should he necessary, especially since she is able to maintain balance even in a totally dark room (which eliminates the visual input) and can perform normal activities such as riding a bicycle (see web page www.brainportinfo.com). Close questioning of the subject revealed that, although she received a diagnosis of "total vestibular loss" both in her local hospital and at a national vestibular function laboratory, she was minimally nauseated at the end of a Barany chair rotation test. This suggests the persistence of at least a small amount of vestibular system tissue; it may be enough for the results obtained after the end of the vestibular substitution sessions.

Why did the therapeutic effect last for only a few seconds with a 1 minute trial or for a few hours with a 20 minute session? Following the vestibular substitution results, we postulated that in the absence of the integrated inputs to a normally closed-loop multisensory control process, an intrinsically unstable system becomes vulnerable to noise (from both internal and external sources). The recordings show the dramatic effects of the open-loop control system, which is evidently suppressed for a short time by the therapeutic effect.

DISCUSSION

Receptor plasticity, both at synapses and on the ceil membrane away from synapses (reached by volume transmission), may play a major role in the reorganization of function after brain damage. Volume transmission may also he the principal means of neurotransmission in the noradrenergic system, which is involved in so many activities related to recovery from brain damage. Both acetylcholine and norepinephrine can provide a state of excitability consistent with cognition, which is consistent with inhibition of the locus ceruleus activity during lack of vigilance.[8] These findings may relate directly to the results of rehabilitation programs: when vigilance is high and the patient is actively involved, good results are more likely to be obtained. There may also he a relationship to functional rehabilitation programs that are based on the interests of the individual patient, and to the positive results obtained with some home programs. In these cases, the increased vigilance and participation may lead to greater locus ceruleus production of noradrenaline. This and other neurotransmitter changes may also be mechanisms by which psychosocial factors influence recovery.[9]

Thus, at least in certain cases, a small amount of remaining nervous tissue may be a sufficient neural substrate. But how can this occur? One possibility is suggested by Wall's studies: unmasking, (as described by Wall)[10] may play a role in the reorganization.

His experiments revealed pathways that exist in the normal state, but do not showed to function until "unmasked", after injury or temporary conduction block. Comparably, the existence of weak non-visual inputs to cells of the cat primary visual cortex had previously been demonstrated; the responses to light were tightly grouped around a mean of 33 milliseconds in latency while those to sound and pinprick were spread out around means of 63 (sound) and 70 (pinprick) milliseconds.[8] Further, these responses to sound and pinprick were less synaptically secure, being less resistant to barbiturate narcosis than the visual responses. Studies in adult congenitally blind persons reveal that the non visual inputs to the visual cortex become prominent.[11]

CONCLUSIONS

These more tenuous pathways may be the type of unmasked pathways that are unmasked following neural lesion, if there

is an appropriate rehabilitation or substitution program, and if there is the functional demand and the motivation to obtain the increased function.

This matter is by no means resolved, and a goal of this communications is to stimulate discussion and research on the fascinating question of the amount of surviving neural tissue necessary for recovery of function.

REFERENCES

1. Bach-y-Rita P. *Plastic brain mechanisms in sensory substitution.* In: Zulch K, Creutzfeldt O, Galbraith G (Eds.). Cerebral Localization. Berlin: Springer-Verlag. 1975:203-16.
2. Glees P. *Functional reorganization following hemispherectomy in man and after small experimental lesions in primates.* In 1'. 1980.
3. Galambos R, Norton TT, Frommer OP. *Optic tract lesions sparing pattern vision in cats. Exper Neurol 1967;18. 8-25.*
4. *Lashley KS. The mechanisms of vision. XVI. The functions of small remnants of the visual cortex.* J Comp Neurol 1939;70:45-67.
5. Bach-y-Rita (Ed.). *Recovery of Function: Theoretical Considerations for Brain injury Rehabilitation.* Bern, Switzerland: Hans Huber. Publisher 106-26.
6. Tyler M C, Danilov Y, Bach-y-Rita P. *Closing an open-loop control system: vestibular substitution through the tongue.* J Integrative Neurosci 2003;2:159-64.
7. Aguilar MJ. *Recovery of motor function after unilateral infarction of the basis pontis.* Amer J Phys Med 1969;48:279-88.
8. Murata K, Cramer H, Bach-y-Rita P. *Neuronal convergence of noxious. Acoustic and visual stimuls in the visual cortex of the cat.* J Neurophysiol 1965;28:1223-39.
9. Bach-y-Rita P, Wicab Bach y Rita E. *Biological and psychological factors from recovery in brain damage in humans.* Canadian Journal of Psychology 1990;44:148-65.
10. Wall PD. *Mechanisms of plasticity of connection following damage in adult mammalian nervous systems. In: Bach-y-Rita P (Ed.), Recovering of function: Theoretical considerations for brain injury rehabilitation.* Ber, Switzerland: Hans Huber. 1980:91-105.
11. Wanet-Defalque MC, Veraart O, DeVokler A, Metz R, Michel C, Dooms O, Goffinet A. *High metabolic activity in the visual cortex of early blind human subjects.* Brain Res. 1988;446:369-73.