Predicting Recovery after a Stroke

James Lynskey, PT, PhD
Associate Professor, Department of Physical Therapy,
A.T. Still University
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Wouldn’t it be great if…

- we could predict if a stroke survivor was going to regain functional use of their hand.
- we could predict if a stroke survivor was going to walk independently again.
- we could predict if a stroke survivor was going to be able to communicate effectively with words.
- tell them and their family what to expect as far as recovery.

How might this information affect how we practice?

- Length of hospital stay
- Types of services ordered and covered
- Discharge location
- Length/intensity of services offered
- Realistic goals
- More personalized treatment
- Patient and family empowerment

Outline

- Predicting Recovery of Arm/Hand Function
- Predicting Recovery of Locomotion
- Prediction Aphasia Recovery

Predicting Recovery of Arm/Hand Function

- Multiple studies have demonstrated that UE strength early after a stroke can predict scores on Functional Outcome Measures at 3 or 6 months post stroke.
  - Patients with active shoulder abduction (MRC grade 1) and some active finger extension after mass finger grasp within 72 hours of stroke onset have a 98% probability of improving by at least 10 points or more on the Action Research Arm Test at 6-month follow-up. (Nijland et al 2010)
    - Those without either only have a 24% chance
    - Those with only one have between a 73% and 84% chance

Predicting Recovery of Arm/Hand Function

- A combined MRC score of 8 or better in testing shoulder abduction and finger extension 72 hours after stroke predicts a score of 54 or better on Action Research Arm Test at 12 weeks after stroke. (Stinear et al 2010)

- The presence of active finger extension at 7 days after stroke predicts higher Barthel Index scores and better hand ability at 6 months as measured by 9-hole peg test, Fugl Meyer, and motricity index (Samnia et al 2007, 2009)

Predicting Recovery of Arm/Hand Function

- Proportional Recovery Rule
  - In individuals with mild to moderate upper extremity paresis, initial Fugl Meyer Score (within a few days after stroke) can predict Fugl Meyer Score at 3 months.
  - (Total Possible Score – Initial Score) x .7 = the predicted change in score
  - This best holds true for individuals who have some level of preserved corticospinal tract function, as measured by TMS

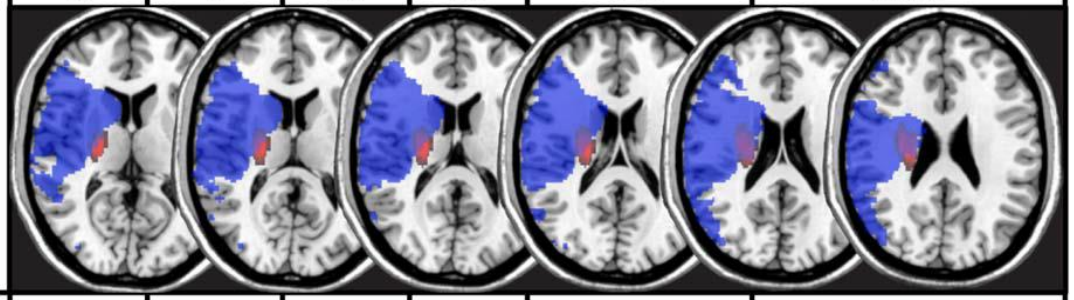
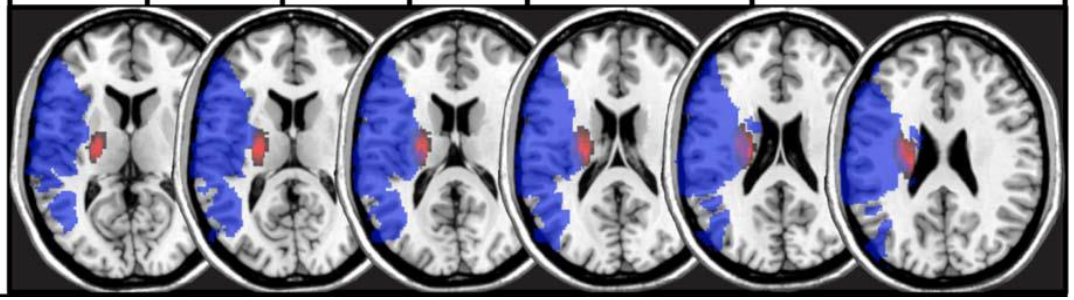
Prabhakaran etal 2008; Zarahn et al 2011; Winters et al 2015, Byblow et al 2015

Predicting Recovery of Arm/Hand Function

- Imaging
  - MRI imaging of the corticospinal tract in the internal capsule and transcranial magnetic stimulation (TMS) have been used to assess the intactness of the corticospinal tract.
  - If weighted corticospinal tract lesion load (wCST-LL) in the internal capsule was $\geq$ 7.0cc as measured by diffusion weighted imaging, then upper extremity Fugl Meyer score will be $\leq$ 25 at 3 months, i.e. poor outcome

Feng et al 2015

Predicting Recovery of Arm/Hand Function

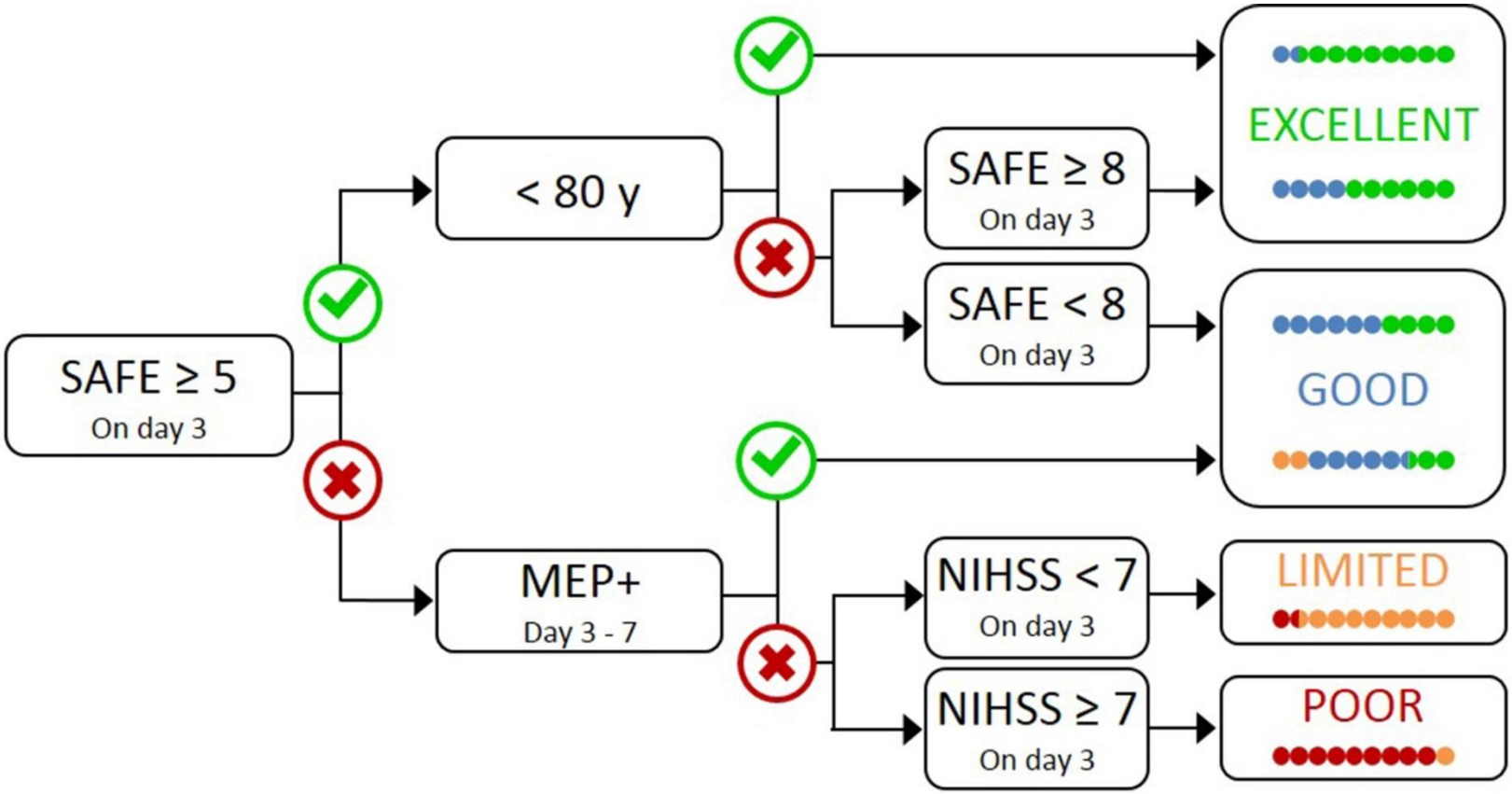
Patients	FM-UE		NIHSS		Lesion Size (cc)	Weighted Lesion Load (cc)
	Acute	3 mo.	Acute	3 mo.		
A	8	8	18	11	149	9.19
						
B	11	65	13	1	143.81	4.38
						

Feng et al 2015

Predicting Recovery of Arm/Hand Function

- Imaging has now been combined with the functional data to create predictive algorithms
- One algorithm for predicting UE function that uses both strength and imaging data is the PREP2 algorithm

PREP2 Algorithm

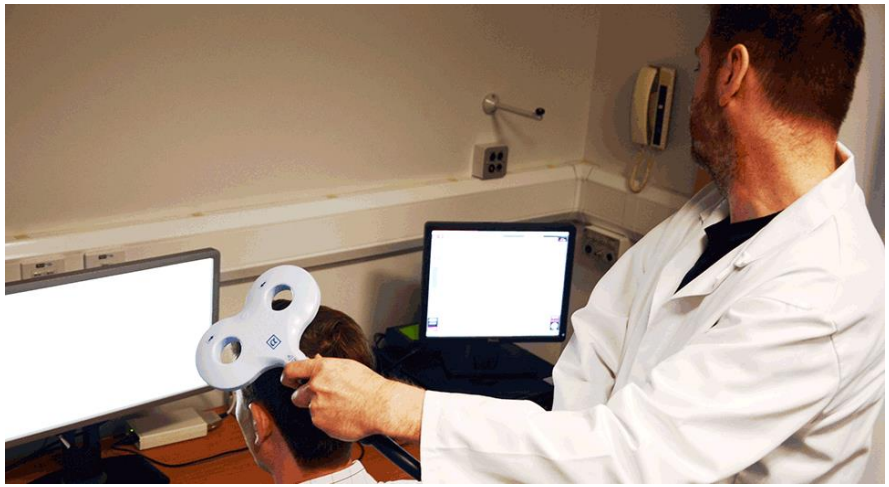


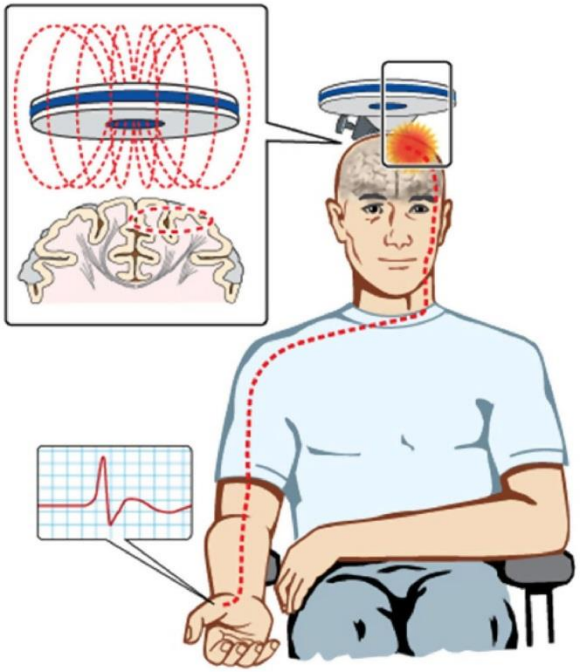
http://presto.auckland.ac.nz/

Stinear et al 2017

PREP2 Algorithm

- Transcranial Magnetic Stimulation (TMS)





PREP2 Algorithm

- NIH Stroke Scale (NIHSS)
  - 15 item scale
  - Each item max score ranges from 2-4
  - Max score is 42
  - Lower score is better
  - https://reference.medscape.com/calculator/nih-stroke-score

PREP2 Algorithm

- NIH Stroke Scale (NIHSS)

Score	Description
1-4	Minor stroke
5-15	Moderate stroke
15-20	Moderate/severe stroke
21-42	Severe stroke

PREP2 Algorithm

- Action Research Arm Test (ARAT)
  - The ARAT's is a 19 item measure divided into 4 sub-tests (grasp, grip, pinch, and gross arm movement).
    - Performance on each item is rated on a 4-point ordinal scale ranging from:

      3) Performs test normally

      2) Completes test, but takes abnormally long or has great difficulty

      1) Performs test partially

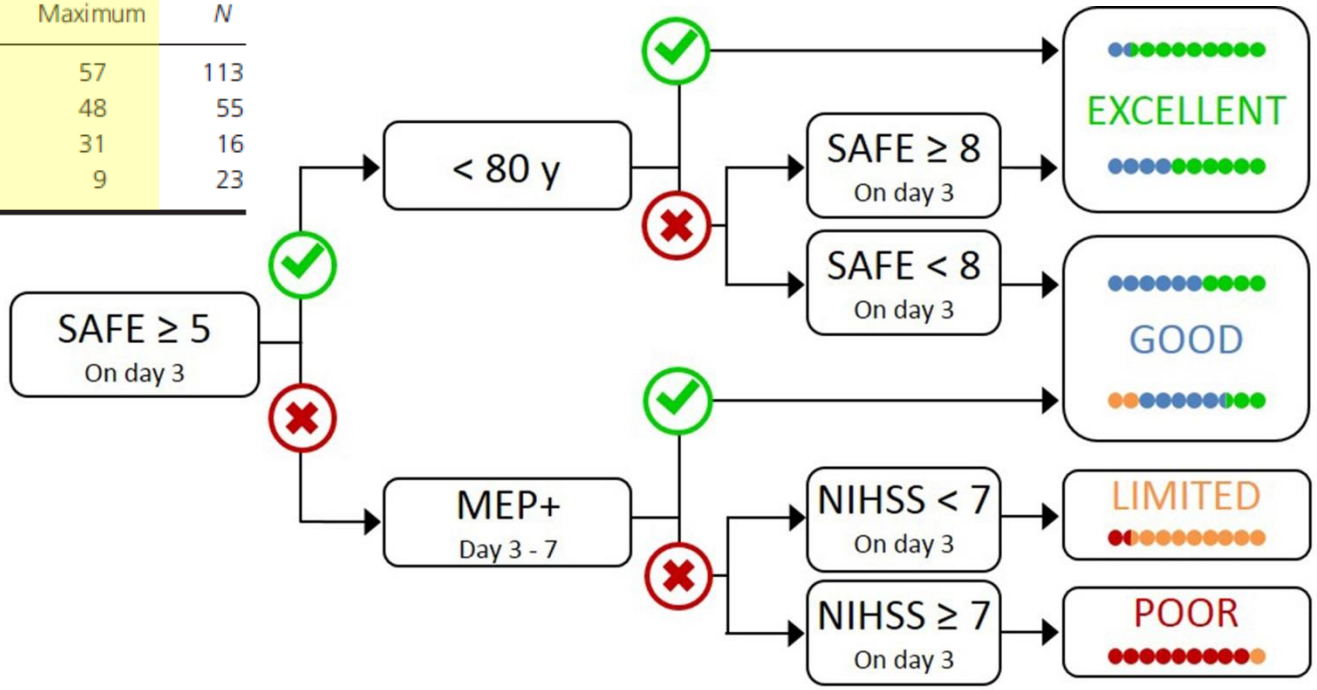
      0) Can perform no part of test
  - Max Score is 57

https://www.sralab.org/rehabilitation-measures/action-research-arm-test

PREP2 Algorithm

Table 2. ARAT scores for functional outcome categories 3 months poststroke.

Outcome	Mean	Median	Minimum	Maximum	*N*
Excellent	56	57	50	57	113
Good	43	42	34	48	55
Limited	22	22	13	31	16
Poor	2	3	0	9	23



	PPV (95% CI)	NPV (95% CI)	Accuracy for SAFE ≥ 5	Accuracy for SAFE < 5
PREP2: Overall accuracy 75%				
Excellent *N* = 113	79% (73–84%)	83% (75–89%)	78%	70%
Good *N* = 55	58% (46–68%)	84% (79–88%)		
Limited *N* = 16	86% (44–98%)	95% (93–97%)		
Poor *N* = 23	91% (73–98%)	99% (96–100%)		

Stinear et al 2017

Predicting Recovery of Arm/Hand Function

- Bottom Lines
  - Active control of shoulder abduction and finger extension early after stroke predict better functional recovery
  - Preservation of the CST in the internal capsule is important for recovery
  - In many stroke survivors 70% of available recovery will be seen in the first 3 months

Rehab After Stroke, Recommendations

- UE
  - http://www.viatherapy.org/
  - http://presto.auckland.ac.nz/prep2-in-clinical-practice/

Predicting Recovery of Locomotion

- Two predictive models have emerged that use trunk control/sitting balance, and lower extremity strength to predict independent walking (Veerbeek et al 2011, Smith et al 2017)

Predicting Recovery of Locomotion

Table 3. Probabilities of Achieving Independent Gait Six Months Post Stroke (N = 154)

		FAC ≥4 at 6 Months	
Determinants	TCT-s	MI leg	*p*
Cutoff	25	≥25	
Model <72 hours			
	+	+	.98
	+	–	.85
	–	+	.75
	–	–	.27
Model day 5			
	+	+	.96
	+	–	.83
	–	+	.59
	–	–	.23
Model day 9			
	+	+	.96
	+	–	.80
	–	+	.40
	–	–	.10

Abbreviations: FAC, Functional Ambulation Categories; TCT-s, Trunk Control Test sitting balance; MI leg, Motricity Index, lower extremity.

Probability of I walking at 6 months

Modified from Veerbeek et al 2011

Predicting Recovery of Locomotion

- Functional Ambulation Category (FAC)

0) Patient cannot walk, or needs help from 2 or more persons
1) Patients needs firm continuous support from 1 person who helps carrying weight and with balance
2) Patient needs continuous or intermittent support of one person to help with balance and coordination
3) Patient requires verbal supervision or stand-by help from one person without physical contact
4) Patient can walk independently on level ground, but requires help on stairs, slopes or uneven surfaces
5) Patient can walk independently anywhere

Predicting Recovery of Locomotion

- TCT-s (Trunk Control-Sitting)
  - Can the patient sit unsupported for 30 seconds?
    - If yes then get 25, if no then 0
- MI Leg (Motricity Index Leg)
  - Patient in sitting position (hip 90-knee 90)
  - Score each of the following movements
    - Dorsiflexion of the ankle
    - Extension of the knee
    - Flexion of the hip
  - Looking for a total score of 25

Veerbeek et al 2011

Motricity Index Leg

The lower extremity scores for muscle strength using the Motricity index.

Quality of muscle contraction	Motricity scores	MRC Grade
No Movement	0	0
Palpable contraction in muscle, but No Movement	9	1
Visible Movement, but not full range against Gravity	14	2
Full range of Movement against Gravity, but not against resistance	19	3
Full Movement against gravity, but weaker than the other side	25	4
Normal Power	33	5

Demeurisse (1990)

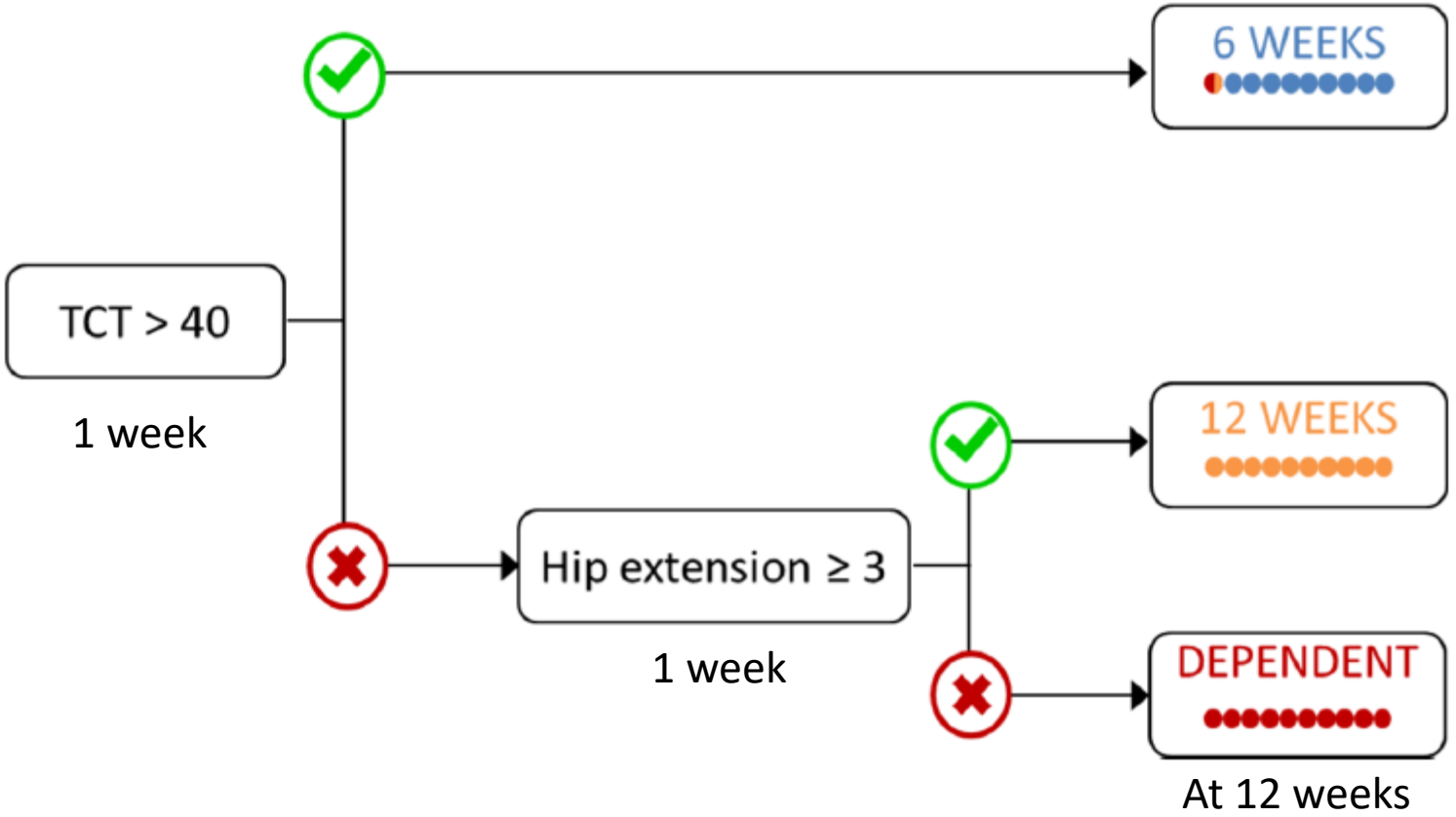
Predicting Recovery of Locomotion

- Bottom Line for Veerbeek's model
  - If a patient can sit unsupported for 30 seconds and has visible contractions in the tibialis anterior, quadriceps, and iliopsoas/rectus femoris by day 9 after their stroke, they have a 96% probability of walking independently at 6 months.
  - If they don't have any of this, then the probability is only 10%.

Veerbeek et al 2011

Predicting Recovery of Locomotion

TWIST Algorithm



http://presto.auckland.ac.nz/

Smith et al 2017

Predicting Recovery of Locomotion

- TWIST
  - Trunk Control Test

4 Items	Score for Each Item
1) Rolling to weak side	0 = unable to perform movement without assistance.
2) Rolling to strong side	12 = able to perform movement, but in an abnormal style, for example, pulls on bed clothes, rope or monkey pole, or uses arms to steady self when sitting.
3) Balance in sitting position (unsupported for 30s)	25 = able to complete movement normally.
4) Sit up from lying down	Score range: 0-100

Predicting Recovery of Locomotion

- Bottom Line for TWIST
  - If a patient has a modest amount of trunk control and can flex their hip against gravity within 7 days after stroke they have a 95% probability of walking independently at 12 weeks.

Veerbeek et al 2011

Predicting Recovery of Locomotion

- The breadth of deficits also predict recovery of locomotion
  - 90% of those with only motor deficits are independent walkers at 14 weeks after stroke
  - 35% with motor and sensory deficits walk at 22 weeks
  - 3%of those with motor, sensory, and visual deficits are walking on their own even at 30 weeks after stroke.

Harvey 2015, from Reding and Potes 1988

Predicting Aphasia Recovery

- A review of the factors predicting aphasia recovery after stroke was published in 2015 (Watila and Balarabe 2015).
  - Predictors were broken down into:
    - Lesion (stroke) related factors
    - Non-lesion (patient) related factors

Predicting Aphasia Recovery

Table 1
Lesion related factors.

Lesion size	Larger lesions predict poor aphasia recovery.	Naeser et al. [70,73]; Mazzoni et al. [67]; Goldenberg & Spatt [29]; Naeser & Palumbo [71]; Heiss et al. [35]; Maas et al. [62]; Henseler et al. [38]
	Lesion size does not predict language recovery.	Lazar et al. [58]
Lesion location	Lesions in the STG predict poor aphasia recovery.	Kertesz et al. [50]; Hanlon et al. [34]; Demeurisse & Capon [19]; Parkinson et al. [76]
	Lesions located in the posterior two thirds of the STG predict poor aphasia recovery.	Naeser et al. [72]; Kertesz et al. [50]; Alexander et al. [1]
	Anterior–inferior lesions in the STG are associated with poorer comprehension recovery.	Selnes et al. [90]
	Subcortical located lesions have a better prognosis than cortical lesions.	Kang et al. [48]
Aphasia/stroke severity	Initial stroke/aphasia severity impacts negatively on aphasia recovery.	Basso [4]; Pedersen et al. [77]; Laska et al. [56]; Pedersen et al. [78]; Fillingham et al. [26]; Lazar et al. [57]; Maas et al. [62]
	Stroke severity does not predict language outcome.	Seniów et al. [92]; Lazar et al. [58]
Type of speech deficit	Global aphasia and anomic aphasia have lower rates of recovery.	Kertesz & Mccabe [51]; Demeurisse et al. [20]; Pedersen et al. [78]; Jung et al. [46].
	Speech comprehension has better recovery compared to expression.	Mazzoni et al. [67]
	Transcortical sensory aphasics have a worse prognosis than Broca's or transcortical motor aphasics.	Basso et al. [4]
	Phonology improves earlier than semantic or syntactic language.	El Hachioui et al. [32]
	No relationship between aphasia recovery and aphasia type.	Sarno & Levita [88]
Stroke subtype/pathology	Haemorrhagic stroke has better prognosis than ischaemic stroke.	Basso et al. [3,5] and Jung et al. [46]
Metabolic factors	Early return of normal CBF and CMR predict better language recovery.	Karbe et al. [49]; Fridriksson et al. [27]; Richardson et al. [83]; Mimura et al. [68]; Hillis [40]

Summary: Superior temporal gyrus lesions, more severe initial aphasia, delayed return cerebral blood flow, and decreased cerebral metabolic rate area all associated with decreased aphasia recovery

Watila and Balarabe 2015

Predicting Aphasia Recovery

Non-lesion related factors.

Gender	Females recover better than males in oral expression	Basso et al. [3,5]
	Females with global aphasia had better improvement	Pizzamiglio et al. [80]
	No gender difference in aphasia recovery	Pedersen et al. [77]; Lendrem & Lincoln [61]; Inatomi et al. [44]; Seniów et al. [92]; Godefroy et al. [28]
Age	Older age predicts poorer aphasia recovery	Pickersgill & Lincoln [79] Lendrem & Lincoln [61] Laska et al. [56]
	Non-significant tendency towards an age influence	Kertesz & Mccabe [51]; Pedersen et al. [77]
	Age does not predict aphasia recovery	Lazar et al. [58]; Lendrem & Lincoln [61]; Holland et al. [41]; Inatomi et al. [44]; Seniów et al. [92]; Pedersen et al. [78]
Handedness	No influence of handedness on aphasia recovery	Pedersen et al. [77]; Pickersgill & Lincoln [79]
Preexisting cognitive deficits	A correlation between cognitive decline and aphasia recovery, which was stronger in post-traumatic aphasia	Vukovic et al. [96]
	The role of cognitive deficit remains unclear	Leff et al. [60]
Education	A preserved visuo-spatial working memory is associated with better improvement in comprehension and naming	Seniów et al. [92]
	No relationship between educational attainment and aphasia recovery	Connor et al. [15]; Lazar et al. [58]

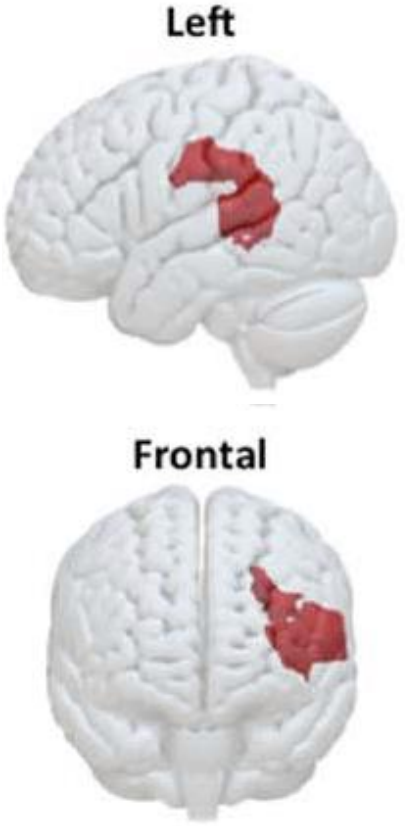
Summary: There is some evidence that suggest that age and sex can predict aphasia recovery

Watila and Balarabe 2015

Predicting Aphasia Recovery

- Left Superior Temporal Gyrus and/or Superior Longitudinal Fasciculus/Arcuate Fasciculus lesions are associated with poorer recovery of naming

- Use of SSRI's is associated with improved recovery of naming in individuals with L STG and/or SLF/AF lesions



Hillis et al 2018

Predicting Aphasia Recovery

- Proportional Recovery Rule
  - Change in score on the Western Aphasia Battery at 3 months for stroke survivors with mild to moderate aphasia can be predicted by the following equation:
    - $(WAB_{max} – WAB_{initial}) \times .73$
      - $(WAB\ naming_{max} – WAB\ naming_{initial}) \times .68$
      - $(WAB\ repetition_{max} – WAB\ repetition_{initial}) \times .70$
      - $(WAB\ comprehension_{max} – WAB\ comprehension_{initial}) \times .83$

Lazar et al 2010

Predicting Aphasia Recovery

- Bottom Line:
  - Aphasia recovery appears most associated with lesion location (STG and SLF/AF) and initial impairment.
  - Efforts are currently underway to improve prediction: http://www.ucl.ac.uk/ploras

Summary

- Functional tests and noninvasive imaging performed during the first week post stroke can predict recovery of UE and LE function at 6 months with a fair amount of accuracy.
- Lesion location and initial impairment appear to be the best predicators of aphasia recovery

Questions?