Is there a connection between increased degrees of freedom from flaccidity and development of abnormal synergic grouping, passive tissue contracture and spasticity following stroke?

By

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"All truth passes through three stages:
First, it is ridiculed;
Second it is violently opposed; and
Third, it is accepted as self-evident".

- (Schopenhauer)

Abstract

Similar to the patients of yester-year, stoke patients today still continue to struggle to regain sensory-motor control and constantly struggle to get rid of spasticity. Therapeutics in the modern times with most modern machines remains to be palliative with focus on muscles. Passive tissue contracture, invariant abnormal synergic grouping, spasticity, associated reactions, depression, spatial neglect, Paraesthesia and central pain are all understood to be part and parcel of the condition. Spasticity is well defined by physiologist in the last century. Yet, there is no effective solution to get rid of spasticity till date despite use of most modern drugs. I think time is ripe in this 21st century for clinicians to relook into stroke symptoms and revisit spasticity. Patients must not continue to suffer endlessly and future stroke victim must not waste time of his life struggling and learning compensatory movement in therapy in place of true recovery of lost sensory-motor control. My heart ached to see suffering of stroke victims. Burning desire in me to help stroke subjects made me think out of the box. I dared to get into unchartered waters of stroke rehabilitation to find root cause of all complex problems. Constant brain storming and haunting questions in my mind about all my patients lead to the answers that uncovered the truth behind compensatory movement as a major road block to true recovery. Neuroscience is heading towards recommending new high tech tools and virtual reality. Understanding the root cause behind complex looking symptoms and the underlying mechanisms about true recovery and compensatory recovery is critical. Therapeutics must be designed so as to prepare the paretic body and the brain to support, balance and propagate entire body with exchange between two sides to lead and to follow to put the patient on the road to true recovery. Vasa Concept: 'to re-reorganize self-organized brain with lesion with expansion of boundaries of COM movement on paretic side'. Vasa Concept is described with "what to exploit", "what to do" and "what not to do" to a self-organized brain and how to re-reorganize it.

Clinically Drawn Conclusion:

1. Paresis makes self-organizing dynamic system unstable from within.
2. Action plans of self-organizing stroke CNS (central nervous system) to re-stabilize the system sets in with uninterrupted use of non-affected body for self-safety.
3. Uninterrupted use of non-affected body for postural and voluntary acts is a compensatory action and is plasticity in a negative sense. It leads to behavioral and structural changes that reduce all chances for true recovery.
4. Gravity constantly influences bilateral Vestibulo-spinal tracts, vermis of cerebellum and bilateral fastigial nuclei to influence one integrated trunk with one side paretic and other non-paretic.
5. Extensor muscles of trunk automatically act to defend safety from falling against gravity. Multiple segments of vertebral spine act together for safety as one functional unit turning multi segmental spine into one log like structure.
6. Increased degrees of freedom in paretic flail MSS (Musculoskeletal system) is an added threat to

safety of COM (center of mass) making brain more defensive.

7. With passage of time, spino-spinal circuits reorganize with inter-limb knowledge and inter-limb sensations with reduced Proprioceptive afferent inflow which remains monotonous due to reduced control on paretic side. Spino-spinal reorganization gives birth to abnormal synergic grouping in paretic limbs.
8. With passage of time some patients develop spasticity that helps restrict variability of movement and it also acts as a "BRAKE" on the fluid movement of COM for; 'safety is a priority'.

9. Reduced ability of paretic body to support and balance neighboring segments and segments at a distance also influences direction of interactive forces and gravitational forces with negative consequences.

10. As, "whole is bigger than sum total of its individual parts" Microscopic morphological changes like contracture, loss of viscosity, and stiffness in paretic muscles, in connective tissue and in basic fabric 'the fascia' develops following stroke. Contracture binds the entire skeleton together at the central axis, 'the spine'. It enables the paretic side body to get mechanically bound together to non-paretic for a macroscopic change in functional behavior of paretic body.
11. Macroscopic change in behavior of paretic MSS can be compared with passive 'Towing' by non-paretic MSS when muscle motors of paretic MSS fail.
12. Towing the huge mass of paretic MSS by non-paretic MSS becomes easy with contracture in widely spread Thoraco-lumbar fascia that spans both sides of the central axis and houses large trunk muscles bilaterally with bilateral innervation helping to bind paretic and non-paretic MSS together at the central axis with contracture and contraction.
13. Contracture in muscles of limbs with its origin on the trunk, e.g. Lattissimus, Pectoral and Iliopsoas enable the limbs to get bound to the trunk with microscopic morphological changes loss of viscosity, loss of sarcomere, to help bind entire paretic body with non- paretic for easy towing.
14. Lattissimus muscle is anatomically well placed in terms of connecting scapula and the pelvic girdle together and having its attachment on to Humerus bone and being in continuity with the gluteus maximus on the opposite side (1) (2). It is interesting to see that self-organizing brain exploits anatomical advantage of Lattissimus to bind two girdles together and turn it into log like structure with spasticity in Lattissimus. It restricts dissociation between two girdles thereby attempt safety of COM, a priority for all living beings.
15. Brain exploits anatomical continuity of left paretic Lattissimus with the right normal gluteus maximus on the opposite side to trigger extended continuous anticipatory contraction in paretic Lattissimus with each step taken to walk.

Also muscles of good leg constantly pull and produce stretch on paretic latissimus while walking. Stroke patient when made to walk without preparing brain and paretic body to sustain huge mass of head arms and trunk, it puts patient in 180 degrees opposite direction to possible true recovery of lost control.

16. Un-opposing pull of normal trunk muscles pulls the torso such that the head, arm and trunk mass (HAT) is pulled away from paretic hip and leg thereby reducing loading on paretic leg. Therapeutic efforts fail to shift weight on paretic LL, unless balance is brought between forces of two sides of trunk.
17. Restoration of sensory motor control of the paretic UL is highly dependent on the restoration of control on global COM safety by paretic LL. Coupling of paretic Lattissimus muscle with opposite normal gluteus makes paretic Lattissimus to get constantly stretched to develop abnormal flexion posture in upper limb at every step taken by the paretic LL in walking, climbing stairs, in standing up and in sitting down with real time inter-limb knowledge and inter-limb coordination.
18. New functional behavior; "Towing" of paretic body by non-paretic body makes exchange of dominance between two sides impossible. This makes "Normally Abnormal, to be Normal" for the stroke subject with disturbed spatiotemporal efficiency needed for energy economy. Normally gait is subconscious automatic and control on COM safety is exchanged between two sides without thinking with one side of body leading and the other side of body following and vice versa.
19. Towing of paretic body by non-paretic body also shifts its geocentric reference on non-paretic body helping it to lead uninterruptedly with paretic body trailing behind and acting as a "brake" on global COM movement.
20. New functional integration between two sides of the body, one 'leading' and controlling the COM all the time and the other trailing behind and 'following' all the time ensure safety of COM always a priority.
21. Added safety to COM is provided by passive inertia of paretic mass.
22. Impedance to movement from spasticity, rigidity and stiffness in muscle and contracture in passive tissue and muscle is a defensive strategy of the self-organizing brain to restrict fluid change in COM movement to prioritize safety of COM.
23. Sensory reweighting is automatic post stroke. Self-organizing brain uses vision in place of proprioception for balance while standing up and walking. Patient tends to look down instead of scanning the environment making "Normally Abnormal, to be Normal".
24. Power of self-organizing brain is mightier compared to any therapeutic efforts made by rehabilitation team unless therapeutics maintain the same goal as that of the brain to prioritize safety with paretic body.

25. Therapy must **not** focus on muscles, segmental voluntary control, descending corticospinal pathways, and promoting compensatory control with task focus. Theoretical claim of plasticity to work with forced use, TMS, and repeated task practice for recovery is not the same as putting plasticity in action without compensation and negative outcome in practice. It is very likely that plasticity can be highly negative with consistent use of non-paretic body and compensatory use of paretic side to complete the task with repeated task practice.
26. Paretic linked body in different geometric alignments, gravity, and ascending proprioceptive sensory inflow to the spine and cerebellum and motor cortex are the best tools compared to manmade machines. These tools remain freely available everywhere and anywhere the patient goes making it so easy also to work at home or in open space, in garden etc. to work for many hours a day to channelize the dialogue between the external environment, brain, and body for desirable motor output.
27. Empowering the patient and family so that they can take responsibility for their own recovery and work for several hours a day in safe environment of home is critical to put the patient on the road to true recovery of lost control.

Acknowledgement

I want to thank my husband Vivek for all his unconditional support all these years in my mission to find solution for complex sensory motor problems of stroke without any expectation.

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I thank all the students and physiotherapist friends from Uppsala, Stockholm, Orebro, Lund, Gothenburg, and SatraBrunn to believe in me and to let the ***wind of change*** to start to blow against all odds in Sweden and to ***Danderyds sjukhus*** therapists for naming my teachings as **Vasa Concept** way back in 1995.

I want to thank Sandeep Ram, my domestic help at home, to take care of me and our home with dedication and love and my two Dogs; Lucky and Radha whom I love.

I want to thank all patients and their family and all the sources for photos and pictures to spread knowledge.

I want to thank god for choosing me and giving me this special strength to sail in uncharted waters of neuro rehabilitation without fear and leading me and guiding me to sail through the rough waters and difficult times with courage and sensibility and sensitivity towards mankind.

I pray to God to help me to float the knowledge treasure ***free for all patients of the world***. Let the river of knowledge flow freely to run to meet the ocean so as to benefit all around the world without any discrimination. I wish to end suffering of stroke victims and bring an end to their dependency on outdated rehab system by empowering them to take responsibility to walk on the road to recovery. I dream to give big broad smile on the face of the patients and their families.

About Rajul Vasa

Rajul studied physical therapy from Bombay University, G. S. Medical College and King Edward Memorial Hospital, Mumbai, India. She is a postgraduate student of Rehabilitation Clinic Valens and post Graduate Centre Hermitage Bad Ragaz, Switzerland. Currently, she is working as a clinical scientist applied movement science for stroke, cerebral palsy and spinal injured patients.

Rajul realized that brain stroke and Neuro-rehabilitation is a field where the diagnosis and early critical care has advanced with modern science and technology, however post-acute care is still in dark state. Rehabilitation of stroke patients is highly palliative and restoration of lost control is difficult with Rehabilitation techniques practiced today. Development of abnormal motor control and spasticity continues to be a challenge for all concerned with rehabilitation around the world! Neuro rehabilitation remains to be an area of unchartered waters.

Rajul began to feel guilty when brain stroke patients visited her with high expectation. She was as clueless as the patient - only difference being that she was on the other side of the table!! Rajul put herself in the shoes of the patient and started questioning herself. She wondered why stroke patient in today's modern times suffer and struggle as much as the stroke patients of the last century! Why stroke patients continue to show similar signature features like using good side of body to get on with life and struggle with abnormal synergic grouping, spasticity, passive tissue contracture, and relearn to move with compromise and compensatory behavior like a fellow patient of the last century! Rajul wondered why patients of yester years and patient of today continue the same battle against spasticity, weakness and passive tissue contracture and synergic grouping with one goal; Restoration of lost control!

Rajul began to read all her patients as books still unread and realized it was not right to fit the symptoms of her patients in the books written by experts who had different experiences with their patients in their times decades earlier.

Rajul became obsessed to find solutions for challenges faced by brain stroke patients and became determined to give a new direction to brain stroke rehabilitation.

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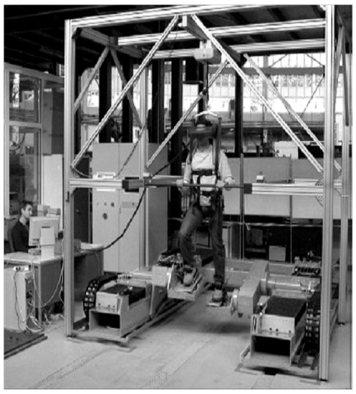
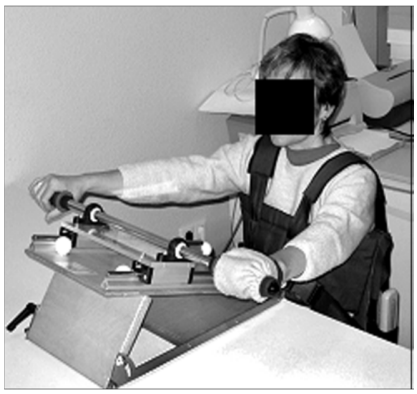
Introduction

In the past, stroke rehabilitation techniques were overestimated by comparing it to no treatment at all or were popular because it claimed some neurophysiologic basis though without evidence. Plethora of new techniques evolved from dissatisfaction of empirical based techniques popular in different times. Today scientific evidences (11) and statistical significance in outcome is critical to understand whether one treatment is better than another. 21st century therapist is equipped with most modern machines (shown in the pictures below) for stroke rehabilitation and prefers many tools in their tool box made of many techniques practiced in different parts of the world.

Huge money is spent on multicenter randomized clinical trials to give scientific evidence to endorse techniques, yet there is no single technique or mixture of techniques that claims to restore lost sensory motor control completely following stroke

Plethora of experimental evidence in stroke motor control (12) is available but it is very difficult for a clinical scientist to synthesize the body of evidence for clinical application to benefit the stroke subject. Clinicians in motor control science sometimes fear that it is highly possible that scientific validation with isolation may easily lose sight of global because of a tendency in the literature to dichotomize on sources of constraint, favoring one or the other without considering mutual interplay of different constraints. Laboratory atmosphere is unrepresentative of activities that stroke subjects indulge in outside the laboratory set up making the conclusions drawn in the laboratory experiment not always fit the clinical condition. Experimental scientists in applied motor control in general, lack hands on experience and empirical knowledge while designing their experimental protocol bound with strict rules and strict boundaries. In addition, experimental validation needs study design to isolate local from global with reductionist approach which is necessary to simplify the research questions making carefully designed experiments to answer questions of typical stroke motor behavior to frequently become the source of more questions than answers and thus the attempt to capture the complexity of purposive action and adaptive behavior following stroke after a century of extensive multidisciplinary research remains far from over. In comparison, clinical therapists are not bound and not restricted to experiment clinically on their willing patients using empirical observations and are privileged to have greater exposure to the patient for a long period of time and therefore has more chances to make introspection and critically analyze their own actions and explore in retrospect why conventional methods of rehabilitation in patients with chronic, severe motor impairments after stroke do not lessen paresis (13).

Introduction

I believe time is ripe for clinical scientists in motor control working day in and day out, hands on with the stroke subjects to take responsibility to bring change in present state of stroke rehabilitation which is highly palliative. I strongly believe that in this 21st century we clinicians have to grow beyond negative and positive symptoms of muscle, beyond neuronal loss from lesion, beyond cortical stimulation and importance of descending corticospinal pathways and voluntary control.

To restore lost control, one must think in terms of

- Ascending dorsal column medial lemniscus conscious proprioceptive and anterior and posterior spino-cerebellar unconscious proprioceptive input hugely capable of changing descending motor output.
- Forcing the anticipatory postural circuits to avalanche paretic muscles in a chain with guarded disequilibrium triggered from within.
- Mirror image structures like cerebellum with its huge input capable of influencing motor cortex, cognition and perception, and descending pathways to spinal cord and thus muscles.
- Balancing out input to the spinal cord on both sides and Re-reorganizing spino-spinal motor circuits is critical for true recovery of lost control.

Brief History

I looked back and tried to understand work done by research scientists in the last century. Focus was on localization of lesion and establishing function of different areas of the brain with reductionist philosophy. Muscle was understood as the sole executants of movement whether in *"whispering a syllable or in felling a forest."* (Quote by The founder of western physiologist Sherrington) Neurophysiologic understanding of Hierarchical role of cortex and uninhibited facilitation inevitable in presence of lesion in CNS influences all therapeutic decisions and actions. Velocity dependent stretch reflex response of spastic muscle is well described in the basic physiology books that made therapist in last century focus on inhibitory exercises, splinting, and hugely struggled against spasticity; the positive symptom of stroke for decades without any long term benefit. A special hands-on technique to inhibit spasticity was developed during the seventies (14). Therapists from around the world dedicatedly learned and followed the technique of inhibiting posture and actively delivered it to the passive recipient; 'the patient'. Therapists worked while patient was highly passive. Lot of time and energy was spent on inhibiting spasticity but spasticity always reappeared in the next session of treatment making therapist feel frustrated and tired. Gradually change began with doctoral studies and evidence-based physiotherapy for patients with stroke. No evidence was found that inhibitory stretching techniques and splinting improved functional outcome (15). One study indicated 39% of stroke patients with first-ever stroke are spastic after 12 months (16). It took historical time and huge efforts of many progressive therapists (17) who helped to shift the focus from positive symptoms to the negative symptom; "weakness" and making the patient active with task oriented practice.

Studies of Sommerfeld et al described 28% hemiplegics were spastic after 3 months and reported that the focus on spasticity in stroke rehabilitation is out of step with its clinical importance and weakness may be directly responsible for compromised motor function (18). This premise has motivated research demonstrating that neither effortful activities nor strength training per se exacerbate spasticity. Based on this new understanding, many researchers are now focusing on weakness rather than spasticity as the primary problem to be addressed in the neuro-rehabilitation of motor impairment to the extent of accepting spasticity as an adjunct in the rehabilitation process. At the point of such a radical reorientation, it is desirable to explore the long range implications of this new appreciation of spasticity and shift of focus from one symptom of the muscle to the other symptom of the same muscle.

Number of therapists in search of progress moved on to evidence based new technique called CI therapy (19) to avoid "learned nonuse" (20) of paretic limb constraining non paretic limb, and forcing repetitive exercises to the extent of accepting compromised and compensatory action at other joints. Task oriented practice helped to make the patient independent as soon as possible keeping in mind the constraints of insurance companies in supporting long term treatment. Most modern technological machines like FES, Biofeed back Robotic help and sophisticated technological advances for gait training with trunk support and treadmill entered the departments of physiotherapy in advanced countries. Yet, unfortunately despite huge efforts of the therapists, stroke patients around the world do not feel satisfied and express their concern on stroke forums with expressions like, "we are looking and struggling for the return of lost control and to get back to our original self, will I ever get there?; Some diplomatically add that therapy has made me learn ADL but, I am doing everything differently not like before, and I feel I am getting adapted to doing things differently in a compromised fashion with my good hand compensating for the paretic side, what I want to know is, when and how I will restore my lost control. How much time will it take? My doctor told me, have patience everything will be alright after some time. Now it is almost 6 months, I have learnt to be independent but what about my hand?

And what about my walking pattern? It is so disgusting the way I walk! I am using my leg almost as a prop. My leg is not any longer like my original leg! I am getting tired so easily. I do not feel as energetic as I was before. I feel drained out. When will I recover completely? Doctor says though recovery is known after many years it does get slow in chronic state. My therapist says my recovery has plateaued. When it was only few weeks after stroke they told me to exercise and have patience and wait, today they tell me to continue to exercise but say that it is quite late and recovery has plateaued, as a lay person I am highly confused please help me! Will I ever restore the lost control? Why should I continue to exercise when I see that I am using my body in an awkward way and not in a normal way?

Flood of questions

Flood of Questions came to my mind during my clinical encounter with stroke patients in different parts of the world. I wondered though stroke is not a progressive disorder,

1. Why and what makes flail muscle to turn spastic and yet continue to remain weak! After all what factors make muscle, already a victim of CNS lesion to develop contracture with passage of time?
2. What is the muscle wisdom behind losing sarcomere, turning stiff and contracted and losing viscosity and elasticity?
3. How does stroke CNS cope with different internal as well as external invariant and variant forces?
4. Does increased degree of freedom of segmental COM of flail paretic linked segments pose serious threat to the safety of global COM?
5. What makes the increased degrees of freedom that predominated in the initial acute state to turn into reduced and restricted degrees of freedom with positive symptoms like spasticity, rigidity, associated reactions and synergic grouping?
6. What does the self-organizing dynamic brain do to prioritize safety of COM in stroke subjects during postural and supra postural tasks?
7. What are the major challenges in rehabilitation therapeutics? Is it the negative symptom, the weakness, reduced sensitivity, learned non-use, positive symptom; 'the spasticity', abnormal synergic grouping, associated reactions, passive tissue contracture that develop with time post stroke OR ***something else?*** (Rajul Vasa unpublished observation)

Turbulent feelings from failed efforts

I felt that a small lesion, hierarchical control, importance of voluntary control, descending Cortico-spinal tract, pyramidal neurons and reductionist thinking that prevailed in the last century made rehabilitation experts to begin on a negative footing. Doctors and therapists thought of complex sensory motor problems of patients as part and parcel of brain lesion. This made the treatment of stroke highly palliative and symptom oriented leading to ever evolving ethos of the different techniques. New machines like treadmill with body support got into PT dept. to facilitate gait training, though it made very little difference in long run, rather some patients are unable to walk beyond few steps despite walking hundreds of kilometers on treadmill with or without trunk support. Electrical stimulation for wrist extension and static cycle etc. entered PT dept. patients got excited to see wrist moving with machine though as soon as machine stopped, there is no carry over effect. Time lost, Hope failed and depression raises its face, all these symptoms once again gets label of being part of stroke. Dogmatic rigid thinking prevails among the clinicians with no place for “out of the box” ideas in search of the root cause of the problem.

I feel, call of the day is to establish more interaction between I) experts in clinical science with critical observation power giving empirical evidence and ii) experts in research science on motor control in laboratory so as to design future studies with paradigm shift. Flow of scientific knowledge in both directions is vital for a new equation to change future of stroke patients around the world. This will change economics of rehabilitation costs in terms of TIME, MONEY and ENERGY of all concerned with rehabilitation and these include patient, family, society, human resource for loss of productive life of an individual with stroke, balance sheets of insurance companies, rehabilitation team and above all, nations that spend in billions world over.

Thoughts that followed

To understand stroke sensory motor complexities, we need a new way of thinking to get to the root cause of the symptoms. The fundamental change in our way of thinking must be to think beyond lesion, to think beyond release phenomenon, think beyond uninhibited facilitation and beyond pyramidal loss and we need to re-think on what makes a tiny lesion in CNS to result into such catastrophic symptoms in MSS (Musculoskeletal system).

- We need to think of, role played by amplification property of CNS in amplifying the symptoms in MSS. Why a tiny lesion in CNS makes opposite one side of MSS to become paretic?
- To think of plasticity that might be functionally negative from mal adaptation with use of good limbs for daily activities. Use of good limbs that enable use of redundant neurons and neural tissue at a distance in non-lesioned hemisphere may result into long term structural and functional changes making it difficult "not to, not use" the good limbs compared to "learned non-use" of paretic limbs. Mal adaptation with structural changes can make restoration of paretic limbs a highly difficult task.
- Stroke subjects find it difficult to use paretic limbs when they are flail and weak and also when they turn spastic. Abnormal synergic grouping of paretic muscles remains invariant despite change of tasks (26). All these factors combined makes repeated use of good limbs for functional reasons simply unavoidable.
- Repeated use of good limbs when becomes a way of life, long-term structural plastic changes become a constraint in terms of difficulties for a stroke subject to stop using good limbs once got adapted to. Forcing the use of paretic limb with conscious repetition and constraint on the good limb to offset subconscious automatic use of good limbs may not necessarily show optimal long term benefit (21) (22) (23) (24) (25) and may not clearly translate improvements in activities of daily living function when plastic structural changes sets in.
- One must re-think of conscious efforts made in re-learning voluntary movements when large repertoire of motion is controlled by subconscious.
- One must think of spatiotemporal economics of conscious re-learning of movement compared to sub conscious spatio-temporal economy of motion.
- One must see movements of linked segments with shift of emphasis from the individual separate parts to the whole. The famous saying that "the whole is more than the sum total of its parts" coined by the Gestalt psychologist gives a special message to multi-disciplinary approach in rehabilitation wherein different parts of one individual are focused by different specialist like OT, PT, Speech therapists. Special attention to parts by specialists may raise chances for division in the minds of the stroke subjects with special attention to body parts when the fact is that,

largely no individual parts function as isolated and divided entity but function as one whole, wholly integrated unit.

- Entire musculoskeletal system (MSS) with paretic and non-paretic both sides remain mechanically connected at the central axis; 'the spine'. Both sides of MSS are interdependent and interact with brain as well as the external environment. This interaction is highly valuable for human machine unlike man made machines wherein parts may operate independent of one another.
- Everything is connected with everything else in the brain. This infinite neural connectivity complicates rehabilitation, but also can make lesion irrelevant if we pay our attention to profound and multilayered interrelations between our cognitive abilities, our emotions, motivation, perception, human spirit, physical body, PNS, ascending system, loss of spirit from loss of time, family, society, culture and beliefs of doctors, under current of pessimism coming to surface once in a while among the multidisciplinary team, attitude towards brain damage sometimes as no hope, sometimes seen as 'dead end' can shape recovery.

I have encountered patients with:

- Undying spirit who does not accept anything less than complete recovery and work relentlessly to progress on the road to recovery.
- Patients who are happy to depend on family, doctors, and therapists and on state funds and want to enjoy life in a wheel chair and have no desire to make efforts to stand up and to walk.
- Patients who emotionally blackmail the family and friends and exploit them by consciously remaining in a pathetic state.
- Patients who are highly negative about the self, like to think of drugs and surgeries if any, that can cure them without their own efforts.
- Patients who suffer from lack of family support, emotional support and feel drained out and lack energy because of emotional vacuum many a times say -- -- ---- that's the date that changed my life forever. I was only -- years old.
- Patients who feel happy that he survived and does not want to do anything anymore to restore lost sensory motor control.
- Some patients are happy that they are walking and happily accept uselessly hanging arm.
- Some are so vigilant that they do not accept compensation and compromised walking pattern and want complete recovery to walk like how they walked pre-stroke.

Contemporary goal in stroke rehabilitation

Stroke subjects come for rehabilitation with the goal of complete recovery and very high expectation of getting back to original self, whereas goal (NINDS 2002) in stroke rehabilitation is to make the patient independent (28) (29) with understanding that rehabilitation does not "cure" stroke in that, it does not reverse brain damage (NINDS).

Stroke Rehabilitation treatment is considered to be palliative and disability reduction remains the cornerstone of care (30) (31).

This makes a huge divide between goal of the therapist, and goal of the patient. Patients seek the treatment to get “complete cure, complete restoration of lost control and to get back to his / her earlier original self”.

General Observations

It was highly brain storming to see that many of the stroke subjects in underdeveloped countries do relearn many of the activities of daily living on their own without any type of multi-disciplinary therapeutic help. They learn to compensate on their own and get on with life despite weakness, spasticity and abnormal sensory motor control.

Patients from developed nation seeks rehabilitation to restore him back to his premorbid state but what they learn in rehab Centers is how to compensate and make compromise with paretic side after paying huge amount of money, time, and energy. To learn the same thing i.e. to compensate and compromise, patients from under developed nations where facility might be not available, or scarcity of money makes them self-learn to compensate and to get on with life and with ADL (Activities of Daily Living) without any therapeutic help.

I wondered once again for answers to stroke patient's concern about return of lost control and the difference that multidisciplinary efforts claim to make in teaching to compensate for lost control.

Multidisciplinary rehabilitation efforts make the patient to relearn movement with forced use and conscious efforts knowing it well that most movements are automatic and subconscious.

ADL (Activities of Daily Living) with good limbs compensates for the loss. Physiotherapist focuses on gait training, sitting and standing balance in short focus of PT is on lower limb and OT attempt to work with UL, though "Best practice" for the rehabilitation of the paretic upper limb is still unclear" (9)

Occupational therapist focuses on teaching ADL to circumvent the loss and compensate with good limbs to make the patient independent. Paretic side is offered stretching, strengthening, splinting, and how to deal with contracture, spasticity, and with other secondary and tertiary complications.

Irony is patients from developed nation with most modern therapeutics and patients from underdeveloped nation without any therapeutic help ask the same question ***"what about recovery of my paretic hand and paretic stiff log like leg and or weak leg?"***

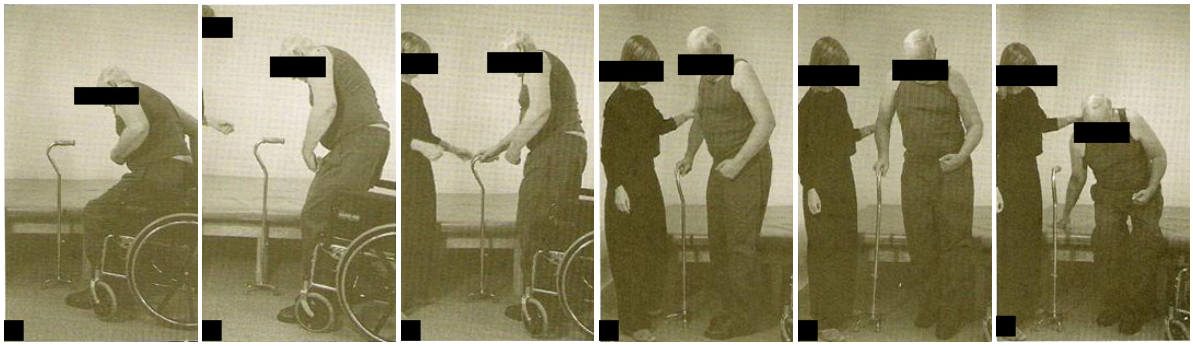
Impact of early gait re-training on self-organizing brain

Standing and walking is of high importance for functional activities of daily living for early independence and discharge. This makes PTs to focus on gait training and balance retraining exercises for early independence crucial for ADL. Weight bearing on paretic Lower Limb (LL) is crucial for stability during gait, difficulties of stroke patients to bear weight on paretic limb is studied in detail (31). Scientific literature gives evidences of muscle weakness, spasticity, and sensory deficits as responsible for weight bearing deficits (32).

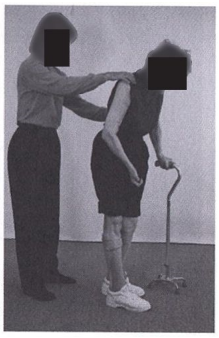
I recognized that not only me, but therapists from around the world those from under developed countries and those from developed countries as well struggled alike in training the stroke patients to teach to weight bear and to achieve symmetric loading on the paretic leg (33).

I began to ask myself, why is it so difficult for the patient and the therapist to achieve weight bearing on the paretic LL? Where is the catch?

While I was training the patient to walk, one problem was consistent; he could not generate active power in flail paretic LL to change resting GRF under the foot (34) and could not set the COM in motion. Resting GRF is highly reduced from reduced limb loading. This made the stroke subject use his good Upper Limb (UL), and good LL with or without the use of walking devices to set the COM in motion much needed for transferring and propelling body.



Using good limbs to ambulate became habit difficult to change for several reasons. Good limbs are more effective than paretic limbs; adaptation also makes it difficult to, **not use** non paretic good limbs. Physiological inter limb constraint also makes it difficult to impose conscious WILL to load the Lower Limb especially when the COM is propelled by non-paretic limb.



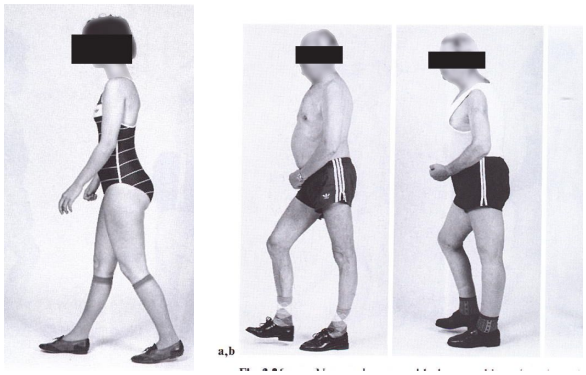
Another consistent problem of stroke patient was difficult to go unnoticed while he was trained to walk. Most patients looked down at the support surface and at the foot for the fear of falling and loosing balance and used vision for the reduced proprioceptive inflow because of inadequate weight shift on paretic LL. Use of vision was automatic from sensory re-weighting (35) with self-organization of the brain to give safety and stability.

While walking COM is very high with narrow support surface and constantly changing base of support. Those who suffered loss of sensation had most difficulty during walking. Use of vision made the gait very slow and spatiotemporally highly ineffective, energy inefficient. Normally alternating cyclical pattern got changed to become in-phase pattern in many patients for safety.

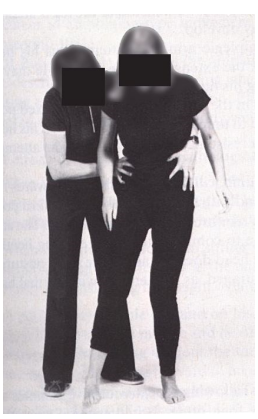
Those patients who had spastic to rigid log like leg from vestibular overweighting had tremendous difficulty to overcome the increased inertia offered by the spastic leg to lift it off the ground.

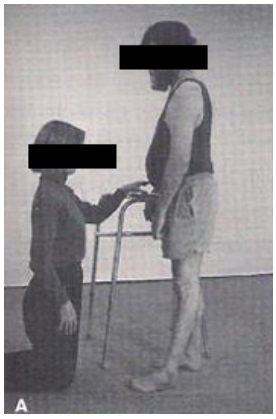
They hiked pelvis to get into swing phase. The rigid LL did support itself but made compromise to support the weight of HAT (Head, Arm, Trunk) when good limb was going in the swing phase. This made the patient take a quick step to get back good leg on the support surface and they used stick in good hand to bear the load in place of paretic leg!

Paretic weak flail knee tended to get into recurvatum while walking.

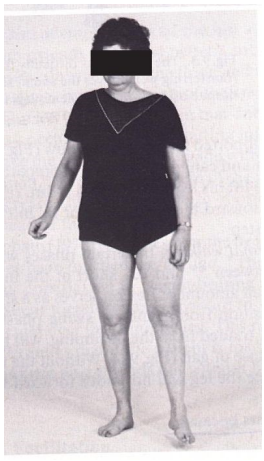


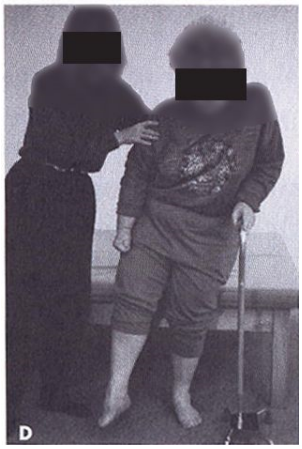
HAT mass got bent at the hip from gravitational force and flexed the hip passively.





GRF from under the foot got realigned with recurvatum of flail weak knee for stability. Contracture at the hip maintains the hip in flexion for added extra stability to the joint and resists any change in the angle. Coplanar hip and knee action seen in individual with normal gait cycle saves energy and makes the gait economic, but spastic contracted hip with recurvatum in flail knee or spastic extended knee no longer exploit coplanar economy of gait (Rajul Vasa unpublished observation). Spastic foot and ankle change initial contact of gait instead of heel striking, toe contact and foot flat is observed.





Changed spatiotemporal parameters of gait in stroke patients made gait look abnormal and made it need active attention of the patient during walking making normally automatic walking highly cumbersome with need of constant attention to walk.

Multi-tasking during walking becomes a dream for a stroke subject with abnormal gait unlike in normal people wherein walking is highly automatic and multi-tasking like walking, talking, eating, looking and carrying objects is easily possible.

One thing became very clear to me that while we therapists were busy treating muscle symptoms and retraining symmetry in standing and in walking with or without treadmill, with without trunk supported treadmill walking, with verbal, visual and bio feedback commands to make the paretic leg to bear weight

again during standing and walking, dynamic self-organized stroke CNS did not change its goal to prioritize safety.

It was not long before I could recognize typical "signature feature" of majority of stroke subjects that used their good non paretic limbs to safeguard themselves automatically without being told to do so. It was not hard to understand that self-organizing nonlinear dynamic brain was automatically highly preoccupied in self-defense when patient was trained to walk. Instead of controlling and restoring the most regulated variable and most critical control parameter the COM, patient developed new motor strategies to defend it. Sensory reweighting and using power from good side of body *(without external instructions to do so)* became the norm automatically when flail weak paretic body fail to control COM against invariant force like gravity during walking. As, Base of support (BOS) is constantly changing and narrowing while walking with COM height very high, cane and crutch and hemi-walker helped to increase BOS and safety in short term with fear getting stronger if assistive devices are withdrawn without equipping the patient's brain and body for support from within.

'Use of good limbs' became the "signature feature" of all stroke patients for all voluntary acts and in ADL and patient became defensive towards COM safety while walking making **"normally abnormal, as normal"** for all the stroke patients.

It was not hard to see that impact of gait training with conscious commands of therapists for an act which is cyclical and highly automatic made the act a conscious act from conscious interference by patient under the guidance of therapist. Gait retraining made normally abnormal, normal.

It was not hard to see that imbalance between two sides paretic and non-paretic, in its ability to support, balance and propagate the entire body and control COM safety automatically made self-organizing brain to take steps in self-safety by compromising with paretic body and compensating with non-paretic body. Self-organizing brain developed vicious circle of not loading paretic lower limb to prevent falling and when proprioceptive input got reduced from poor loading; brain also took steps to endorse not to load paretic leg.

Chain of constraints adds onto initial constraints when goal in therapeutics do not match with goal of the brain.

Under normal circumstances brain controls and restores safety of COM automatically using body segments close to BOS. Following stroke, self-organizing stroke CNS turns defensive when threat to safety increases from paresis. In an attempt to reduce threat to safety against gravity, brain begins its journey to exploit all possible resources from within and from outside in the constant game of self-defense.

I began to see that stroke brain fell in a trap of vicious circle, in solving initial constraints like lesion in CNS, flaccidity of muscles, increased degrees of freedom at joints, constant threat of falling from force of gravity, with development of new physiological, biomechanical, and psychophysical constraints in the ongoing efforts of not falling and defending the self constantly.

Dependence of Stroke subject on the non-paretic limbs exclusively automatically for all postural motor acts like gait, standing up, sitting down, standing etc. can be more alarming with reverberating severe consequences compared to use of good hand for volitional acts which are mostly unilateral also in normal people.

Adaptation at Functional level with functional flexibility and functional adaptability to balance out the imbalance in inflow to the mirror image structures like spine and cerebellum needs serious consideration. Cerebellar vermis, fastigial nuclei, vestibular circuits and vestibular nuclei with both labyrinths, and trunk extensor muscles are integral to combat external force gravity. Paresis of trunk muscles with huge inertial mass over sensitizes extension response in defense against gravity. Spine acts as one single log like structure in place of many individual segments to combat gravity. Vestibular overweighting seen with extensor over activity in spinal muscles carves the path to life time of dependency and handicap unless therapeutics prevents log from the very start.

Use of non-paretic upper limb and LL makes two separate girdles upper girdle and lower girdle on the same side of the MSS to participate in postural change instead of both LL and pelvic girdle primarily. This biomechanical shift of control makes sensory inflow from non-paretic side to influence spine and cerebellum and all subcortical postural processes without similar input arriving to the other side of spine, cerebellum and subcortical postural processes. This imbalance between the two sides of spine and cerebellum if not interrupted therapeutically from the very start, has its huge consequences in terms of weak side learning to adapt to trail behind good side with inter-limb knowledge and inter-limb coordination.

Repetitive use of non-paretic limbs makes physiological inter limb and intra limb knowledge from spino-spinal sensory motor circuits to make the brain become *kind of slave* to limited monotonous input. Periphery tends to overpower brain with limited restricted input from affected side. Physiological inter-limb knowledge makes paretic limbs to cooperate with non-paretic leading limbs with development of typical synergic grouping labeled to be abnormal synergic grouping when in fact it is physiological spino-

spinal self-organization that give new geometrical alignment to paretic segments to support the action of non-paretic leading limb by itself "following" *(Rajul Vasa unpublished observation)***.** New geometric alignment of paretic MSS with synergic grouping in flexion in UL and extension in LL, which remains invariant helps restrict the freedom of segmental COM and restricts it to curtail within the BOS thereby give safety.

Psycho-physiological adaptation varies from person to person. Some highly anxious stroke patients have phobic behavior from fear of losing balance in sitting, standing and walking making them depend on wheel chair for ambulation for life resulting into complications from not walking and pathological fractures from bone softening. Many patients have depressed behavior, non-cooperation for therapy and no interest or reduced interest in working. Stroke CNS continuously experiences two different mechanical states in one integral psychophysical self, making them pay special attention to the affected side. Patients tend to watch out on paretic side all the time and keep fiddling with hand, out of a new habit that changes their behavior. Self-image is seen to influence some patient in terms of desire to work towards recovery and some simply accept the condition and deteriorate with passage of time.

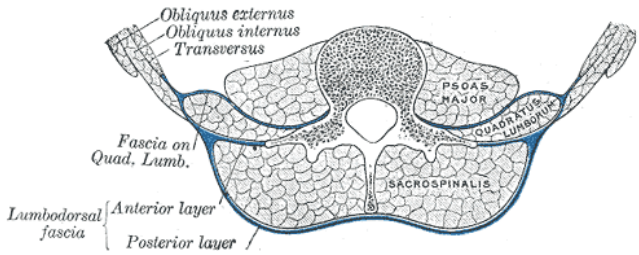
Biomechanical adaptation also takes place at muscle and joint and segmental level to ensure structural stability with tightness and stiffness and contracture in connective tissue, fascia and in paretic muscles that helps to bind flail paretic linked segments together thereby reduce threat from internal interactive forces and external forces in the safety of COM.

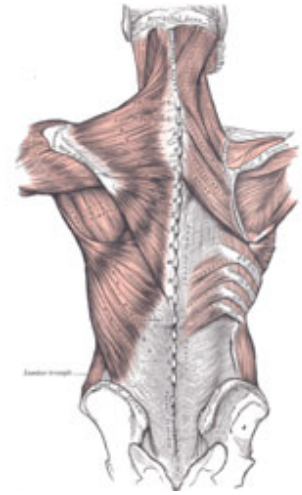
Being Repetitive

I may sound repetitive about few core points, one of it being the center of mass [COM], in that let me take the liberty to express COM as an “APPLE”. I am making an effort to make my readers to view this apple from different angles or view points from where I see the same apple (I mean COM!!!!!) which is constantly influenced from continuous dialogue between the brain, body and external environment. I wish to unfold the journey of the stroke patient from initial flaccidity to spasticity, associated reactions, abnormal grouping, and connective tissue contractures as an attempt of self-organizing brain to solve the problem of paresis, increased degrees of freedom, that makes the MSS unstable and trigger changes from within to prioritize safety of COM, a priority need for living biological systems. Interesting to note that dialogues between brain, paretic body, and non-paretic body keeps changing under the influence of invariant force like gravity capable of generating cob web of constraints with snow ball effect with passage of time in the process of defending COM.

Snowball effects of acts generally taken for granted as part of stroke:

1. Stroke causes muscles of one side of the MSS to turn flail. Large paretic trunk muscles attached to central axis via Thoraco-lumbar fascia loses its tautness allowing the trunk to mechanically rotate away from unopposed pull of the non-paretic trunk muscles attached to the common central axis thro' Thoraco-lumbar fascia. This rotation of trunk away from paretic side results in large mass of head arm and trunk (HAT) to get mechanically moved away on to the good LL thereby reducing the loading of paretic LL. Reduced loading on LL reduces the magnitude of GRF under the paretic limb which helps the paretic LL from collapsing especially when paretic LL muscles cannot absorb even highly reduced magnitude of GRF vector during standing. Reduced loading of paretic LL helps it from collapsing with its own weight thereby also safe guard COM. Mechanical unloading of paretic LL gets neural endorsement from self-organizing CNS to maintain automatic safety of COM making reloading a highly difficult task.





2. During walking, support surface is constantly changing and COM remains way above the ground, further increasing threat to the safety of COM. Self-organizing brain is in continuous dialogue with gravity and the body. Ongoing reduced sensory inflow from the paretic trunk and paretic limbs warns the stroke CNS about continuing mechanical threat to the COM. Threat makes the stroke CNS to take anticipatory postural (36) (37) action to go ahead and endorse the mechanical action of non-weight bearing and weight shifting away from paretic side when paretic LL does not have capacity and ability to sustain the force of gravity and can be a threat to the safety of COM. Anticipatory automatic sub cortical postural neural action is to endorse passive mechanical unloading of paretic limb by endorsing exclusive rights to the non-paretic MSS for the safety of COM as its priority during walking and during postural and supra postural acts. This self-organizing anticipatory action of stroke CNS makes reloading of paretic leg a difficult task for therapist and patient combine.

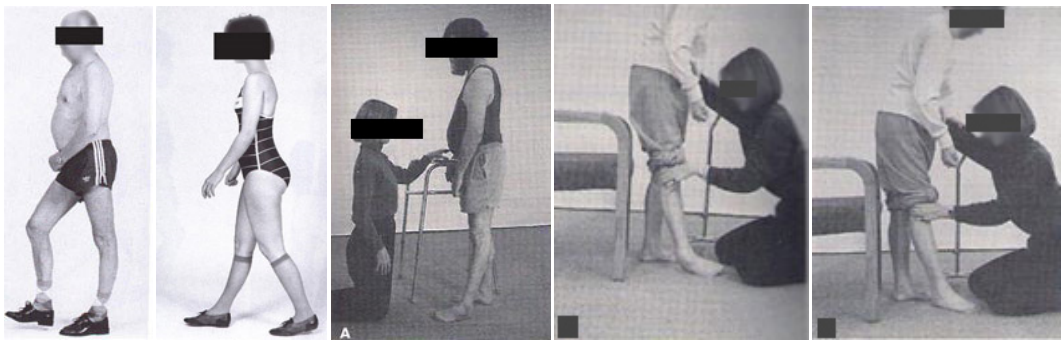
3. Getting adapted to poorly loaded paretic LL and long term Use dependent plastic changes in non-lesion hemisphere and in distant areas of brain makes it difficult for the stroke subject not to, 'not use' non-paretic limbs (Rajul Vasa unpublished observation) to change posture, to sit and to get up making all conscious cortical repeated efforts of patient and repeated verbal and auditory

commands of therapists fail to have desirable impact on re-loading the paretic limb (Rajul Vasa unpublished observation).

4. Deficient loading of LL reduces magnitude of GRF. Reduced GRF reduces the demand on the motor outflow from paretic muscles with action reaction being equal and opposite. Reduced loading of LL and reduced proprioception makes self-organizing stroke CNS in continuous dialogue with periphery and outside world endorses to avoids use of paretic lower limb with neural endorsement **"not to use it"** for safety from falling. With passage of time without the electric neural signals to motor neuronal pool, axonal degeneration may begin making it almost irreversible and impossible to reload.

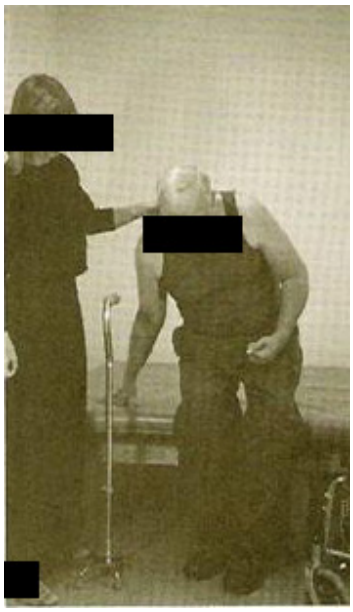
5. Lack of muscle power at paretic hip and paretic knee makes it difficult for hip to sustain large mass of HAT that easily drops down changing the levels of two shoulders with paretic shoulder drooping down.

6. Passive hip flexion from large trunk mass bent from force of gravity realigns GRFs making knee to lock passively and sometimes when knee muscles are flail to get recurvated with bone on bone locking forces.



7. Use of external support like cane or internal resources like non paretic hand and leg could be instant solution that helps to stand and walk but on a long run it becomes a difficult constraint to change with COP generation from under the hand that makes postural control to be shifted to good arm. Once the patient gets adapted to Use of non-paretic good hand for postural acts, availability of good hand for voluntary acts at the same point of time is not possible. Efficiency reduces to great extent and fatigue looms in.

8. Stroke subjects are seen grabbing and holding on to any outside support available thereby using touch for balance while standing up, sitting down, and walking. Use of good hand reduces the need for power at the hips and switches the GRF from under the paretic foot to GRF under the hand with its mechanical consequences. Touch cutaneous sense is used for postural control; this sensory re-weighting of proprioception with touch for postural control by self-organized brain becomes a habit difficult to change with its negative consequences and adaptation.

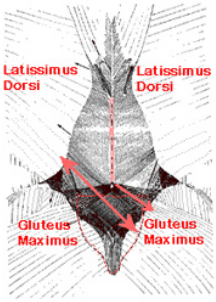


9. Stroke patients are seen outsourcing power for postural change like sitting and standing up, to walking using pelvic and shoulder girdle on the same side of the axis with use of good leg and good hand all the time compromising use of girdles on the paretic side. This also has its mechanical and neural consequences in terms of adapting to new postural control that exclude and compromise use of muscles of girdles of affected side for posture change and posture control. Touch cutaneous sense from good limbs when repeatedly used for postural control it may trigger sensory conflict amongst visual, vestibular proprioceptive sensory systems. Use of touch and vision for postural change, compromises on availability of vision to gauge environment at the same given point of time.

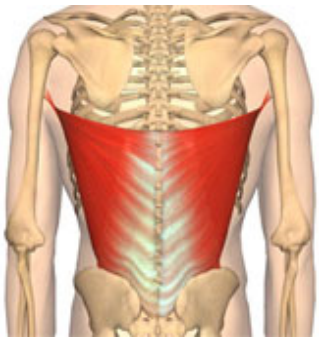
Patient uses hand and vision to get up.

10. Predominant use of good limbs to navigate makes trailing paretic side to be supportive to non-paretic MSS with physiological constraint inter limb knowledge and inter limb coordination. I feel this may prepare the niche for dependence of paretic body on non-paretic side for gravity reference with external world.  

11. Spasticity in large latissimus muscle is known in stroke patients. I think anatomical continuity of latissimus with opposite side gluteus muscle (1) (2) is responsible for this common encounter. Reduced loading on paretic leg with increased pull of the non-paretic gluteus, pulls on to the flail Latissimus on opposite side stretching it at every step of gait. Slightest movement of COM triggers anticipatory activity when stroke patient stands up and walks, making flaccid latissimus with its attachment on scapula and on the pelvic girdle to contract continuously. This continuous contraction from anticipatory activity makes both girdles to get bound together like a log and bind paretic MSS to the central axis with its attachment on Thoraco lumbar fascia (2). This binding of paretic MSS to the central axis with bilateral innervation of trunk muscles makes it easy for the non-paretic MSS to tow large mass of the paretic MSS mechanically. But in turn, exchange of dominance between paretic and non-paretic MSS gets compromised and non-paretic MSS begins to lead the entire body uninterruptedly making "Normally Abnormal, Normal" under the circumstances (Rajul Vasa unpublished observation).



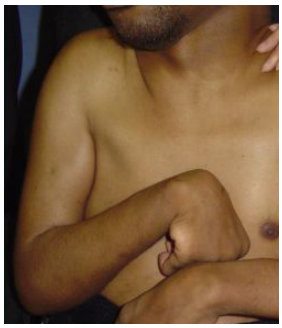
12. Attachment of latissimus on Humerus bone helps arm to get adducted to the trunk and get closer to the central axis with extended continuous contraction in muscles from anticipatory activity during postural and supra postural tasks.

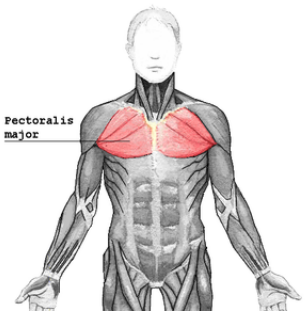


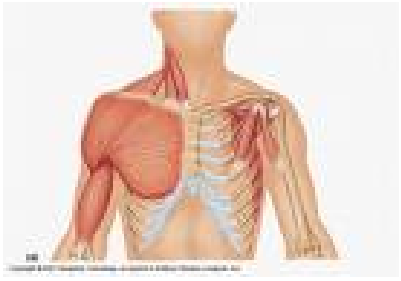
13. Reaching out difficulties in stroke patients and compensatory trunk movement while reaching is known in stroke patients. Despite huge efforts of therapists and of the stroke subject in repetitive task training (3) and constraint on good arm, desirable results in terms of long term success in using paretic hand is not known (4). A specific selection criterion for the efficacy of CI therapy is also known.

14. I feel in addition to learned non use the bigger problem is latissimus spasticity (Rajul Vasa unpublished observation). At every step of walking normal gluteus pulls Latissimus and therefore the paretic arm in adduction, extension, and internal rotation making it very hard for the stroke subject to reach out in open. Anatomical arrangement of the muscles with muscle wisdom in its action helps restrict segmental COM of UL from running out of the BOS thereby defend and protect global COM safety.

15. Abnormal flexion posture of UL with reaching out difficulties has been studied. I feel besides anatomical attachment of latissimus, and pectoralis major on the Humerus being responsible for adduction of the UL, Physiological constraint inter-limb co-ordination and intra limb knowledge prepares the niche with spino-spinal circuit's reorganization when stroke subject uses non paretic limb predominantly during all postural and supra postural acts. with reduced BOS from non-weight bearing on paretic leg that can be a threat to the safety of COM when gravicentric reference is maintained by non-paretic MSS.

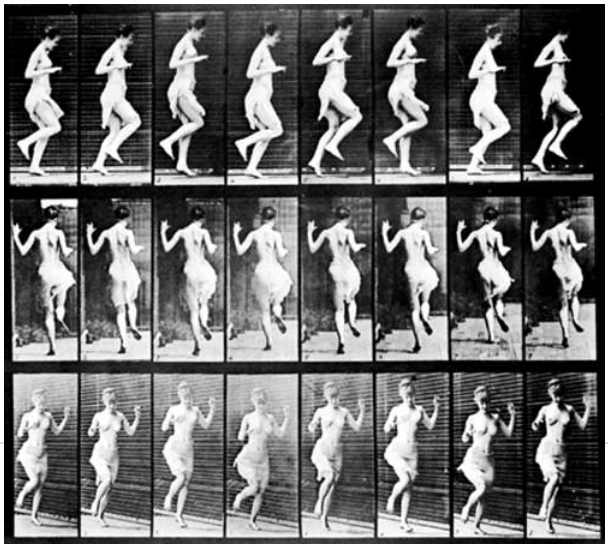






Flexion synergy in UL of a stroke patient is studied to be task-inappropriate from a kinematic perspective. I think it is physiologically appropriate to have flexion synergy in UL in stroke subjects from reduced loading of Lower Limb and reduced GRF under the paretic foot. Inability to fully load the paretic hip with HAT mass negatively influences UL recovery in a stroke patient. (Rajul Vasa unpublished observations).

Physiological constraint inter limb coupling and inter limb co-ordination and interdependence of all four limbs makes paretic UL moves in flexion from reduced loading of LL in stroke subjects with can be compared with healthy normal subject hopping on single leg who is also seen to have their UL go in flexion posture while hopping. (Rajul Vasa unpublished observations)



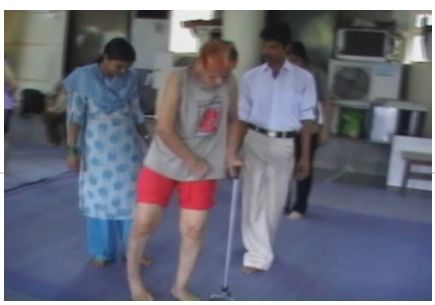
Snowball effects

16. Flexion in UL is task invariant (10) and selective control is sacrificed, this makes therapeutic efforts to teach the stroke subject to solve problem of learned nonuse with repeated forced use of paretic limb and constraint on good hand not a highly recommended approach when in fact, flexion of UL though looks abnormal is highly optimal considering muscle properties, neuro-motor noise, Sensory-motor delays, and the need for stability taken into account. Reaching difficulties in stroke with weakness in arm muscles makes it difficult for stroke subject to control long lever of the arm making reaching out a difficult task (Rajul Vasa unpublished observations). Unfortunately, the number of effective treatments aimed at improving arm function due to stroke is still low. Stroke patients compensate with increased trunk flexion for reaching with greater involvement of the trunk in arm transport.

17. Some patients have special psychophysical behavior, they look for wall support and refuse to walk away from wall, some get dragged towards wall consistently unknowingly and have high amount of fear for simple tasks like, to stand and walk and climb stairs making them feel safe to ambulate in wheel chair with its effect on general metabolism, cardiovascular efficiency and bone loss from not weight bearing while walking and possibilities for fractures (5).

18. Fear of falling makes patient pay constant attention to simple acts like walking and standing up and sitting down and during ADL. Patient feels highly insecure if these simple acts are not attended. Paying attention on more than one area makes stroke subjects feel his short comings of physical capacity and feel depressed about self-perceived disability and vicious circle.

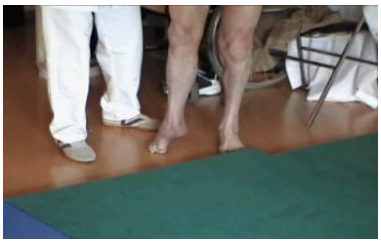
19. Many stroke subjects with weakness in leg are seen to use knee extension primarily for stability because of delay in weak paretic hip muscle to stabilize the leg



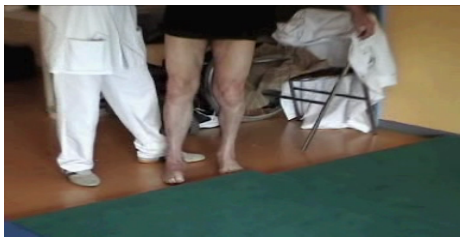
against the force of gravity. Primary extension at the knee for stability pushes the pelvis and hip further away from paretic hip. Intersegmental interactive forces help change direction of forces towards the non-paretic hip making it almost impossible to reload the paretic LL.

20. Weak flail knee goes in recurvatum from bone on bone forces that overstretch ligaments.

21. Spastic knee from Quadriceps over activity is seen in some sub cortical lesions. Knee torque in general is higher than knee torque on normal side for knee extension as part of a compensatory strategy for defensive reasons and for extra stability



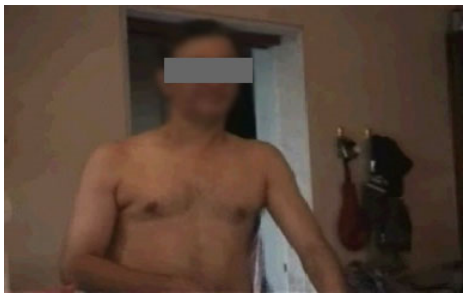
22. Primary Knee extension torque influences adjoining linked segments like Foot and ankle which is known to get inverted.



23. Hip and femur are also influenced from passive inter segmental interactive forces from knee extension to get approximated into acetabulum and give added passive stability when hip muscles are weak.

Snowball effects

24. Stroke patients are seen using their neck muscle proprioception and vision for balance to compensate for reduced proprioception from reduced loading on paretic leg. Neck stiffness with eyes glued on the ground while standing and walking sacrifices crucial spatial information needed for anticipatory actions in Stroke patients. This makes them depend on reactive response rather than anticipatory action that may not be safe always, making them feel unsafe and insecure all the time resulting into mental caution, physical caution and spatiotemporal delay and vicious cycle.



Neck Muscle and Vision for Balance

25. Common example of compensatory movements used to compensate for inadequate knee flexion and ankle dorsiflexion displayed by stroke patients during the swing phase of gait is increased pelvic elevation and circumduction in the frontal Plane of the paretic leg. Repetition of walking training with aim to increase speed when patient has abnormal circumduction gait with pelvis hiking has its consequences in terms of long term memory of abnormal compensatory movement with irreversible plastic changes.

26. Difficulties of multitasking are known and studied; those with normal speech are seen talking only when seated. They need to stop walking to be able to talk. They are seen afraid to talk while walking

27. Use of vision for balance is known and is encouraged by therapists for balance retraining to compensate for proprioceptive deficit. Adapting to vision for balance leads to more constraints (Rajul Vasa unpublished observation) in terms of safety and multi-tasking difficulties with great impact on self-perceived disability (6)

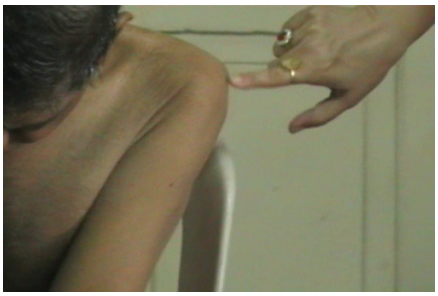
28. Vestibular modulation has been also reported following stroke (7). Stroke CNS exploits vestibular sensations to be able to stand with stiff knee. Quadriceps spasticity or quadriceps and hamstring co-contraction makes knee bending difficult during swing phase affecting spatiotemporal parameters of gait cycle.

29. Some stroke patients with ataxic trunk are seen to make their body rigid with co-contraction in conscious attempt of not shaking. Rigidity

and co-contraction makes them move like robot with a lot of limitation (Rajul Vasa unpublished observation).

30. Use of shoulder sling is expected to reduce sub luxation of flail shoulder, sling prevents automatic swing of the arm in walking.

31. Large number of stroke patients despite using shoulder sling continues to get pain and continue to have subluxated shoulder and may develop shoulder hand syndrome with swollen hand fingers. Drugs to relieve pain also have only minimal effect making patient feel depressed from severe pain. Most of the time passive shoulder movements, use of pulleys is the precipitating factor of pain and shoulder hand syndrome. Shoulder sling also many a times has mental impact on the patient in terms of developing a feeling of not to let the shoulder move, rather to protect it from any movement from the fear of pain. This can prevent automatic arm swing during walking and standing up, thereby preventing the chance for paretic shoulder to participate in inter limb activity that could internally change the dynamics to trigger action in motor neuronal pool that could generate intrinsic force in Deltoid muscle that could support the subluxated shoulder from within which is superior to any external support from sling.



32. Use of cock up splint and dynamic finger wrist extension splint many a times can be the source of continuous stretch that can produce continuous contraction in the wrist finger flexors strengthening the spastic state as well as facilitating passive tissue contracture making reaching out and picking objects with the hand highly difficult.

33. Wrist and forearm pronation with hooking of fingers is repeatedly seen when patient actually wants to open the fingers and release the object. Some studies indicate that Impaired anticipatory control of fingertips might be responsible for reaching deficit (8) Constant attempt of self-organizing stroke CNS to keep the UL closer to the central axis in defense of global COM by restricting UL COM from running out of the BOS by exaggerating egocentric reference for paretic UL may be the reason for flexion contracture and flexion spasticity.

34. Post stroke tactile allodynia is known. Stroke subject is known to get troubled painful sensation to a light touch, soft breeze, cold or hot temperature. I feel Paraesthesia and painful sensation and over reacting to non-injurious stimulus to the skin might be result of long standing unloading and reduced loading on limbs, long standing neglect, and abnormal sensory motor state with sensory conflict resulting into limbs becoming useless for postural and supra postural acts. Some stroke patients are known to be “pushers”, they not only cannot use their paretic limb to stand but cannot load good LL as well and begin to push if made to stand. Chaotic conflict between cerebello-cerebellar connections when the lesion is in some distant area can be helped to re-reorganize so that pusher can ambulate independently on his own feet and do

not suffer from the label of “difficult to rehabilitate” and suffer from consequences of wheel chair ambulation and general deterioration with bone loss, pathological fractures etc.

35. Some stroke patients have spatial neglect, hemi neglect and they refuse to accept the stroke condition happening to them. Time factor is important in rehabilitation not only for tissue healing but for emotional part of the brain that can make or break individual efforts for recovery. Before patient gets adapted to the condition and before he goes into denial zone for what has happened to him, early therapeutics to re-reorganize stroke CNS timely can help to overcome denying difficulty.
36. Ability to produce smooth movement is impaired in stroke subjects and movements are seen to be very slow, perhaps slow movements an act of self-organizing brain to minimize disequilibrium in defense of COM.
37. Gutter splint to stabilize the weak knee from buckling actually gives knee recurvatum for passive mechanical stability when knee is flail and not able to generate force.
38. Strengthening of weak paretic muscles is not the same as strengthening muscle with normal tone in normal people. It is most likely that paretic hypotonic muscle strengthening may trigger muscle wisdom to outsource contraction in synergic muscles, muscles at a distance resulting into compensation rather than strengthening of targeted hypotonic muscle. Adaptation and long term memory of the undesirable muscle work makes ‘Normally Abnormal, Normal’ for stroke patients making ‘stroke a stroke for the rest of the life’.

Changing the Course

It may help to outgrow desire to treat negative and positive symptoms of muscle and ask why negative symptom like weakness and flaccidity changes into positive symptom; spasticity? Why spastic muscle offers high resistance to yield but continues to remain weak? Is there a connection between increased degrees of freedom and development of synergic grouping, passive tissue contracture and spasticity? What could be the possible role of passive tissue contracture for a dynamic self-organizing brain that always works optimally? We need to ask why abnormal synergic grouping remains invariant. We also need to know limitations of definition of spasticity based on laboratory experience when the spastic subject is lying passive and researcher is actively attempting to move the limbs under testing. We need to consider patient's experiences of spasticity in their daily life and experiences of therapist about spasticity in clinical practice. We need to think is spasticity inevitable? Can we not prevent spasticity from surfacing at all? Once spasticity sets in, can we get rid of it? If we did, it will save huge amount of money, time, and energy of the patient, family and above all, use of state funds coming from tax payer's pockets for better cause. As a clinician in motor control science, I feel the need of reviewing birth of spasticity with clinician's view point is of critical importance. We need to consider possible reasons other than the lesion, why spasticity surfaces at all? To answer the questions of our patients about return of lost control we need to change our course to identify the real reasons besides lesion behind the development of chain of symptoms in the muscle that evolve with passage of time following stroke.

'WE DO NOT KNOW' all about stroke recovery makes young, curious minds of neuroscientists to ask questions to find solution with new ideas. If 'out of the box' ideas in clinical practice are understood and taken into consideration in evidence based research science while designing new research studies to give scientific evidence to empirical clinical knowledge, it can lead to revolution in stroke rehab and in neuro science. Until then, who continues to suffer? 'THE PATIENT'

We physiotherapists in clinical neuroscience and in research neuroscience need to take our responsibility to bring much needed change in stroke rehab. Role of the neurologist is over once life is saved and diagnosis is made. Research scientists have their own compulsions when designing research question. Physiotherapists need to design therapy that meets brain's goal of self-safety and bring balance between non-paretic and paretic body to be able to independently and equally take responsibility of gravity referencing without letting it be a monopoly of non-affected body.

Spasticity; clinical understanding, biomechanical function and physiological end effect

Till date, spasticity is well described in physiology as velocity-sensitive increased resistance of a limb to manipulation in subjects with lesions of descending motor pathways from increased tonic stretch reflex when experimenter passively tries to move the limb during clinical examination.

I feel it is time now, to think beyond physiological definition built on the laboratory experience when limbs under the tests are moved passively by experimenter. We need to know about spastic muscle activity in action, outside the laboratory during real life experiences and who else is better privileged to do that other than clinical scientist in applied motor control.

I think that the term spasticity is dedicated to stretch reflex in unloaded condition during clinical examination. The term Spasticity does not “deserve” to be used in functional conditions such as during locomotion to define the extension of muscle activity. Indeed, this muscle activity is usually a prolonged continuous activity (not a phasic activity) as a result of proactive central command (not as a reflex reaction to muscle stretching).

Clinically one can describe spasticity as an attempt of self-organizing brain to restrict fluid change in movements of global COM by restricting segmental COM movement and keeping them invariant, only towards central axis in an attempt to give safety to COM with extended anticipatory action from slightest movement of COM.

Biomechanical function of the extended muscle activity in stroke patient

1. Extended muscle activity in paretic muscles has mechanical effect to compress and restrict the degrees of freedom of paretic segments. Extended muscle activity observed on the paretic limb also has a functional role of controlling dynamic equilibrium with automatic neural postural control.
2. Continuous muscle activity in trunk muscles restricts boundaries of COM movement on paretic side of the central axis. This supports the reason why patients find it difficult to shift head, arm, and trunk [HAT] mass over to paretic leg. One can assume that this problem of shifting weight is nothing but self-organizing brain's solution to prevent falling when paretic weak LL muscles cannot sustain the force of gravity and pose threat to the safety of COM.
3. Extended Continuous contraction in latissimus connects two girdles upper and lower with its attachments on scapula and pelvis. This helps to make trunk rigid log like and restrict dissociation between two girdles.
4. Extended Continuous contraction in latissimus, pectoral, Psoas, that span from trunk on to limbs binds the limb to the torso thereby restrict the increased degrees of freedom of paretic limbs that can pose threat to the safety of COM, safety being a priority for living biological system.
5. Extended Continuous spastic contraction in latissimus with its attachment on Thoraco-lumbar fascia connects central axis with paretic torso and paretic UL, and activity in Psoas helps bind LL to the torso thereby to central axis and thereby restricting limbs from posing threat to the safety of global COM.
6. Extended Continuous spastic contraction in paretic weak leg muscles helps make the leg act as a prop and sustain the leg from buckling at the knee against the force of gravity.
7. Extended Continuous spastic contraction in the flexors of arm reduce moment arm of the UL with flexion to restrict it to remain closer to the central axis and thereby restrain segmental COM of UL from running out of the reduced BOS from reduced loading of paretic LL that can be a threat to the safety in standing, walking, climbing.
8. Extended Continuous contraction helps paretic side to act optimally as a BRAKE on COM movement lead by the non-paretic side and thereby turn paretic side a defender of COM instead of a controller of COM.
9. Extended Continuous spastic contraction helps prevent any exchange of dominance between two sides thereby prioritize safety of COM with new functional integration between two sides wherein non paretic side continuously leads COM and paretic side follows the non paretic side as against exchange of dominance between two sides to control and lead COM when normal before stroke.
10. New functional integration between two sides of the MSS makes clear division of role between two sides making "normally abnormal, as normal" for the stroke subject.
11. Extended Continuous spastic contraction prevents task related variability in the paretic limbs thereby reduce threat to the COM and maintain safety a priority.

Neuro-physiological end effect

1. Slightest movement of COM with change of posture and movement of non-paretic limbs during postural and supra postural tasks, anticipatory postural neural activity gets triggered at various level of neuraxis for subconscious automatic synergic grouping in paretic limbs with reorganization of spino-spinal motor circuitries from inter limb and intra limb physiological constraint. Self-organized stroke CNS exploits spinal circuits to restrict degrees of freedom of paretic segments and to give specific direction to the paretic limb that remains invariant and always towards the central axis for automatic physiological safety of COM.
2. Spino-spinal reorganization, spastic latissimus, contracted Thoraco-lumbar fascia and bilateral innervation of torso helps bind paretic torso to the central axis thereby sustain huge mass of paretic torso from collapsing against the force of gravity and mechanical unloading of the paretic LL gets physiological neural endorsement to maintain reduced loading of paretic LL for safety of COM with physiological inter limb and intra limb constraint.
3. Spino-spinal reorganization coupled with functional adaptation makes automatic synergic grouping in paretic limbs effortless and to become permanent making safety a priority an automatic sub conscious affair.
4. Plastic changes in distant areas of the brain from consistent use of non paretic limbs for all supra postural tasks and for postural change lead by non paretic MSS uninterruptedly makes “normally abnormal, normal” for stroke CNS.
5. Neurally endorsed mechanically reduced loading of LL with reduced proprioceptive inflow triggers sensory reweighting for balance control with use of visual, haptic and vestibular sensation. This makes otherwise automatic balance reactions to become highly cortically controlled.

Potential dangers to the true recovery

- While brain is naturally healing and recovering, what it experiences and what the patient does or does not do have major influence in shaping sensory motor output.
- Self-organized brain and its automatic action to prioritize its safety if not channelized timely it can be of permanent problem once patient gets adapted to it.
- What ‘NOT TO DO’ to avoid compensatory movements and more importantly to recognize compensatory movement as negative plasticity (43) and not positive is critical to be on the road to true recovery and what ‘TO DO’ with brain and with body to achieve it.
- Ongoing peripheral sensory motor state is reported exactly to the CNS.

Potential dangers to the true recovery

  - Dialogue between brain body and external environment can be misdirected if, stroke subjects are trained for compensatory and compromised behavior to reach for objects, to stand up, to sit down, and to walk with external devices, it can make the brain, normally a controller to get controlled by periphery.
  - Balance problems are automatically substituted with vision. Therapeutic promotion of vision and auditory feedback for balance can make **"Normally Abnormal, Normal"** for the stroke.

- Negative mind of the patient and their family about possible recovery can be a major constraint.
- Some want to get independent as soon as possible; this makes them use their non-affected side without exchanging dominance with paretic body.
- Some depend on family, and some take advantage of condition to rely on state benefits and develop lay back attitude and develop self-destructive practices complicating every possible little constraint into major problem despite having good physiological potential to recover.
- Divided focus in multidisciplinary palliative rehabilitation approach for paretic upper limb, lower limb, and speech, cognitive and perceptual abilities by OT, PT, SPEECH, and psychologist respectively makes mental division of anatomically united paretic and non-paretic MSS. Constant exclusive attention to paretic body in different departments of special teams makes patient to develop habit to pay attention to divided entities most of the time of the day even outside the departments.
- Inability to weight bear and weight shift on paretic side during walking poses huge threat to the safety of COM. Self-organizing brain may trigger foot turning into supination, co-contraction, rigidity, freezing of COM and varied psychophysical behavior from fear of falling unless brain and body are prepared to support, balance and propagate entire body alternately with equal exchange of dominance between the two sides.
- Abnormal grouping in flexion of the paretic UL becomes inevitable if paretic trunk and LL is not prepared to support balance and propagate entire body.
- Physiological constraint inter limb and intra limb coupling and inter-limb coordination makes paretic LL with reduced weight bearing to re-organize spino- spinal circuits with interaction of spinal interneurons at all levels of spinal cord that makes the paretic UL to develop flexion posture.
- Do not allow overweighting with bilateral vestibulo-spinal circuits to combat gravity with over activity in trunk extensors that turns multi-segmented spine into one log like structure.
- Do not allow vision to replace reduced proprioceptive sensory input for automatic balance.

Theoretical underpinning behind Vasa Concept

A) Self-organization of the brain following stroke plays vital role in birth of Sensory-motor problems.

1. Capacity of self-organizing brain to automatically depend on non-affected side to defend safety of COM when paretic body cannot control and restore it is a huge constraint following stroke.
2. Paresis of one side makes the body highly unstable. Self-organizing dynamic non-linear system takes internal actions to re-stabilize by inducing changes from within to prioritize safety of COM.
3. Consistent imbalance of the proprioceptive sensory inflow between non-paretic and paretic side to the mirror image structures like spine and cerebellum results in self-organization in these structures from consistently reduced input from affected side periphery. Ability of cerebellum to regulate, modulate and influence motor output to lesioned cortex and reduced output from cerebellum to spine are problems to be attended in therapeutics on emergency basis by flooding proprioceptive input to spine and cerebellum thro' dorsal column pathways and anterior and posterior spino-cerebellar pathways to be able to influence true recovery.
4. Ability of self-organizing stroke CNS to bring in homeostasis of forces between within and outside when paretic muscle motor fails to generate force is the constant constraint in restoring lost control.
5. Ongoing efforts of self-organizing stroke CNS to tow the paretic body with non-paretic body to function as one whole integrated unit highly automatically sub consciously gives birth to chain of added constraints.
6. Amplification property of the brain makes symptoms to amplify with different physiological, functional, and psycho-physical constraints that give devastating impact from a small lesion.
7. Non-linearity of the biological system makes surfacing of different symptoms highly unpredictable making evolution of symptoms from flaccidity to spasticity, synergic grouping, Paraesthesia, loss of proprioception, passive tissue contracture, associated reaction, a challenge for all in the field of stroke rehabilitation.
8. Ability of self-organizing stroke CNS to exploit visual vestibular and tactile sensation sensory reweighting to compensate for reduced proprioception is considered to be the solution for balance difficulties and is therapeutically encouraged to compensate for the loss. This automatic functional compensation with sensory reweighting by self-organizing CNS followed by functional adaptation makes restoration of lost control highly difficult.

9. Ability of self-organizing brain to induce morphological changes in muscles, in connective tissue, fascia, to set contracture to restrict degrees of freedom of segments is also a challenge for therapists.
10. Self-organizing stroke CNS exploits slightest movement of COM to trigger anticipatory contraction in postural muscles. Inter limb-coordination and anticipatory activity on non-paretic side influences motor behavior of paretic side.
11. Adaptability and Movement experience dependent plasticity can be an additional constraint in making "Normally Abnormal, as Normal" for the stroke patient with uninterrupted use of good limbs to get on with life and to prioritize safety of COM.

All the above mentioned factors become the fountain of continuous reverberating source of all sensory motor problems of stroke making contemporary therapeutic efforts to treat negative and positive symptoms of paretic muscles an act, which can be compared with boarding a flight in the direction towards SOUTH when the destination is NORTH.

B) Power of Self-organized stroke CNS is superior over any man made efforts

President Woodrow Wilson
1918

Senator Mark Kirk
2012

Over a century now, therapists and doctors of the world are struggling to find solution for stroke motor problems. As you see in above photos both US president Mr. Wilson and Senator Kirk are using stick to balance, both have uselessly hanging arm in flexion synergy over a span of almost 100 years, neuroscience is struggling for solution and is promoting virtual reality and robot to announce that rehab medicine is also modernizing.

We need to recognize that it is the power of self-organizing brain, is what we are struggling against. To be able to tip the "see saw" balance in favor of therapeutic efforts as against the power of self-organizing brain one must recognize that it is critical in therapeutics to maintain the same goal as that of the brain, 'safety of COM' a priority. Therapeutics must be designed to accommodate and exploit CNS priority to control, restore COM safety automatically with paretic body and prepare it to support balance and propagate entire body in order to successfully re-re-organize self-organized stroke CNS.

C) Different Events and Sub Goals for the Primary Goal; "Safety of COM"

1. Pre dominant consistent uninterrupted use of non-paretic limbs for safety of COM during different possible postural and supra postural activities makes spinal circuits to reorganize to support the act with supportive spino-spinal self-organization, that makes paretic Upper Limb to go in flexion posture. Thus flexion in paretic UL is inevitable making extension and reaching out in open with paretic Upper Limb a difficult proposition unless therapeutics aim to restore postural control and safety of COM with paretic lower limb in all the 3 Cartesian coordinates
2. Spino-spinal reorganization leads to synergic grouping in paretic limbs to support the action of non-paretic limbs with limb to limb knowledge, and inter limb coupling a physiological constraint. This synergic grouping remains task invariant to prioritizes safety of COM by restricting direction of synergic grouping in paretic limbs to remain towards the central axis to restrain it within the narrow BOS during postural and supra postural tasks seen in adduction at paretic hip sometimes even scissoring of LL and adduction in UL of stroke patient with flexed elbow to reduce moment arm length of UL and bring the UL segmental mass closer to the central axis.
3. Abnormal grouping called Flexion synergy in UL remains invariant despite change of task. This invariant behavior of paretic upper limb from self-organized efforts of brain makes therapeutic efforts to constraint the good limb and force the paretic upper limb to reach out in open in different directions repeatedly can be compared with expecting a car to accelerate when hand brake is on.
4. Spino-spinal reorganization for safety of COM during all tasks carried out by non-paretic limbs and synergic grouping of muscles in paretic UL and paretic LL from inter limb coupling that remains task invariant and brings the limbs closer to central axis to remain within BOS (Base of Support) for safety makes loading of paretic LL and reaching out with UL, highly difficult task. This difficulty of loading of paretic LL actually helps to add safety to COM as paretic LL with weak paretic flaccid muscle is not capable of generating force to support itself and the weight of HAT (Head, Arm, Trunk) against the force of gravity.
5. Deficient loading of paretic LL influences paretic UL with Inter limb coupling and inter limb sensation. This makes reaching out difficulties of paretic UL a challenge in therapeutics not only from "learned non-use" of paretic limbs as always understood but largely because deficient loading of paretic LL is interconnected with reaching difficulties of UL being

constrained from physiological constraint “inter limb coupling” that makes spino-spinal connectivity to reorganize for safety of COM a priority.

6. Inertial mass of paretic segments stretches the paretic segments from its own weight in presence of gravitational force to stimulate heteronymous Ia spindle that connects many muscles together triggering reflex contraction in stretched muscle. Anticipatory proactive activity in chain of muscles with slightest movement of COM in addition to reflex contraction gives birth to synergic grouping and extended continuous spastic activity that sacrifice selective control.
7. Self organizing stroke CNS makes use of impedance offered by extended continuous spastic activity in chain of paretic muscles to restrict movement of paretic limb and it also offers resistance to non paretic limbs being mechanically connected at the central axis helping to restrict boundaries of COM movement on non paretic side to remain within the safety limits of BOS (Base of Support) for safety a priority for all living biological system.
8. Paretic side with its huge inertial mass being connected to non paretic side influences the global COM safety with its huge inertial mass during postural and supra postural tasks. Self organizing stroke CNS takes steps towards the safety by binding the anatomically connected paretic MSS to the central axis by inducing Microscopic morphological changes in soft tissue, fascia and connective tissue to make it stiff and contracted for easy binding of paretic MSS with good MSS at the central axis and to tackle interactive forces to reduce threat to the safety of COM.
9. Microscopic morphological changes triggered in MSS by self-organizing stroke CNS to induce contracture in all available tools like fascia, connective tissue, muscle tissue, with bilateral innervation of the trunk muscles bind paretic torso and limbs at the central axis and at proximal joints with contracture in iliopsoas, rectus Femoris, and pectoral and biceps brachi, collectively result into solving increased degrees of freedom of paretic segments and help provide an inroad into a new Macroscopic change in motor behavior that can be compared with ‘TOWING’ action wherein non paretic side tows the paretic side making it to trail behind and follow the non paretic side.
10. Towing of paretic side with power of non paretic side results into no longer any exchange of dominance between two MSS. No exchange of dominance between two sides of MSS helps reduce threat to the safety of COM with paretic side no longer leading COM. Non paretic MSS controls as well as leads the entire MSS all the time. This new functional integration between two sides makes clear division of role between two sides with paretic side turning a follower all the time. This new modified functional integration between paretic and non paretic side makes “Normally Abnormal, as Normal” for the stroke subjects making stroke problems a huge challenge in rehabilitation till date.
11. Optimality (82) of control in biological system makes self organizing brain to make optimal use of paretic MSS by turning paretic trailing MSS into a defender (Rajul Vasa unpublished observation) of COM by preparing it to act as a powerful BRAKE (Rajul Vasa unpublished observation) on the fluid change in movement of COM with passive tissue contracture offering resistance to change in joint space extended continuous spastic contraction in chain of paretic muscles with slightest movement of COM offer increased impedance and increased inertia to move

and also resist change in joint space in the direction that can be a threat to the safety of COM.

12. Anatomical arrangement of widely spread Thoraco-lumbar fascia (83)continues till cervical and sacral region connecting the entire spine and both sides of MSS together. It houses large trunk muscles on both sides of the spine dorsally and connects abdominals as well ventrally. This arrangement of Thoraco-lumbar fascia and large muscles it houses with bilateral neural innervation is designed by nature especially for the entire body to work as one whole integrated unit despite lesion in the brain and despite paresis on one side that no longer counter the pull from non paretic trunk muscles. This unopposed pull from non paretic muscles balances torso in a new alignment wherein the torso is mechanically rotated away from the paretic hip thereby offloading the paretic LL from the burden of the HAT mass creating chain of direct, indirect problems of non weight bearing, asymmetry of limb loading, and consequences thereof.
13. Lattissimus muscle's spasticity and contracture help to restrict COM movement as this muscle and Thoraco-lumbar fascia both brace the sacroiliac joint where Imaginary point the COM is located.
14. Widely spread Lattissimus muscle connects upper and lower girdle. Anticipatory proactive contraction in this widely spread muscle with slightest movement of COM makes the paretic side almost like a log and does not allow dissociation movement between two girdles of the paretic rotated torso from unopposed pull of Thoraco lumbar fascia and large number of muscles it houses thereby adding safety to the COM by restricting COM motion in the paretic territory in addition to unloading of paretic LL.
15. Spastic Lattissimus also helps bind UL with the torso from its anatomical attachment on Humerus and on spine through Thoraco lumbar fascia. In all, all this arrangements help good side MSS to tow paretic side like a passive log.
16. Another interesting arrangement of nature is very special coupling between Gluteus maximus the LL muscle and the contra-lateral Lattissimus dorsi (84) muscle which is fanned from torso all the way to UL but on opposite side to the LL that allows swing of the arm when the opposite leg extends. Self organizing dynamic stroke CNS exploits this arrangement of continuity between Lattissimus and gluteus on opposite side to neurally endorse provisional mechanical reduction in loading of paretic LL from rotation of the trunk with unopposed pull of non paretic muscles of torso and bending of trunk from gravity with following.
    a. First, Normal gluts on one side and affected weak lattissimus on the opposite side, makes the Gluteus maximus to pull on the Thoraco-lumbar fascia on one end from good side but lose its tension on the other end on paretic side making the spine rotate mechanically.
    b. Second, Affected gluts on the paralyzed side, with normal lattissimus of opposite side makes the Thoraco-lumbar fascia lose its tautness at lower end, but get pulled at upper end, further consolidating the rotation of spine and thus consolidating mechanical unloading of paretic lower limb.

c. Third, Getting adapted and habituated to using non paretic limbs for ADL is known, this results in reorganization of postural neural circuits from consistent use of non paretic limbs for postural change and for supra postural tasks making sub cortical neural circuits to neurally endorse mechanical unloading.
d. Fourth, Plastic changes in distant areas of the brain and in non lesion hemisphere [N S Wade] from consistent use of non paretic limbs can make it very difficult for stroke subject to, "not use" non paretic segments.
e. Fifth, Consistent use of non paretic side makes the sensory inflow to the spinal cord influence physiological constraint the inter limb coupling with inter limb sensation and inter limb knowledge that influence motor outflow on paretic side with spino-spinal reorganization to endorse mechanical unloading sub cortically making almost all conscious therapeutic efforts to go in vain to help reloading of paretic limb during gait and other postural acts.

17. Spastic Latissimus also helps bind UL with the torso and to the central axis that can help good side MSS to tow paretic side like a passive log.
    a. Self-organizing stroke CNS exploits anatomical spread of pectoral and Psoas to limbs from the torso to bind UL and LL to the torso at the shoulder and hip respectively to reduce degrees of freedom at proximal joints to block movements of the limbs that can pose threat to the safety of COM and allows a movement that brings the limb closer to central axis like adduction for easy towing of limbs by non paretic side when bound to the torso.
    b. Peripheral sensory inflow from paretic side MSS is capable of turning PNS (Peripheral Nervous System) into a kind of *'Boss'* or *'Dictator'* of CNS with constant report about peripheral unloading or reduced loading and monotonous segmental alignment of limbs that remain almost constantly in unchanged abnormal state from extended continuous spastic contraction. Monotonous sensory information about mechanical unloading of LL makes Stroke CNS to go ahead to neurally endorse non weight bearing to offload inertial mass of HAT with sub cortical postural reorganization when paretic LL cannot generate enough power in paretic muscles to cope against the force of gravity that can be a threat to the safety of COM making PNS to rule over stroke CNS.
    c. Self organizing stroke CNS exploits bilateral innervation of the trunk to neurally bind mechanically connected paretic side with non paretic side at the central axis to protect the weak paretic MSS from collapsing from the force of gravity that could pose threat to the global COM.
18. Passive binding of paretic MSS at the central axis from connective tissue contracture and task invariant configuration of paretic limbs from extended continuous spastic contraction and synergic grouping gives rise to development of new gravicentric reference in the external Cartesian coordinates for paretic side to be able to sustain the force of gravity via the non paretic side and thereby defend COM. Paretic side maintain egocentric reference with the spine the central axis with limbs adducting at proximal joints and distal wrist and fingers flexing to reduce the moment arm of the limb for easy towing and restricting it to remain within the BOS (Base of Support).
19. Foot ankle planter flexion from foot drop from gravity force and spastic calf helps foot to maintain contact with support surface and prevents Tibia from rolling anteriorly thereby restricting Tibia from moving forwards in saggital plane in anterior direction.

20. Weak flail paretic knee hyper extends with recurvatum from passive interactive forces and joint compression forces from GRF falling behind the knee joint that gives passive stability to the paretic knee from buckling and makes the femur to approximate into acetabulum for added stability when muscles of hip are weak that can pose threat to safety of COM.

Vasa Concept is to re-reorganize self-organized brain by expanding boundaries of COM movement on paretic side to restore lost sensory motor control following stroke.

Vasa Concept – Practical Application

1. Prevent, provisional arrangement made by self-organizing stroke CNS from becoming permanent;
    a. To outsource motor power exclusively from non-paretic MSS to prioritize safety of COM.
    b. To outsource sensations with sensory reweighting from visual vestibular and tactile sensation to compensate for the proprioceptive loss from reduced loading of LL to prioritize safety of COM
2. Expand boundaries of COM movement in all the Cartesian coordinates on paretic side of the central axis.
3. Make paretic side body capable to control and regulate most regulated variable the global COM to safety spatio temporally effectively automatically without verbal instructions.
4. Re-re-organize self-organized stroke CNS by reconfiguring linked MSS wherein non paretic limbs are used to trigger internal destabilization in specially designed postures for controlled disequilibrium of COM that unleash avalanche in anticipatory proactive sub cortical postural motor circuits to influence eagerly awaiting motor neuronal pool that connect paretic muscles in a chain reaction to control COM.
5. To make paretic MSS to be part of one whole posture wherein spastic segments are cornered / forced to support the COM with some external assistance if necessary when Non-paretic segments are exploited to destabilize the posture in controlled disequilibrium to trigger sub-cortical postural proactive motor activity to act optimally as a ***brake*** on COM movement making need to do splinting for inhibition, and need for inhibitory exercises become obsolete.
6. To monitor dialogue between stroke CNS, MSS, PNS, and external variant and invariant forces in specially designed postures so that paretic MSS do not turn a controller under the behest of invariant force gravity and start controlling stroke CNS as against the role of CNS as a "controller" and MSS as what is "controlled".

What to exploit

1. To exploit CNS priority: "to control COM" in order to expand boundaries of COM on paretic side in all Cartesian coordinates to bring fluid change in movement of COM during postural and supra postural tasks.

2. To exploit non paretic limbs before they become liability by coming into action all the time to compensate for the loss and to compromise.
3. Exploit non paretic limbs to trigger controlled disequilibrium to induce intrinsic change in internal dynamics that pose threat to the safety of COM.
    - Disequilibrium from within unleash avalanche in postural motor neuron pool at various levels of neuraxis from anticipatory proactive sub conscious activity to generate forces in chain of weak paretic muscles automatically to control COM and thereby prioritize safety of COM without any external commands that make an inroad for restoration of lost control as a byproduct
4. Exploit overflow of negative activity in paretic muscles from Global synkinesis and associated reactions to turn it into positive by fixing paretic segments against the support surface
5. Exploit GRFs. Paretic fixed limb muscles generate GRFs when fixed against the support surface. Paretic muscles of fixed segments are forced to react to GRF to sustain against the force of gravity with equal and opposite forces.
6. Exploit inter-limb coordination and exchange of dominance between two sides to prevent abnormal synergic grouping in paretic limbs from spino-spinal reorganization.
7. Exploit different postures as a whole to be able to get control on individual segments which are part of the posture instead of treating and focusing on individual segments, and individual joint. “Whole is bigger than its individual parts” for a dynamic biological system
8. To exploit a posture that gives mechanical safety and helps give balance confidence & emotional security that with centrally initiated postural adjustments.
9. To exploit closed chain postures such that internal resistance from fear of falling to change posture is minimum as long as COM remains controlled and safe.
10. To exploit environment and its physical laws and biological physics to give desirable stability to the system without letting undesirable compensatory motor patterns to set in with adaptive behavior.
11. To exploit active participation of the stroke subject in interesting games wherein many stroke subjects participate together and have fun with one another and be free of anxiety. Patients playing together sorts out number of other effects of sensory motor paralysis on many different aspects of the life other than movement for example psychosocial factor that influences rehabilitation and recovery
12. Exploit structural properties of the MSS to turn it into an advantage instead of disadvantage. Structural properties of the MSS like Size, shape, length, instead of posing a threat to the stability are exploited in closed chain posture that give passive mechanical stability and off load the neural system from the need for extra defense when muscles of one side of MSS are flail and not capable to combat invariant force of gravity and all other variant forces.

13. Large trunk mass can become a huge constraint for balance and equilibrium in standing, walking when all muscles on paretic side are very weak but one can exploit the same huge trunk mass to give passive mechanical stability in NAMAZ and BUDDHA posture that helps to reduce the paretic trunk rotation from the unopposed pull of the good trunk with pelvis acting as the BOS keeping COM close to the support surface thereby reducing the threat on the COM a major constraint.
14. Exploit joint compression forces for stability by approximating joints (42) in Closed chain postures without letting the elbow and knee joint to recurvate with bone on bone forces when muscular forces are weak or absent from paresis.
15. Exploit closed chain posture to restrict and reduce number of biomechanical degrees of freedom and channelize and control sensory inflow with fixed angles of joint segments that maintains the length and tension in muscles to guide more desirable motor output capable to constrain variability from Neuromotor noise (41).
16. To exploit Closed chain posture that allows the exploration of environment within the postural stability limit thereby helps psychomotor behavior to be calm and free of anxiety for fear of losing balance. Fear for balance once taken care of with intrinsic assurance it helps automatic emergence of more stable, desirable sensory motor configurations of multiple MSS links without cortical auditory visual feedback and interference for sub-cortical action like balance.
17. To exploit closed chain posture to exploit property of muscle's reflex structure whose inherent force-length and force velocity property creates an intrinsic response to perturbation with zero delay.
18. Exploit bilateral vestibular connections, vermis of cerebellum, anterior corticospinal tract on the same side from non-lesioned hemisphere and trunk muscles in BUDDHA posture to make paretic trunk to act against forces of gravity when normal leg is made to move to cause guarded disequilibrium trying to go to side sitting posture.

"What TO DO"

1. Make paretic muscles to be the window to the brain in specially designed closed chain posture to channelize sub-cortical postural motor neuronal pool at different level of neuraxis to connect to spinal motor pool, the final common path that connect eagerly awaiting flail paretic muscles in a chain to prioritize safety of critically controlled and most regulated variable the COM automatically thereby introduce contractility in flail muscles and begin the journey of paretic muscle towards selective control without any room for spasticity and abnormal synergic grouping.

2. To direct the dialogue between brain and body in presence of invariant force gravity to restore lost sensory motor control despite presence of lesion, making lesion irrelevant.
3. To restore weight shift on paretic lower limb and restore proprioceptive and tactile sensations as a byproduct by restoring control over COM with paretic LL segments.
4. To restore cognitive and perceptual abilities as a byproduct with restoration of control on posture and control on change of posture lead by, paretic segments as against control on posture and change of posture with non paretic segments.
5. Postural activities are highly sub cortical and automatic (44) therefore to restore sitting and standing and walking abilities with visual guidance, auditory feedback, verbal instructions, and cortical interference makes it highly conscious and abnormal.
6. Pusher patient is helped to get out of the state of pushing for complete restoration of control before his mind learns that he is a difficult "pusher".
7. To work on the stroke subject and his entire MSS as one whole unit in specially designed postures instead of focusing on individual parts.
8. To Re-introduce to paretic MSS how to lead COM and how to control COM instead of allowing it to become a follower and get towed by good non paretic MSS.
9. Vasa Concept proposes to restore communication abilities with return of sensory, motor speech as a byproduct by working globally on basal postural circuits that connect temporal and frontal cortices
10. To avoid secondary depressive mood changes arising out of physical limitations and self image crisis from stroke by restoring lost control in a short span of time with goal set by therapist but achieved primarily by patient himself / herself simply under periodic guidance of therapist.
11. To amplify restoration of lost sensory motor control multifold by prioritizing safety of COM with paretic MSS so as to avoid various different negative constraints like Paraesthesia, neglect and cortical signals of pain that would otherwise get snow ball effect from amplification property of brain when it got under threat from lack of control on COM safety.

"What not to do"

- Not to get biased with a lesion in CNS during clinical handling of the physical body of the stroke patient and not to overestimate role of a small lesion behind complex stroke impairment.
- It is also important not to under estimate role of various different variant and invariant constraints in ongoing deterioration of MSS with passage of time.
- Not to promote sensory reweighting with compensatory visual vestibular, auditory and haptic sensation for proprioceptive loss during balance training.

- Not to promote compensatory movement (43) and compromised behavior for postural acts. Compensation can be ugly once stroke subject gets adapted to it making it highly difficult to change when negative plastic changes from compensatory movement experience make it almost permanent making “Normally abnormal, as Normal” with passage of time.
- Not to promote and force paretic UL for those voluntary activities which are generally unilaterally performed before stroke. Forced compromised actions of paretic UL when repeated for reaching purpose actually promote undesirable spino-spinal reorganization to support the posture and control COM from inter limb coupling, a neuro-physiological constraint making altered reaching action permanent.
- Not to pay exclusive attention to paretic segments to strengthen the weak muscle with resistive exercises and weight training exercises to a muscle which is weaker compared to muscle in a normal healthy subject because wisdom in weak flail muscle will trigger to outsource strength from muscle abundance and many muscles available for one movement at a joint instead of making weak to get strong. Strengthening can be made possible by making weak paretic muscle to contract in specially designed closed chain postures wherein many muscles act together and many spinal motor neurons at many levels are linked together in a chain to safe guard COM using paretic muscles when good limbs are made to cause small guarded disequilibrium, anticipatory preemptive, proactive actions in many motor neuronal pool at many levels of neuraxis make paretic weak muscles, part of closed chain posture get reinforced with higher magnitude of contraction subconsciously automatically without voluntary efforts and without external commands.
- Not to stretch the spastic contracted tight muscle in order to facilitate selective control. Not to stretch spastic muscle to lengthen it by passive stretching and splinting. Splinting might only reinforce the reflex contraction in the spastic muscle with splint acting as a constant stimulus to trigger contraction we are trying to prevent. Solution lies in re-reorganizing stroke CNS with expansion of boundaries of COM movement and not in victimizing the victim; “the spastic paretic muscle”.
- Not to pay direct attention to any paretic segments at all as too much attention to individual joint and paretic segment for too long and during almost all waking hours could segregate the paretic side from non-paretic side mentally, emotionally, functionally, making a clean divide between anatomically, mechanically and physically united one body into a functionally divided entity making it hard for CNS to restore paretic MSS to its pre stroke state.
- Not to use verbal, auditory, visual, therapeutic feedback commands for restoring balance in sitting standing and walking as, balancing acts is not a conscious act but is a highly sub-cortical automatic postural act. Conscious training for subconscious automatic acts makes abnormal to become normal.
- Not to use the external support and externally unbalancing force, moving platform etc. as a stimulus for retraining balance. Externally generated unbalancing force makes the stroke subject to use good limbs to control COM out of defense instead of promoting

paretic limbs whereas intrinsically generated unbalancing force by moving some good segments promote feed forward anticipatory muscle actions from internal change for automatic balance.

- Not to put COM at such a high risk when paretic MSS is not able to control COM automatically. It makes the stroke CNS to surrender to the threat and switch back to its self-organized defense strategy to use non paretic segments to prioritize safety of COM when faced with an external threat from invariant force like gravity
- Not to under estimate power of brain to help prioritize safety of COM despite absence of forces in paretic muscles. Stroke CNS begins to exploit self-organizing characteristics, amplification property, and morphological changes in passive structures like connective tissue and fascia that could passively bind many segments with contracture. Forces generated from contracture can help bring homeostasis of forces between outside and within. Loss of sarcomere and loss of viscosity makes the muscle stiff and does not allow it to yield and change joint space when paresis increases degrees of freedom and gravity is a threat to the safety.
- Not to underestimate non-linear property of the brain why some stroke patients remain flaccid for long and some develop spasticity after long period compared to others in that non linearity of the brain to react to a stimulus plays a huge role besides geographical location of lesion.
- Vasa Concept proposes to grow beyond techniques beyond muscle symptom, beyond relearning of movement as learning is conscious affair when large numbers of day to day postural movements are highly subconsciously controlled.
- Restoration must be channelized thro' sub-cortical postural circuits for restoring automatic control (44).

Basic postures to work with

Buddha Posture

Buddha posture is safe with BOS wide and COM height low, it makes stroke subject feel calm safe and secure from within and not from third party efforts. This helps self organizing stroke CNS not to trigger defensive motor activity. Once the patient feels safe, one can work with asking the patient to move the non paretic limbs that sounds silly to the patient as he can easily move it, but he does not know that therapist is tricking him into not letting good limbs to be in control of COM and using good limb to cause guided controlled disequilibrium by moving the good leg to unleash avalanche of proactive activity in motor neuronal pool at different levels of neuraxis that connect paretic flail muscles thereby begin to have desirable activity in flail muscles to restore equilibrium with COM safe within BOS with use of paretic muscle contraction without triggering self-organizing proactive activity with nuisance value in terms of abnormal synergic grouping.

Namaz Posture

Namaz posture, see the fig. is safe with BOS wide and COM height low makes stroke subject feel calm safe and secure from within and not from outside. This helps self-organizing stroke CNS not to trigger defensive motor activity. Once the patient feels safe, one can work with trunk as one whole unit without having trouble of rotation of torso from unopposed pull of non-paretic trunk.

Cobra Posture

Cobra posture gives great stability with closed chain posture with both arms against the support surface generating GRF that makes paretic limb muscles to act to support the limb to safe guard the COM. Some external support at the elbow and wrist may help to begin with, to support this posture that makes wrist and fingers to not develop undesirable contracture and spasticity.

Camel Posture

Camel posture gradually leads to raising the COM height without fear of falling. One can be very creative in this posture to destabilize from within without external instructions from third party by moving good limbs and re-stabilize the COM using paretic segments sub-cortically with avalanche of proactive activity in awaiting motor neurons

Incidental Benefits From Vasa Concept

1. Stroke subjects get confidence of 'Being in control' and being ‘responsible for the self’ of therapy session with an exercise programme wherein patient has to take control of the self without much dependence on external help and without being a passive recipient of therapeutic techniques while moving ahead on the road to recovery and expanding boundaries of COM on paretic side in all Cartesian coordinates.
2. Stroke subject exercises in his own familiar home set up with some help if needed from unskilled personnel under the supervision of the therapist to assist the patient and keep him highly active, for 6 to 8 hours of the day continuously striving to reach the short term therapeutic goal set by therapist.
3. “Being in control” hugely helps stroke subject to take control of the condition in their own hand. Periodic guidance from therapists after achieving short term goals instills huge amount of self confidence and self assurance in the stroke subject and helps save a lot of money spent on daily 40 minutes therapy by therapists.
4. Periodic guidance from therapists makes patients responsible for the self, saving time for all. Therapists can see more number of patients, chronic patients and wait list gets reduced as same patient is called only periodically and not daily.
5. Long hours of exercises at home and being in control of the self takes care of general condition, density of bone calcium, heart rate and blood pressure, and above all it reduces the hidden costs of illness.
6. Fulfillment of goal keeps “depressive mood swings” and anti-depression drugs and anti - spasticity drugs out of the window.
7. Family and friends who suffers emotionally financially and loses on time the most important cost in today’s fast life is hugely saved.
8. Patient exercises in his / her home environment saving time of therapists for more patients to be attended.
9. Patient can exercise for more hours at home and remain occupied, minimizing the chances for psychological constraints from inactivity.
10. Patient’s state of mind becomes responsible towards the self for recovery rather than depending on the doctors and therapists for recovery by recognizing that it is their own brain and their own body that can only be helped by putting it all to work unlike in any other medical condition wherein either the pill in the mouth or the scalpel of the surgeon that works and patient is simply a passive recipient.
11. Insurance companies have not to support the illness for long periods

12. Need to have expensive indoor rehabilitation facility can be reduced, patient can exercise in open air in the garden on the soft grass and fresh air that can make mind feel more good too.
13. State can see a new chance to collect the tax with productive life of the patient returning back, rather than support the life of the patient in bed for the rest of the life.
14. Many unskilled workers get employment to work with patient to exercise, they get paid and in turn they pay tax to government instead of getting unemployment benefits from western government.
15. Costs on many drugs consumed for secondary and tertiary changes no longer needed.

Genesis of Vasa Concept

1. I felt very bad to see that stroke patients around the world were struggling to restore the lost sensory motor control. I wondered how I would feel if I was in the shoes of the patient and the patient was on the other side of the table! Certainly, I would not accept the loss and a life of dependence despite spending so much TIME, ENERGY, MONEY all these COSTs for rehabilitation that is not productive in true sense. Family, society and state all loses productive time period in addition to the patient's time of life. It was not difficult to see and feel frustration among the patients, their family, medical fraternity consisting of the therapists, doctors.
2. I began to make introspection to realize that I only knew some techniques and I delivered them to the stroke subjects without much results because these techniques did not solve the root cause nor did I know what the root cause of all these complex problems was. I began to take interest in experimental evidence in motor control and what I recognized was that questions of typical stroke motor behavior frequently became the source of more questions than answers. After a century of extensive multidisciplinary research, attempt to capture the complexity of purposive action and adaptive behavior remained far from over.
3. Repeated failure of mine in solving complex problems despite combining many techniques I learnt from world over, finally I decided to explore unchartered waters of stroke rehabilitation myself. I began to experiment clinically on the chronic stroke subject in the clinical atmosphere to find answers to series of unanswered questions with number of highly willing patients who had stroke for more than 6 months to 10 years and wanted to recover completely and were not willing to accept dependent life, were fed up of sensory loss, paraesthesia, spasticity, abnormal synergic grouping in UL with wrist finger contracture and elbow flexion contracture with reaching out difficulties. Depression became common crisis in stroke subjects because of being dependent and from difficulties in walking and climbing the stairs hurting self-image. Antidepressant did not do any good to them to improve self-image or get independent and self-reliant.
4. I began to think with "out of the box" ideas. I convinced the patients not to work on the negative and positive symptoms of the muscle. I convinced the patients that weakness and spasticity in muscle strongly indicates that muscle is simply a victim of CNS lesion. I suggested patients not to focus on individual units of the body like Upper Limb in occupational therapy and Lower Limb and gait training in physiotherapy and speech with speech therapy but to begin to handle the entire body as one whole integrated unit by focusing on postural control instead of individual voluntary control on the segments because "whole is bigger than sum total of its parts for a living biological system". Focusing on individual parts is dangerous in terms of making a division in the mind about paretic side

and non-paretic side and this division in the mind makes it difficult for the paretic body to work in normal integration with non-paretic body.

5. I made the stroke subject realize that brain is a dynamic self-organizing non-linear structure that does not wait for anybody when in danger and self organizes to prioritize self-safety with safety of COM, always a priority for any living biological system. I made them use the same paretic body as a window to the brain and taught to exploit paretic body coupled with gravity to channelize the brain. I made the patients aware that their own brain is the best tool easily available with infinite power to help it to re-reorganize it over any man made machine.
6. The above journey into the unchartered water took shape of Vasa Concept which in essence channelizes and directs the dialogue between brain, body and gravity by reconfiguring entire musculo skeletal system to manipulate afferent proprioceptive inflow so as to re-reorganize the stroke brain to achieve desirable motor outflow that helps expand boundaries of COM movement in all Cartesian coordinates on the paretic side of the central axis and restore lost sensory motor control without external commands only by inducing change from within. Re-reorganization of self-organized brain also helps to restore communicative, perceptual and cognitive abilities as a byproduct.
7. Vasa Concept works on the human being as a whole in specially designed postures that gives the patient confidence of 'being in control' of the self to help the self and not waste time on palliative treatment but restore the lost control that helps restore him back with the family, society, country with his productive life.

ABBREVIATIONS

- ADL activities of daily living.
- BOS base of support
- CNS central nervous system
- COM center of mass
- HAT head arm trunk
- LL Lower Limb
- MSS musculoskeletal system
- PNS peripheral nervous system
- UL Upper Limb

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