

UNDERSTANDING GLASGOW COMA SCORES AND PREDICTING RECOVERY

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BACKGROUND: WHAT IS A GCS SCORE?

A score evaluating responsiveness for patients with traumatic brain injury.

3 Components

“Eye Opening” : 1-4

“Best Motor Response” : 1:6

“Best Verbal Response” : 1:5

Taken at one hour intervals over the course of a patient's hospital stay

EYE RESPONSE (E)	Open Spontaneously	4
	Open to verbal command	3
	Open in response to pain	2
	No response	1
VERBAL RESPONSE (V)	Talking / Orientated	5
	Confused speech / Disorientated	4
	Inappropriate Words	3
	Incomprehensible sounds	2
	No response	1
MOTOR RESPONSE (M)	Obeys commands	6
	Localizes to pain	5
	Flexion / withdrawal	4
	Abnormal flexion	3
	Extension	2
	No response	1
	TOTAL	3-15

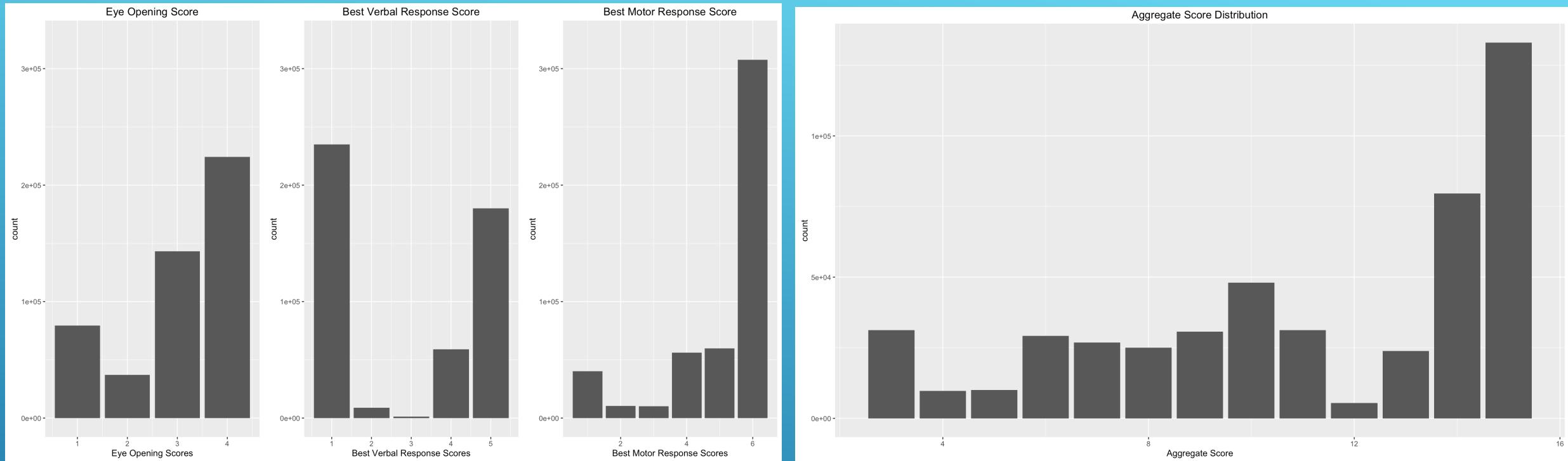
- ▶ Mount Sinai Neurosurgery Department Data
- ▶ GCS Scores from 2012 – 2016
- ▶ 1,936,854 entries
- ▶ 5456 patients

	MRN	VISIT ID	GCS SCORE	RECORDED TIME	FLO MEAS ID	MEASURE NAME	DISPLAY NAME
78	8001848	46940221	5	2012-02-23 18:00:00	888401000	R CPN GLASGOW COMA SCALE BEST VERBAL RESPONSE	Best Verbal Response
79	8001848	46940221	6	2012-02-23 18:00:00	888160302	R CPN GLASGOW COMA SCALE BEST MOTOR RESPONSE	Best Motor Response
80	8001848	46940221	15	2012-02-23 18:00:00	888401001	R CPN GLASGOW COMA SCALE SCORE	Glasgow Coma Scale Score
81	8001848	46940221	4	2012-02-23 19:00:00	888160301	R CPN GLASGOW COMA SCALE EYE OPENING	Eye Opening
82	8001848	46940221	5	2012-02-23 19:00:00	888401000	R CPN GLASGOW COMA SCALE BEST VERBAL RESPONSE	Best Verbal Response
83	8001848	46940221	6	2012-02-23 19:00:00	888160302	R CPN GLASGOW COMA SCALE BEST MOTOR RESPONSE	Best Motor Response
84	8001848	46940221	15	2012-02-23 19:00:00	888401001	R CPN GLASGOW COMA SCALE SCORE	Glasgow Coma Scale Score
85	8001848	46940221	4	2012-02-23 19:59:59	888160301	R CPN GLASGOW COMA SCALE EYE OPENING	Eye Opening
86	8001848	46940221	5	2012-02-23 19:59:59	888401000	R CPN GLASGOW COMA SCALE BEST VERBAL RESPONSE	Best Verbal Response
87	8001848	46940221	6	2012-02-23 19:59:59	888160302	R CPN GLASGOW COMA SCALE BEST MOTOR RESPONSE	Best Motor Response
88	8001848	46940221	15	2012-02-23 19:59:59	888401001	R CPN GLASGOW COMA SCALE SCORE	Glasgow Coma Scale Score
89	3195616	46966355	5	2012-01-17 17:30:00	888401000	R CPN GLASGOW COMA SCALE BEST VERBAL RESPONSE	Best Verbal Response
90	3195616	46966355	4	2012-01-17 17:30:00	888160301	R CPN GLASGOW COMA SCALE EYE OPENING	Eye Opening
91	3195616	46966355	15	2012-01-17 17:30:00	888401001	R CPN GLASGOW COMA SCALE SCORE	Glasgow Coma Scale Score
92	3195616	46966355	6	2012-01-17 17:30:00	888160302	R CPN GLASGOW COMA SCALE BEST MOTOR RESPONSE	Best Motor Response

BACKGROUND: DATA

- ▶ Can we use time series patterns of GCS scores and sub-scores to understand and predict recovery?
- ▶ ...but first
- ▶ What information is contained in a GCS score? What are the three scores telling us?
- ▶ Is a GCS score a well-conceived metric?
- ▶ (...would I ask that question if it were?)

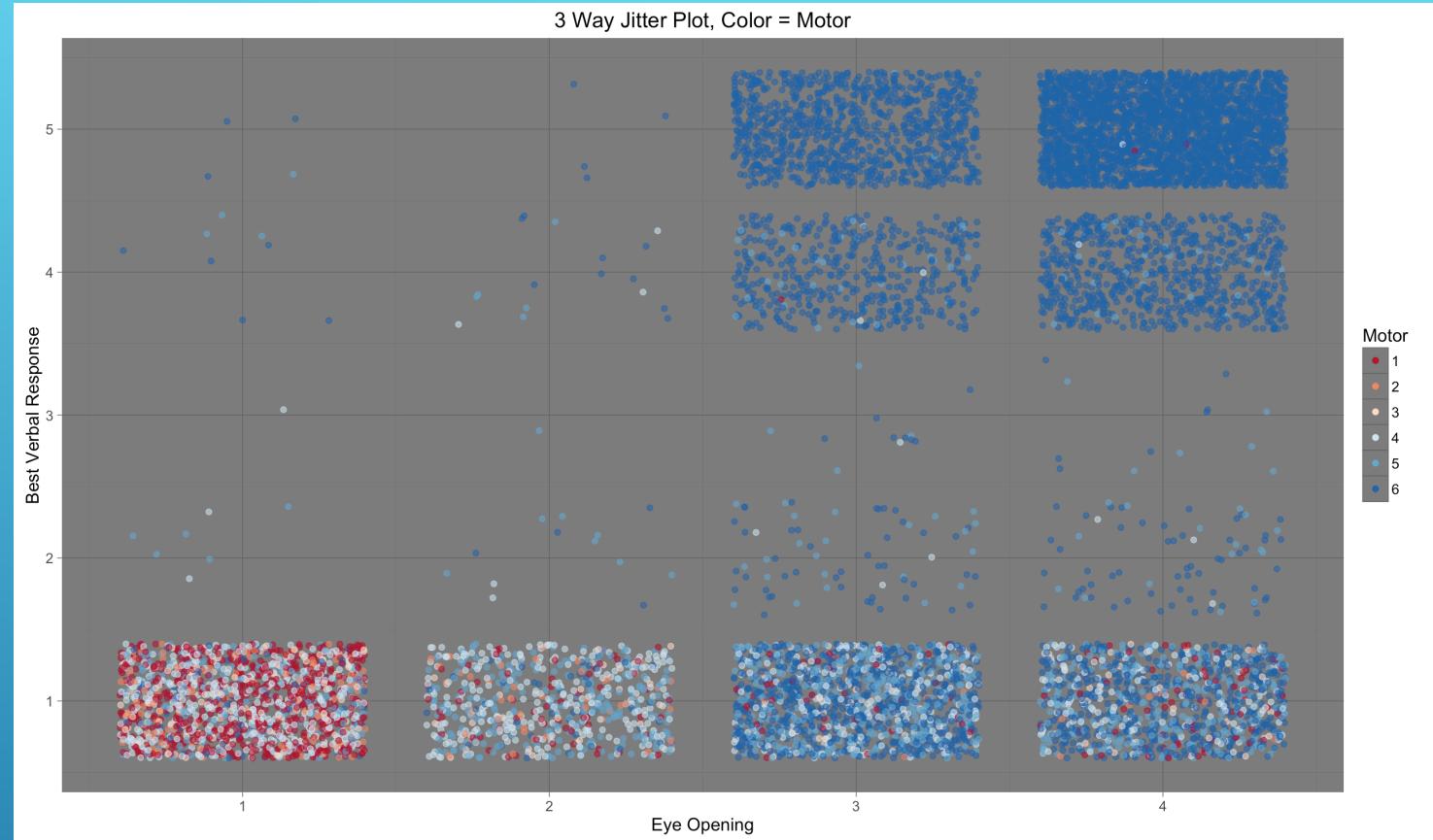
QUESTIONS



WE HAVE A LOT OF WELL-DATA (LEFT SKEWED); VERBAL IS WEIRD

- Verbal is interesting; lowest correlation, best predictor visually.
→ Dependence is not just linear.

	eye	verbal	motor
eye	1.0000000	0.5828530	0.6855822
verbal	0.5828530	1.0000000	0.5832587
motor	0.6855822	0.5832587	1.0000000

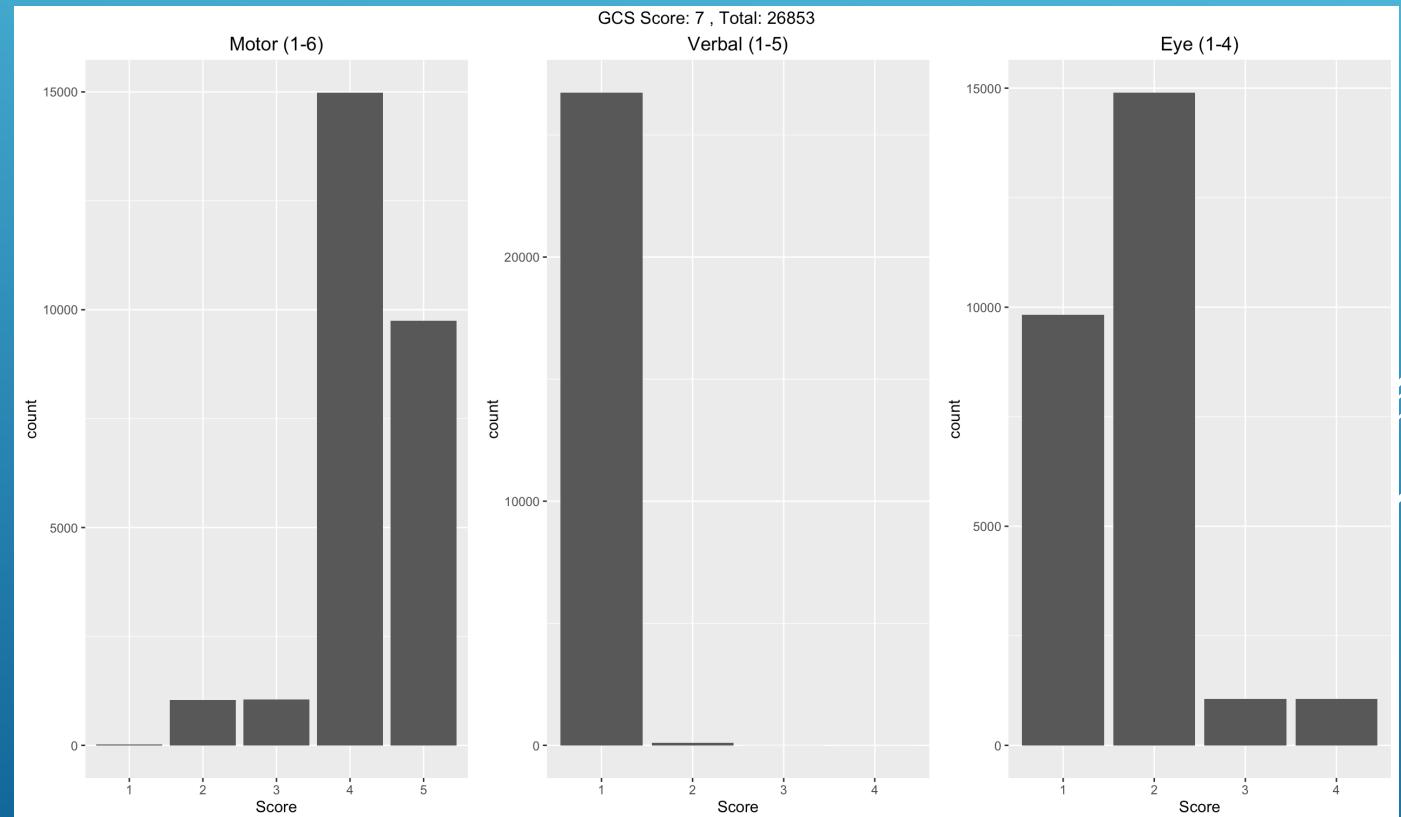


GCS SUB-SCORES ARE HIGHLY CORRELATED

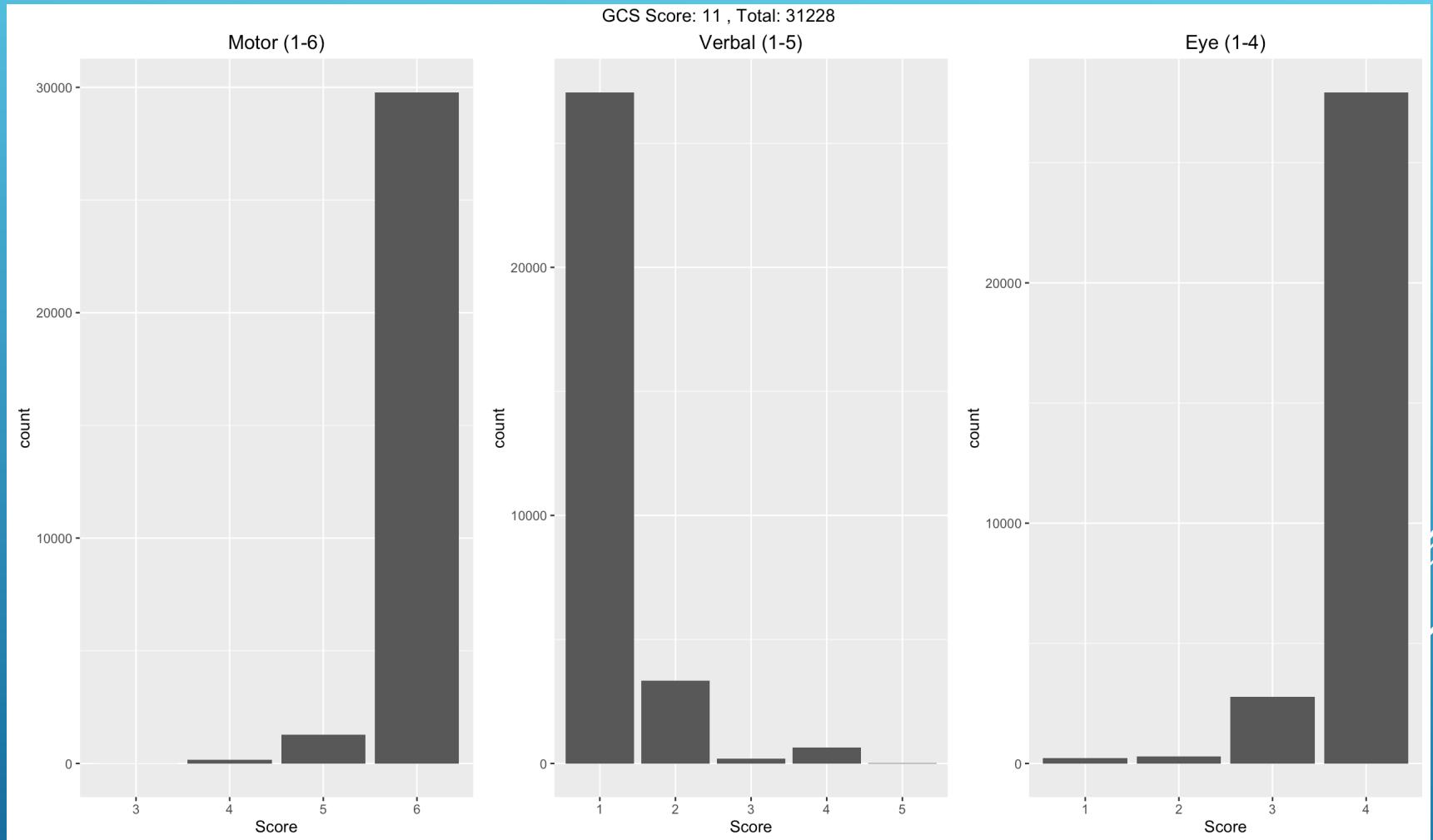
HOW MUCH INFORMATION DO AGGREGATE SCORES PROVIDE? A LOT!

- ▶ Very low composition variance for each aggregate score.

GCS =
7

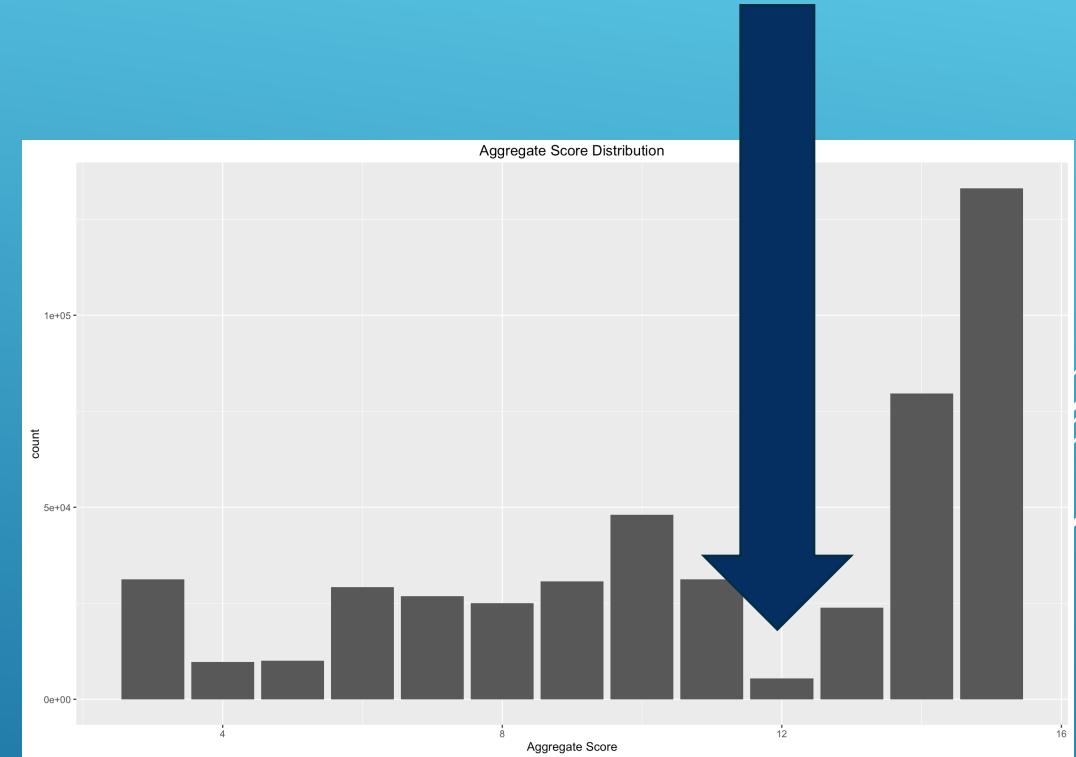
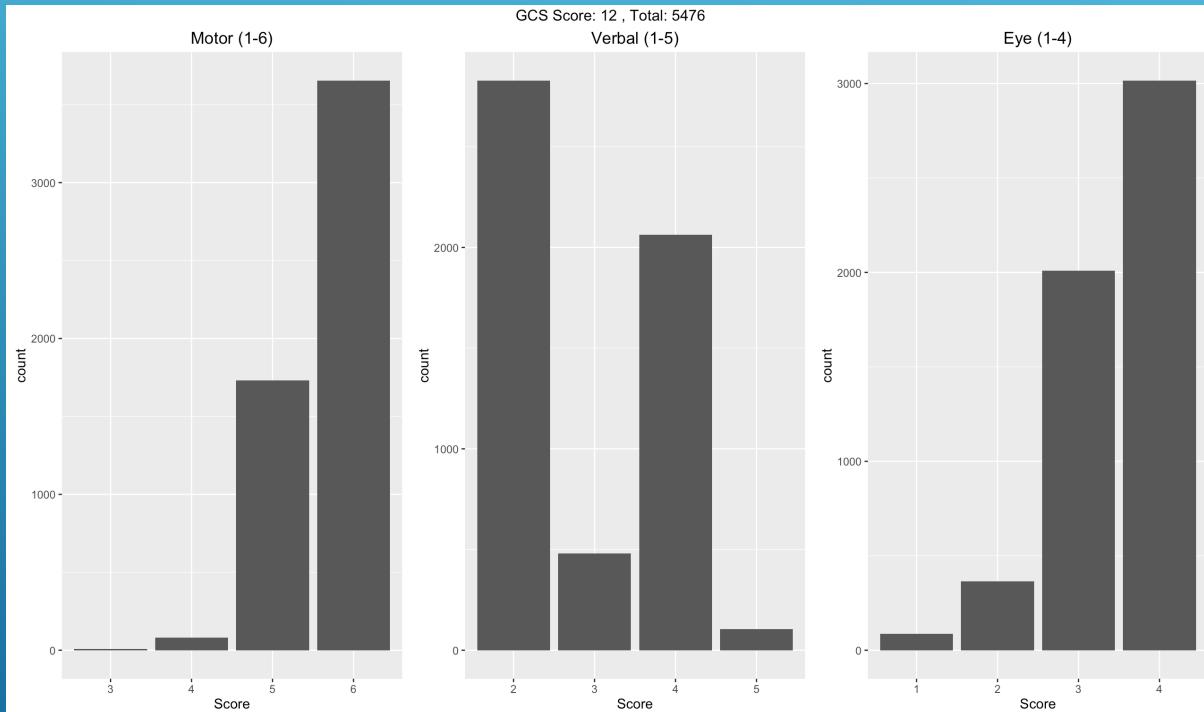


GCS = 11

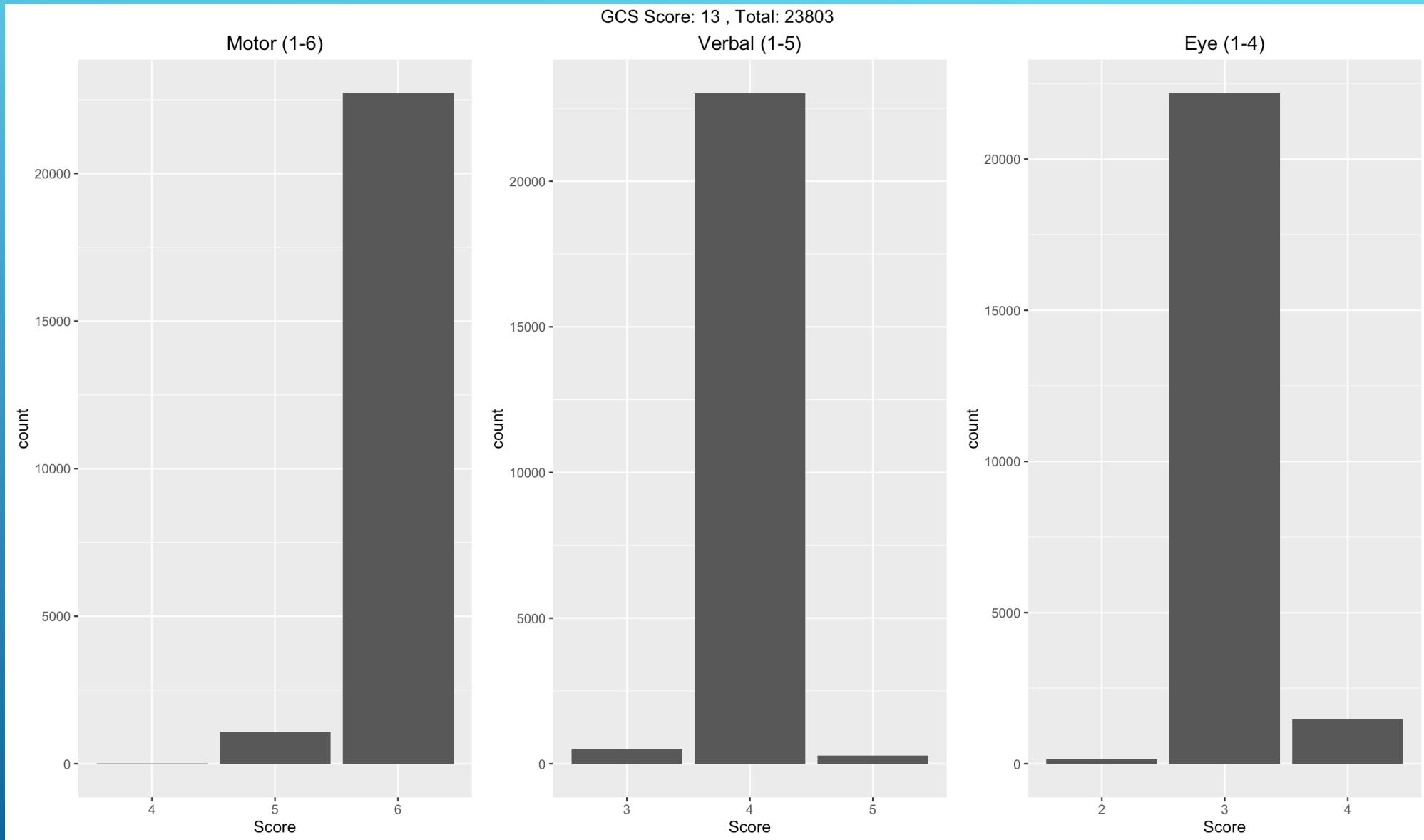


VERBAL FINALLY PICKS UP AROUND 12

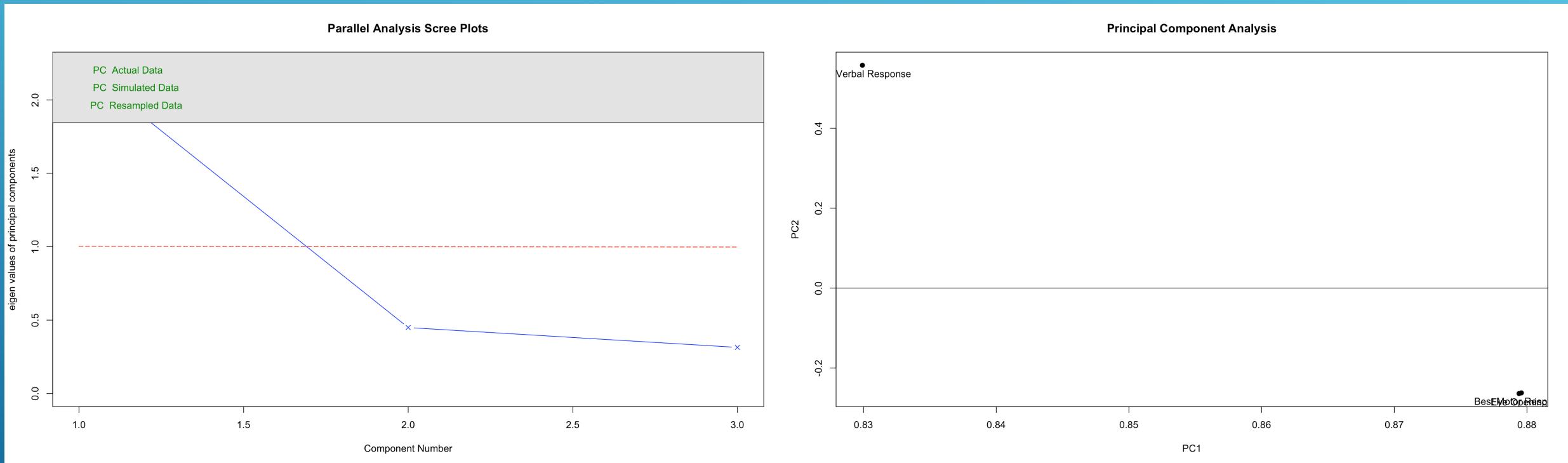
But...



GCS = 13



PCA IS DAMNING



IS THE GCS A WELL DESIGNED METRIC? NO!

- ▶ Parallel analysis suggests 1 principal component
 - ▶ Factor plot shows motor and eye on top of each other! and verbal near...
 - ▶ Aggregate GCS Scores usually have one possible composition!
 - ▶ High linear correlation coefficients
-
- ▶ My recommendation: one numeric score for motor/eye and a binary verbal.

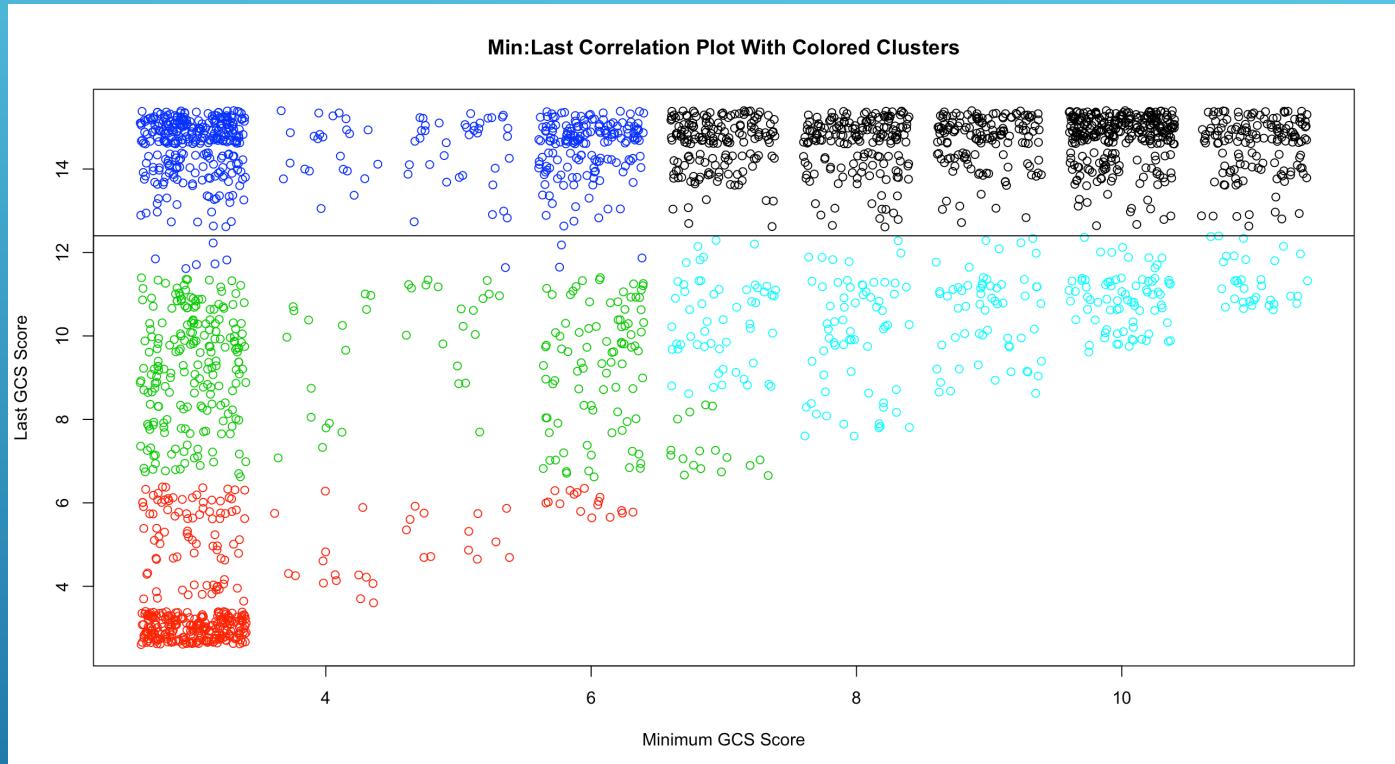
HOW DO PATIENTS DO?

Understanding patients with low minimum GCS scores.



HOW DO PATIENTS DO?

- Cluster patients by minimum and last score.
- Patients seem to get better!
- 12 is a natural last score separator
- Clustering separates patients into intuitive prognosis groups.



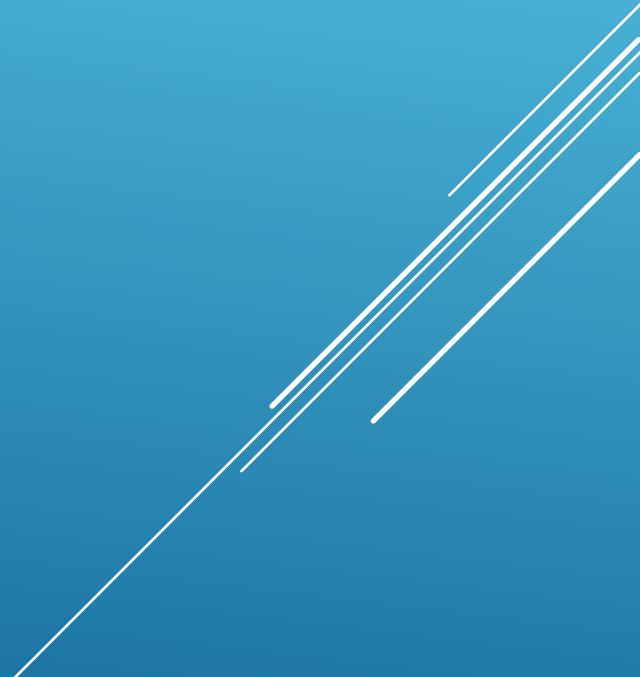
PREDICTION?

- How can we separate blue from green/red?
Light blue from black?
- or, how EARLY can we make claims about recovery? How does our confidence change over time?

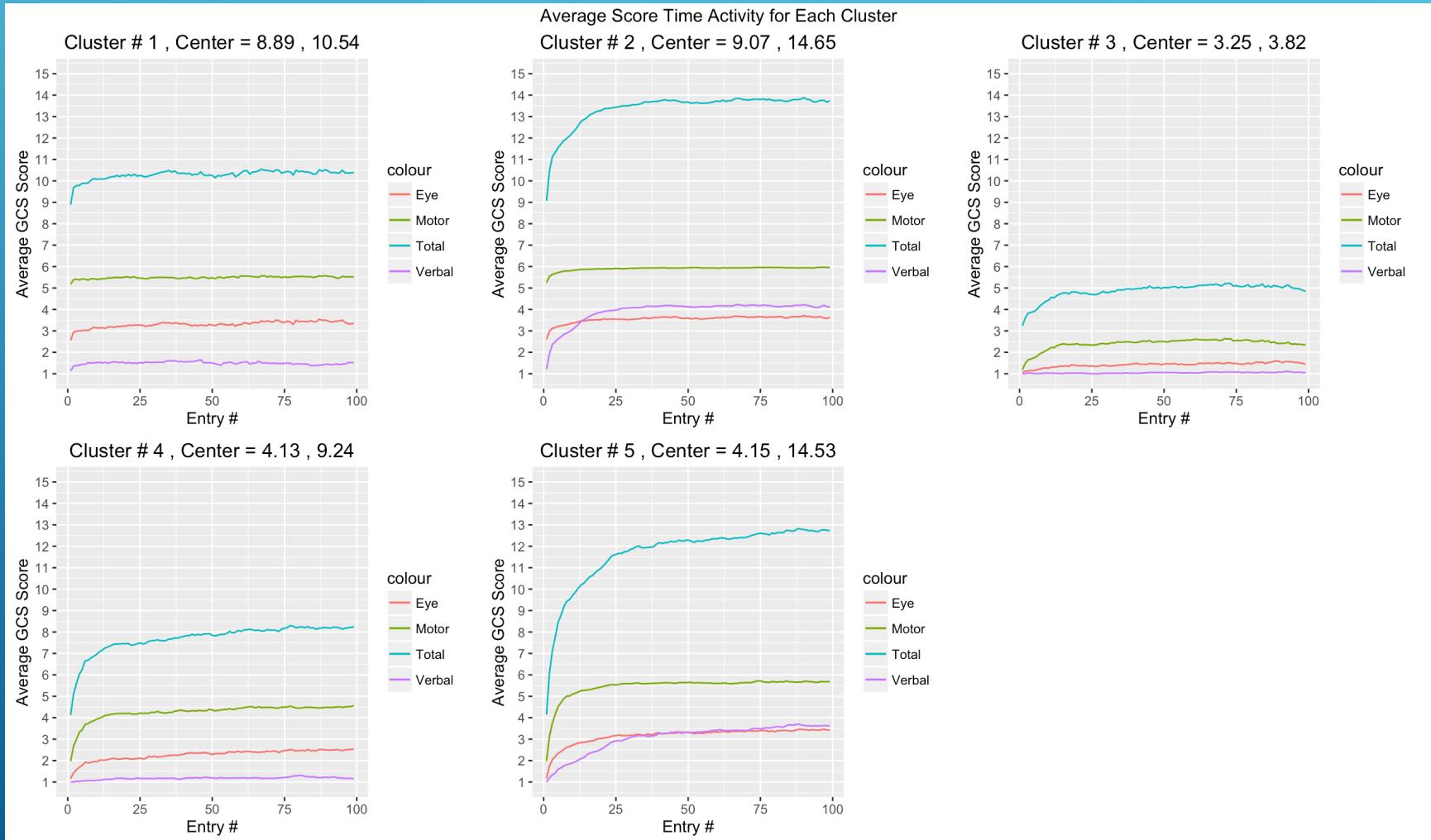


PREDICTING RECOVERY FROM TIME PATTERNS

For patients with low minimum scores (<12)



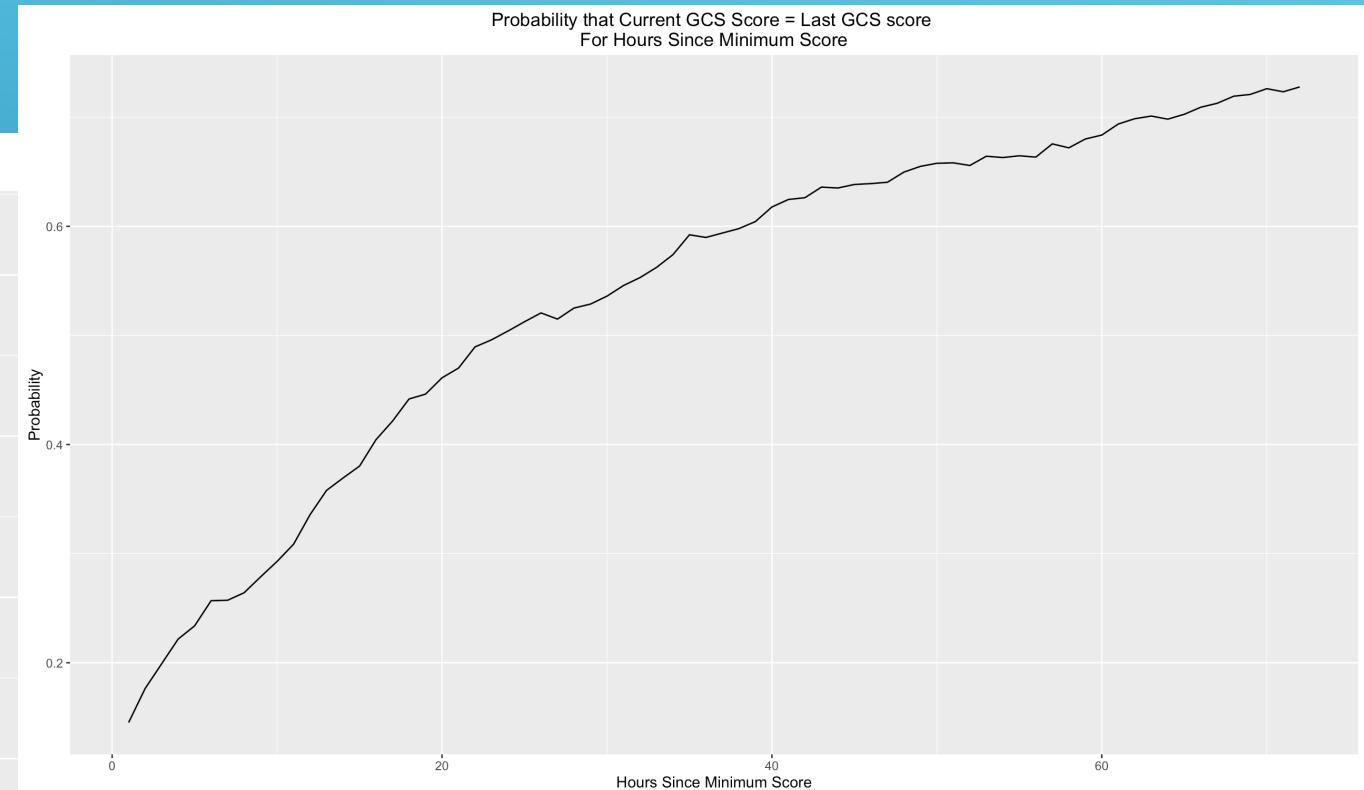
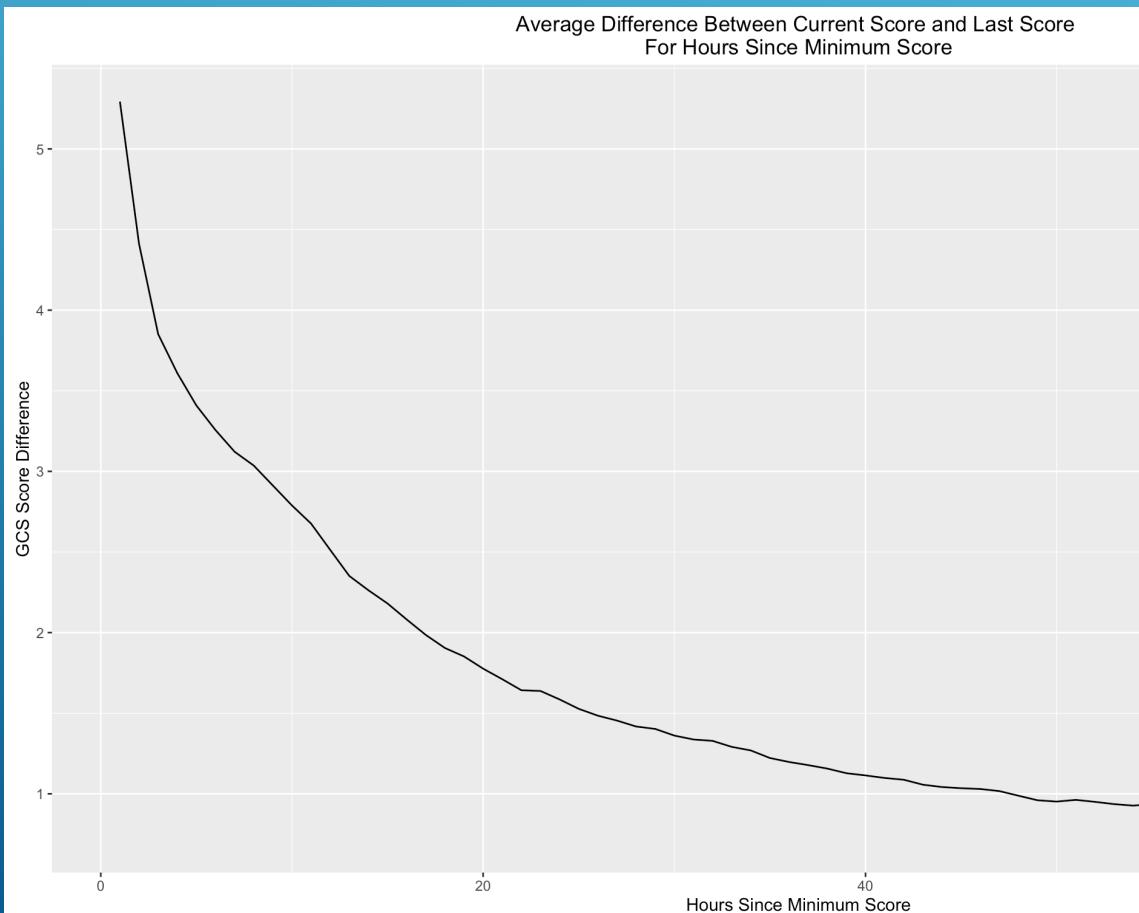
THE TIME ACTIVITIES OF CLUSTERS THAT GET BETTER SHOW SUBSTANTIAL RECOVERY WITHIN THE FIRST ~25 HOURS.



MODELING EVERY ENTRY AS A DATA POINT WITH THE FOLLOWING FEATURES

- ▶ Current Score
- ▶ Hours since Minimum Score
- ▶ Time Spent between 3 and 8
- ▶ Time Spent between 9 and 11
- ▶ Time Spent between 12 and 15
- ▶ Increases
- ▶ Decreases
- ▶ $(\text{Current Score}-12) * \log(\text{Hours Since Minimum Score})$

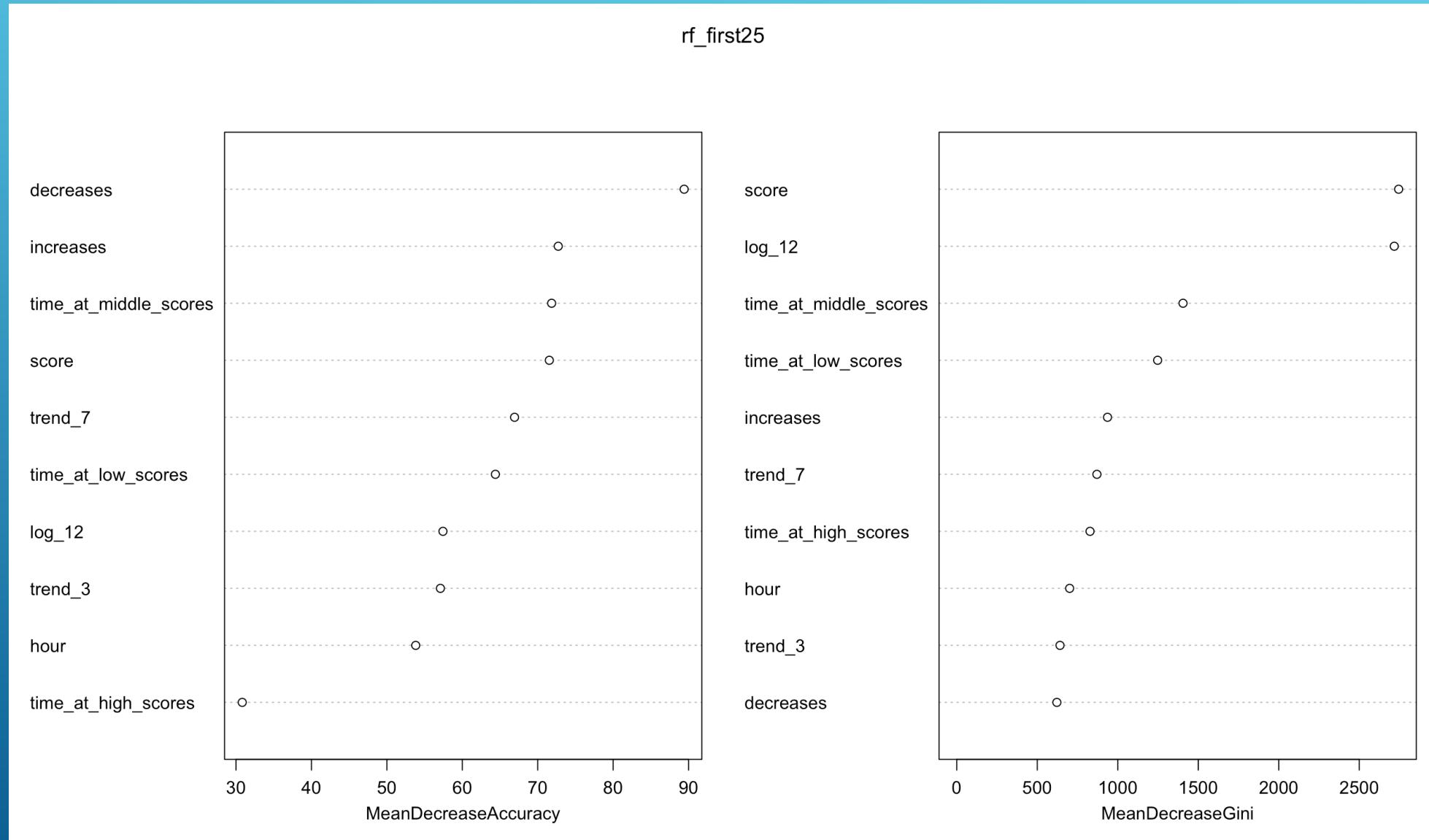
GCS SCORES BECOME CLOSER TO DISCHARGE SCORES OVER TIME (APPROXIMATELY LOGARITHMICALLY)



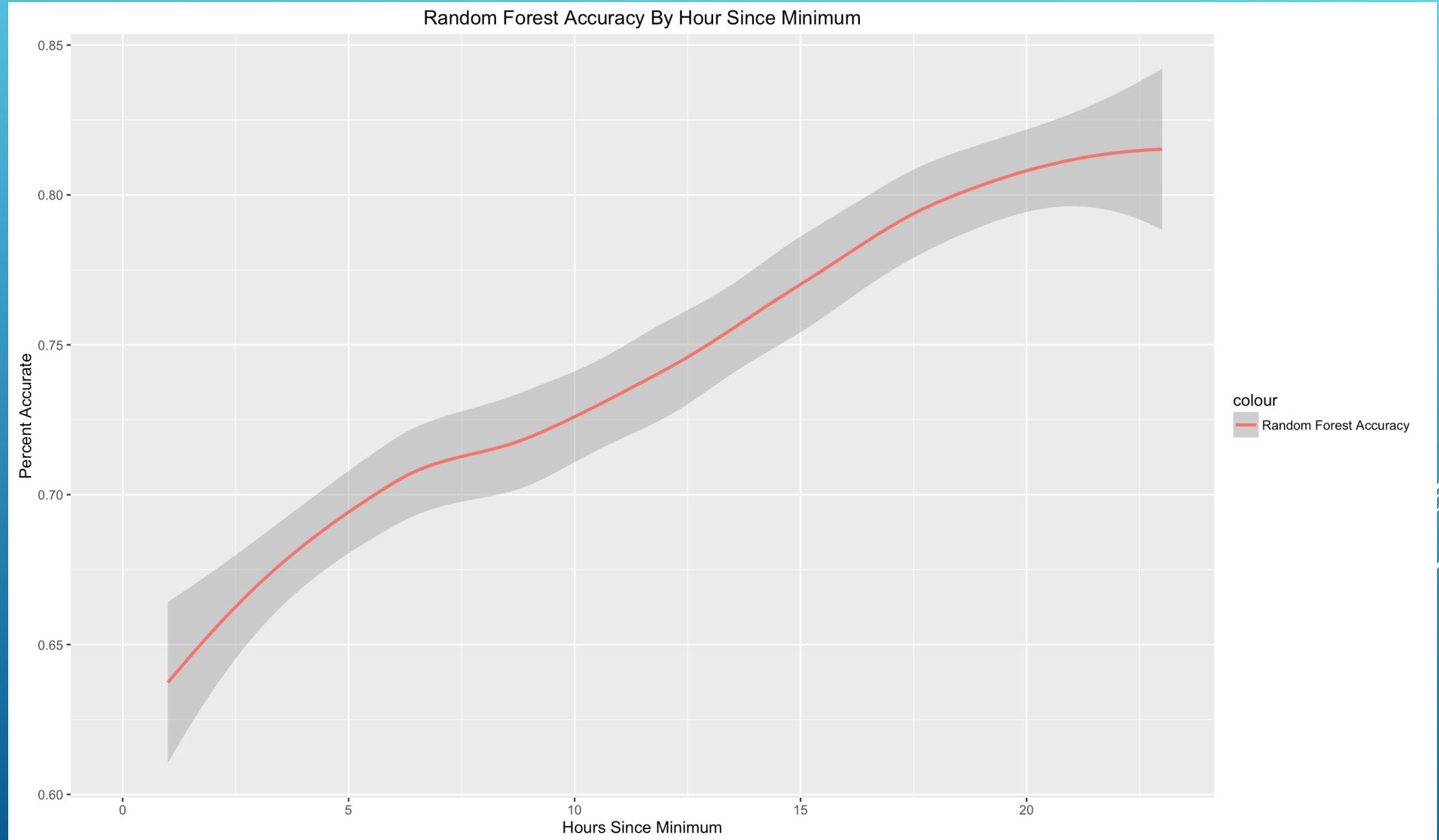
RANDOM FOREST SET UP

- ▶ Bin all entries by what that patient's last score turned out to be.
 - ▶ Last Score between 3-8: **1**
 - ▶ Last Score between 9 and 11: **2**
 - ▶ Last Score between 12 and 15: **3**

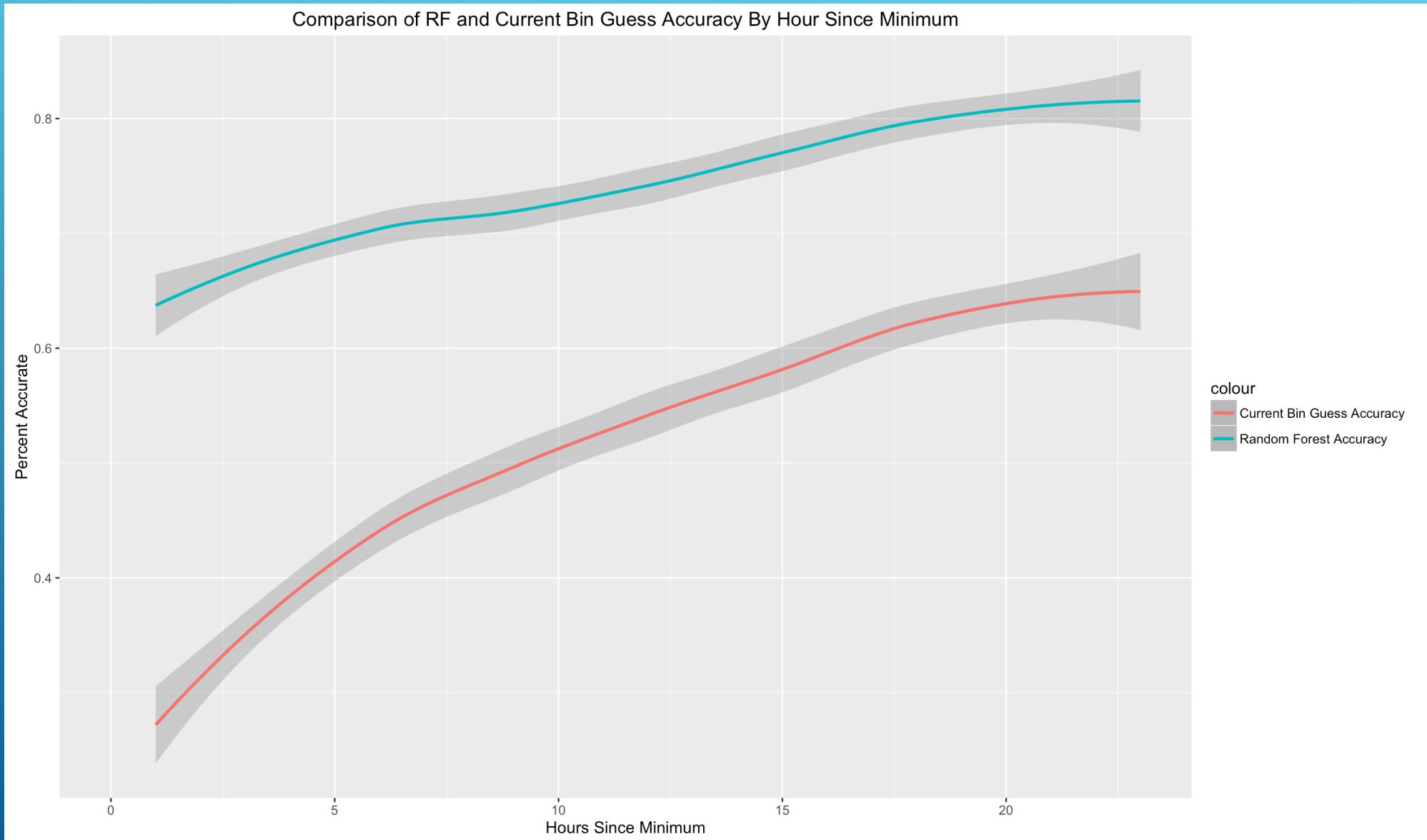
RANDOM FOREST: 75% ACCURATE ON TEST SET



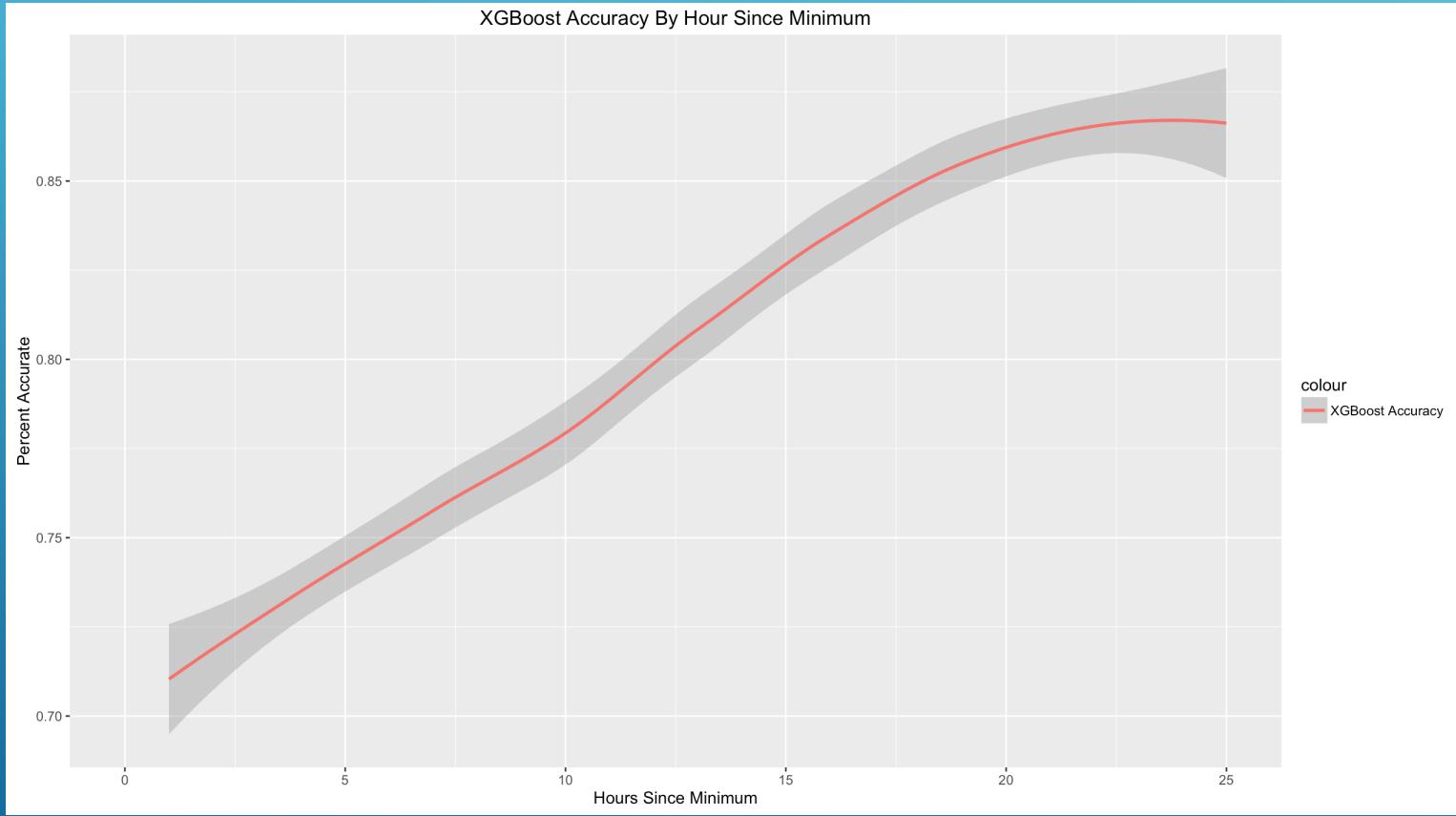
AT WHAT POINT CAN WE PREDICT RECOVERY?



COMPARED TO GUESSING CURRENT BIN



XGBOOST: 80%



NEXT STEPS

- ▶ Discuss other features with Neurosurgeons
- ▶ Fit more powerful models to increase absolute accuracy
 - ▶ Tune parameters
 - ▶ Analyze the performance of different models based on hour
- ▶ Add clinical features
- ▶ Analyze minimum score probability