

Original Article

Predictive model of length of stay and discharge destination in neuroscience admissions

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Abstract

Background: The purpose of this study was to try and determine the best predictors of hospital length of stay and discharge destination in patients admitted to a neuroscience service.

Methods: Valid data was collected for 170 patients. Variables included age, gender, location prior to admission, principle diagnosis, various physiological measurements upon admission, comorbidity, independence in various activities of daily living prior to admission, length of stay, and disposition upon discharge. Study design was a correlational descriptive study performed through the analysis of data and the development and validation of statistically significant factors in determining the length of stay.

Results: All factors with a strong ($P < 0.05$) relationship with the length of stay were entered into a forward stepwise linear regression with length of stay as the dependent variable. The three most significant variables in predicting length of stay in this study were admission from an outpatient setting, modified Rankin score on admission, and systolic blood pressure on admission.

Conclusions: Functional status at admission, specifically, a higher modified Rankin score and a lower systolic blood pressure along with the acquisition of deep vein thrombosis, catheter associated urinary tract infections, intubation, and admission to an intensive care unit all have a statistically significant effect on the hospital length of stay.

Key Words: Comorbidity, functional status, length of stay

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INTRODUCTION

A valid estimation of hospital length of stay (LOS) and accurately predicted discharge destinations can help significantly improve hospital discharge planning and resource efficiency. This information can also be useful for caregivers in their preparation of post-discharge care. The development of a predictive model that is efficient and easy to use may lead to improving patient care within a neuroscience service line. Various studies have linked a wide range of sociodemographic and clinical factors to both LOS and discharge destination.^[1]

A Swedish population-based cohort study examined the factors that influenced acute and total LOS for 298

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first-ever stroke patients.^[1] Age, gender, social factors, risk factors such as, dementia, stroke type, and stroke severity were registered. Results showed that stroke severity, pre-stroke dementia, smoking, and pre-stroke dependency in activities of daily living (ADLs) were strong independent predictors.

A retrospective cohort study in an acute hospital rehabilitation center in Singapore determined the predictors of LOS in 491 stroke patients.^[14] Results showed that the functional independence measure (FIM) motor score at admission, the presence of more than three comorbid conditions at admission, living with nonimmediate relatives before admission, and hospital subsidy status were all significant predictors of inpatient rehabilitation LOS in stroke patients. Researchers concluded that patients' motor function, socioeconomic status, and family structure were found to influence LOS and should be considered in allocating resources and determining treatment need.

Simonet^[12] conducted a prospective study in a general internal medicine service to develop and validate a score predicting discharge to a post-acute care (PAC) facility. They developed logistic regression models predicting discharge to a PAC facility based on patient variables measured on admission and on day 3 of the hospital stay. The five variables they used for their score index were patient partners' inability to provide home help (4 points); inability to self-manage drug regimen (4 points); number of active medical problems on admission (1 point per problem); dependency in bathing (4 points); and transfers from bed to chair (4 points) on day 3. A score ≥ 8 points predicted discharge to a PAC facility.

The cited studies clearly support the predictive nature of certain sociodemographic and clinical factors with regards to LOS and discharge destination. Using this information and adapting the elements of the Charlson Comorbidity Index^[2] the Neuroscience Service Admissions Questionnaire (NSAQ) was developed. The NSAQ is designed to facilitate the collection of patient data that is easy to obtain and pertinent to the prediction of LOS and discharge destination. Analyzing NSAQ data allowed the investigators to develop an accurate and efficient predictive model to be used throughout the neuroscience service in determining LOS for the patients admitted to the service.

Objective

The objective of this study was to determine the best predictors of hospital LOS and discharge destination in patients admitted to a neuroscience unit.

MATERIALS AND METHODS

This study was approved by the Winthrop University Hospital Institutional Review Board (#661464-3).

Data collection

Data from patients' medical record was obtained using the NSAQ [Appendix A]. Data variables included age, sex, height, weight, location prior to admission, principle diagnosis, various physiological measurements upon admission, comorbidity, independence in various ADLs prior to admission, LOS, and disposition upon discharge. Additional variables collected were service to which patient was admitted (stroke, neurointensive care, etc.), modified Rankin scale (mRS) on admission and discharge, whether the patient received a tracheostomy or feeding tube during the stay, number of consults and whether those consults included palliative care, citizenship status, whether the patient experienced a nosocomial infection, and whether the patient experienced a deep vein thrombosis.

Study design

This study was a retrospective correlational descriptive study. The dependent variables were the LOS and discharge destination. The independent variables were principle diagnosis, age, physiology on admission, comorbidities, etc., as described above.

Sample

The sample for this study was a convenience sample of patients admitted to any and all units within a neuroscience service line in a 590 bed metropolitan area hospital.

Inclusion criteria

Adult patients admitted to the neuroscience service from November 2014 to September 2015.

Exclusion criteria

Patients under the age of 18 and patients whose complete data were unavailable.

Statistical analysis

There were 50 binary factors. For each of these a *t*-test was performed to determine whether the LOS was longer when the factor was present. Using the Bonferroni correction, the significance level for these univariable tests was chosen at .05/50 or <0.001. For the variables with multiple levels such as the mRS at admission or discharge or the discharge status, an analysis of variance (ANOVA) test was used to determine whether the value of that factor affected LOS. Again a *P* value of <0.001 was chosen for the significance level. For those variables that took on either many levels or continuous values, a Spearman rank correlation between the variable and the LOS was performed and the significance of the correlation was computed. All variables available on admission with *P* < 0.05 in the univariate analyses were then entered into a forward stepwise linear regression against the LOS with *F* to enter of 2 and *F* to remove of 1 (Statistica, Statsoft Tulsa, OK, USA).

RESULTS

Table 1 shows the results of *t*-tests applied to each of the binary pre-admission risk factors and clearly demonstrates that the largest effect is a significantly shorter length of stay in patients admitted from an outpatient setting. There was a minor increase in LOS in patients with a history of drug abuse. Table 2 shows that patients who had a feeding tube or tracheostomy placed while hospitalized had a prolonged LOS as did patients who were intubated or admitted to the intensive care unit. Table 3 demonstrates that patients with more consultants during the hospital stay had a significantly longer LOS. Patients with higher mRS at admission or discharge had prolonged LOS [Table 4] as did patients who were admitted from an outside hospital [Table 5a]. There was a tendency for patients discharged to a rehabilitation facility or a nursing home to have a prolonged LOS [Table 5b]. There was also

a tendency for those with a lower systolic blood pressure on admission and lower hemoglobin to have a longer LOS. The patient's insurance did not correlate with LOS.

In order to see which of these variables available on admission are most useful in predicting LOS, all of the factors with a strong ($P < 0.05$) relationship with the LOS were entered into a forward stepwise linear regression with LOS as the dependent variable. Table 6 shows that admission from outpatient setting, the mRS on admission, and the systolic blood pressure on admission were the three most significant variables in predicting LOS.

DISCUSSION

Many factors describing what happened during the hospital stay have a significant relation to the length of stay. The statistically significant factors are discussed below.

Table 1: Pre-admission binary factors and their associations with hospital length of stay (LOS)

Factor	#	Mean (SD)		df	t	P
		No	Yes			
Smoking	96/22	10.8 (12.6)	10.5 (9.7)	116	0.12	0.91
Drug abuse	104/14	9.9 (9.7)	16.6 (22.8)	116	-1.98	0.05
Needs help taking meds	106/12	10.3 (12.0)	14.6 (12.4)	116	1.17	0.24
Needs assistance with Walking	86/32	10.9 (13.3)	10.3 (7.8)	116	0.23	0.82
Needs help at Home	106/12	11.1 (12.6)	7.8 (5.5)	116	0.87	0.38
Cancer with metastases	111/7	10.6 (11.8)	13.4 (17.0)	116	-0.61	0.54
Cancer without metastases	110/8	10.5 (12.3)	12.9 (7.4)	116	-0.52	0.61
Cirrhosis	116/2	10.8 (12.1)	6.0 (-)	116	0.55	0.57
Dementia	114/4	10.6 (12.1)	15.5 (10.2)	116	-0.47	0.64
Known mental illness	105/13	11.1 (12.1)	7.5 (11.6)	116	1.03	0.30
Diabetes	102/16	10.7 (12.4)	11.1 (9.6)	116	-0.12	0.91
COPD	113/5	10.8 (12.3)	8.6 (5.9)	116	0.40	0.69
Prior stroke	110/8	10.7 (12.4)	10.8 (7.1)	116	-0.03	0.97
History of CHF	115/3	10.8 (12.2)	9.3 (8.4)	116	0.2	0.83
History of MI	114/4	10.5 (12.2)	16.0 (6.8)	116	-0.89	0.37
Headache	107/11	11.2 (12.4)	6.2 (5.2)	116	1.3	0.19
Dizziness	116/2	10.8 (12.1)	3.5 (7)	116	0.85	0.39
Brain tumor	108/10	10.3 (12.1)	15.2 (10.5)	116	-1.2	0.22
Multiple sclerosis	114/4	10.8 (12.2)	8.3 (5.0)	116	0.41	0.68
Trigeminal neuralgia	114/4	10.9 (12.2)	4.0 (2.2)	116	1.1	0.26
Subarachnoid hemorrhage	110/8	10.3 (11.9)	17.1 (13.4)	116	-1.6	0.12
Subdural hematoma	110/7	10.6 (12.4)	17.1 (13.4)	115	-0.66	0.15
Intracranial hemorrhage	106/12	10.6 (12.4)	12 (8.1)	116	-0.38	0.51
Stroke as admitting diagnosis	112/4	10.6 (12.1)	17.3 (10.7)	116	-1.1	0.26
Seizure	100/18	10.4 (12.1)	17.7 (10.7)	116	-0.53	0.6
Lumbar spine	101/17	10.9 (12.5)	9.9 (8.9)	116	0.31	0.76
Thoracic spine	116/2	10.6 (12.1)	17.5 (12.4)	116	-0.8	0.43
Cervical spine	109/9	10.9 (12.4)	8 (6.4)	116	0.71	0.49
US Citizen	101/2	11.1 (12.7)	12.0 (4.2)	101	-0.10	0.92
Admit from outpatient	24/94	20.5 (2.0)	8.2 (7.2)	116	4.8	<0.001

The first column gives the number of patients with that factor and number without that factor. The second and third columns give the mean value of the LOS (and standard deviation) in those without and with that factor, respectively. The next columns give the degrees of freedom (df) and the value of *t* associated with the Student's *t*-test and the associated *P* value

Table 2: Binary factors occurring during the hospital stay and their associations with hospital length of stay (LOS)

Factor	#	Mean (SD)		df	t	P
		No	Yes			
Died during hospital stay	116/2	10.54 (11.8)	21.5 (26.2)	116	-1.25	0.20
DVT during hospital stay	109/9	10.0 (11.5)	20.1 (14.8)	116	-2.48	0.01
Urinary tract infection during hospital stay	112/6	10.1 (11.7)	22.5 (11.6)	116	-2.5	0.01
Feeding tube	109/9	8.8 (8.0)	34.2 (24.1)	116	-7.3	<0.001
Tracheostomy	108/10	9.9 (8.1)	28.4 (27.1)	116	-5.4	<0.001
Intubation	91/27	7.5 (5.9)	21.7 (19.3)	116	-6.2	<0.001
Palliative care consult	112/6	10.6 (12.2)	12.7 (9.1)	116	-0.4	0.69
Admit to ICU during hospital stay	47/71	5.4 (4.5)	14.2 (14.1)	116	-4.2	<0.001
Shunt placed	113/5	10.1 (9.4)	24.2 (39)	116	-2.6	0.01
Altered mental status	110/8	10.9 (12.4)	8.1 (4.6)	116	0.53	0.63
Comfort measures started	112/5	10.8 (12.2)	11 (8.9)	115	-0.04	0.97

The first column gives the number of patients with that factor and the number without that factor. The second and third columns give the mean value of the LOS (and standard deviation) in those without and with that factor, respectively. The next columns give the degrees of freedom (df) and the value of t associated with the Student's t-test and the associated P value.

Table 3: Spearman rank correlations between continuous factors at admission and the number of consults obtained during the hospital stay with the hospital length of stay

Factor	Mean	SD	R	P
Age	59	17.8	0.13	NS
Weight	168	50	-0.02	NS
Systolic BP	139	26	-0.22	<0.05
Heart rate	82	15.6	-0.06	NS
Creat	0.83	0.38	-0.07	NS
Wbc	9.7	4.3	0.15	NS
Hgb	13.8	10.4	-0.19	<0.05
#consults	2.1	2.3	0.35	<0.001

NS: Not statistically significant

Deep venous thrombosis, Cauti, feeding tube placement, intubation, admission to intensive care unit, and shunt insertion

These factors were all determined to have an effect on LOS, and the current literature supports these findings. Okere *et al.*^[8] studied predictors for increased LOS in patients with nonsurgical ischemic stroke. This study found that patients with Medicare insurance and severity of illness were important predictors for increased LOS in their stroke patients. While the data from our study did not find a statistically significant relationship in those patients insured by Medicare versus private insurance, the fact that severity of illness was a predictor in the Okere study,^[8] supports the findings in this study which found that there is a significant relationship between admission to the intensive care unit and prolonged length of stay.

George *et al.*^[6] confirmed a statistically significant relationship between hospital-acquired infections and prolonged LOS in ischemic stroke patients. Their study also showed that contraction of a hospital-acquired

infection was a contributor of poor short-term outcome following an ischemic stroke.

Dasenbrock, *et al.*^[3] showed that CAUTI after craniotomy for tumor resection was a predictor for prolonged LOS. These findings were also substantiated by DeLuzio, *et al.*,^[5] who found that UTI and DVT during admission resulted in a prolonged hospital stay. De la Garza-Ramos^[4] studied patients undergoing posterior surgery for cervical spondylolytic myelopathy and found that patients with DVT had a prolonged LOS (>6 days). Relatedly, there is robust literature to validate the occurrence of DVT and CAUTI as significant contributors to prolonged LOS in various patient populations including patients with a neurological diagnosis.^[7,9]

In addition to events that occurred in hospital and their relationship to LOS, the factors at admission that are important are discussed below.

mRS

Saxena *et al.*^[11] examined 55 consecutive stroke patients in a rural hospital. This study did not find that either the National Institutes of Health Stroke Scale (NIHSS) nor mRS was a statistically significant factor in prolonged LOS in their population. Conversely, however, DeLuzio, *et al.*,^[5] studied risk for prolonged LOS after undergoing anatomical lung resection. Functional status at admission, that is, those that were dependent in their functional status before surgery was a statistically significant factor in a prolonged LOS, which supports the information presented in this study. mRS is a measurement of functional status and those with a higher modified mRS at admission in this study had a longer LOS.

Sapsosnik *et al.*^[10] studied predictors in patients receiving tissue plasminogen activator (tPA) and prolonged LOS. Their study demonstrated that patients who received

Table 4: Effects of mRS at admission (a) and discharge (b) on hospital length of stay

	LOS (SD)	N
(a) Modified rankin on admission		
0	5 (4.5)	6
1	9 (3.5)	10
2	8.6 (2.2)	25
3	6.9 (2.1)	26
4	10.3 (1.9)	34
5	23.6 (2.7)	64
ANOVA	F (5, 112)=6.0	P<0.001
(b) Modified rankin on discharge		
0	4.8 (2.5)	20
1	2.1 (2.0)	31
2	9.5 (2.3)	24
3	13.3 (2.6)	19
4	22.5 (3.5)	10
5	17.6 (3.5)	10

Table 5: Effects of discharge status (a) and admission location (b) on the hospital length of stay. Only discharge statuses with more than 2 patients were included

(a) Admission location			
Discharge status		Mean length of stay (days)	N
1	Nursing home	20.40000	5
2	Acute rehab	18.00000	6
3	Home w. assistance	7.89474	19
4	Subacute rehab facility	17.56000	25
5	Home	5.69388	49
10	Rehab facility	14.66667	3
ANOVA		F (12, 103)=2.7, P=0.003	
(b) Hospital length of stay			
From where was PT admitted to hospital?		Length of stay (days) Mean	N
1	Outside Hospital	21.3	21
3	ER	8.8	68
5	Home	6.9	23
ANOVA		F (6, 111)=4.2042, P=0.00075	

Table 6: Results of forward stepwise linear regression with LOS as the dependent variable and drug abuse, admit from outpatient, mRS, systolic blood pressure at admission and hemoglobin at admission as independent factors

	Slope	Standard error	t (114)	P
Admit from Outpatient	-10.8305	2.387645	-4.53607	0.000014
MRS at admission	2.4972	0.699373	3.57067	0.00052
Systolic BP	-0.0899	0.036757	-2.44633	0.016
$R^2=0.28,$				
F (3, 114)=15.111				

tPA with a pre-stroke mRS of $>$ or $=$ 2 had a prolonged LOS. Finally, Suarez *et al.*^[13] also demonstrated that being moderately disabled before admission, and being admitted to a neuroscience critical care unit via another ICU or regular floor, was independently associated with increased hospital LOS.

Dasenbrock *et al.*^[3] demonstrated in a group of neuro-oncological patients undergoing tumor resection that a preadmission functional status of either partially dependent or completely dependent was an independent predictor of a prolonged LOS. Although our study used the mRS as the metric to measure pre-admission functional status, the fact that functional status alone acts as a predictor of increased LOS is factually demonstrated in the literature.

Patients admitted from another facility (outpatient or inpatient)

Data from this study indicated that patients had a prolonged LOS if they were admitted from other locations such as rehabilitation or nursing home. This data was also validated by the Dasenbrock study,^[3] where neuro-oncology patients who underwent craniotomy for tumor resection had a prolonged LOS if the patients were admitted from a location other than home.

Lower systolic blood pressure on admission

In this study, a lower systolic blood pressure at admission was found to be an independent predictor for prolonged LOS. While this finding is not supported in current literature, this variable presents an opportunity for further research into whether this information can be useful in a future model. For example, low systolic blood pressure can signal early stages of sepsis, adverse coronary events, and reduced renal function (except in the case of severe proteinuria^[15]). Further studies looking more closely at this variable can either confirm this finding or show that this factor is less important in determining LOS.

Intervening to decrease preventable complications

While no institution can escape adverse outcomes, all providers can intervene to prevent complications that can increase LOS. Please refer to Tables 7a and 7b for suggested interventions to mitigate and/or prevent these complications.

CONCLUSIONS

A number of factors demonstrate that certain circumstances during a hospital stay, whether at admission or occurring during the hospital stay itself, can prolong a patient's length of stay putting them at risk for increased morbidity and/or mortality. These factors include lower systolic blood pressure on admission, higher mRS or decreased functional capacity at admission, the acquisition of a DVT or CAUTI, and being intubated and/or admitted to an ICU can have deleterious effects

Table 7a: Preadmission Factors Contributing to Increased Length of Stay with suggested interventions

Pre-admission factors and increased LOS	Action/Intervention
Decreased functional status at admission (high mRS)	Rapid assessment of premorbid functional status, early involvement of social work and case management, early mobility utilizing PT, nursing, and properly trained family members
Admitted from a facility other than home	Early involvement of case management and social work. Realistic discharge planning. Frequent family conferences with the health care team
Low systolic blood pressure on admission	Early recognition of etiology, rapid intervention to treat underlying cause, and frequent monitoring

Table 7b: Intra-hospital factors contributing to increased length of stay with suggested interventions

Intra-hospital factors contributing to increased LOS	Action/Intervention
Catheter associated urinary tract infection	Aseptic technique during insertion, frequent assessment, remove as soon as possible, follow institutional protocols
Deep vein thrombosis	Early mobility, follow institutional protocols, anticoagulants if indicated.
Feeding tube placement	Early speech and swallowing assessment by nursing, follow-up by speech therapy, early placement of feeding tube, ongoing monitoring and assessment after placement
Shunt insertion	Aseptic technique during insertion, frequent assessment, remove as soon as possible, follow national guidelines
Admission to ICU	Early mobility, optimize medical care, transfer to floor or step-down unit as soon as possible

on patients' hospital stays. Being vigilant and proactive in recognizing and treating these conditions can help mitigate adverse events and poor outcomes in patients hospitalized on a neuroscience service.

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Conflicts of interest

There are no conflicts of interest.

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APPENDIX A

Neuroscience Service Admission Questionnaire

Full Name: _____		Date of Admission: _____		
Gender: <input type="checkbox"/> Male <input type="checkbox"/> Female	Age: _____	MRN#: _____		
Height: _____	Comfort Measures Only?			
Weight: _____	<input type="checkbox"/> No <input type="checkbox"/> At Admission			
	<input type="checkbox"/> During Hospital Stay (If so HD#) _____			
From where was the patient admitted to the hospital?				
To which service was the patient admitted?				
<input type="checkbox"/> Home	<input type="checkbox"/> Outside hospital			
<input type="checkbox"/> ER	<input type="checkbox"/> In-house transfer			
<input type="checkbox"/> Rehab	<input type="checkbox"/> Other (specify):			
<input type="checkbox"/> Hospitalist	<input type="checkbox"/> ICU			
<input type="checkbox"/> Stroke	<input type="checkbox"/> Neurosurgery			
Principle Diagnosis:				
<i>Neck/Back Pain:</i>		<i>Seizure:</i>		
<input type="checkbox"/> Cervical spine	<input type="checkbox"/> Epilepsy/seizure			
<input type="checkbox"/> Thoracic spine	<input type="checkbox"/> Status epilepticus			
<input type="checkbox"/> Lumbar spine	<input type="checkbox"/> Other epilepsy related			
<input type="checkbox"/> Other neck/back pain related				
<i>Stroke:</i>		<i>Other:</i>		
<input type="checkbox"/> Stroke/TIA	<input type="checkbox"/> Trigeminal neuralgia			
<input type="checkbox"/> Intracerebral hemorrhage	<input type="checkbox"/> Multiple sclerosis			
<input type="checkbox"/> Subdural hemorrhage	<input type="checkbox"/> Brain tumor			
<input type="checkbox"/> Subarachnoid hemorrhage	<input type="checkbox"/> Dizziness			
<input type="checkbox"/> Other cerebrovascular related	<input type="checkbox"/> Headache			
	<input type="checkbox"/> Altered mental status			
	<input type="checkbox"/> Hydrocephalus			
	<input type="checkbox"/> Shunt			
	<input type="checkbox"/> Other (specify):			
Physiology (*on admission*):				
Systolic BP: _____	Heart rate: _____	Creatinine: _____	White count: _____	Hemoglobin: _____
Was the patient ever in the ICU?		Was the patient ever intubated?		
<input type="checkbox"/> Yes <input type="checkbox"/> No		<input type="checkbox"/> Yes <input type="checkbox"/> No		
If yes, which ICU? <input type="checkbox"/> MICU <input type="checkbox"/> SICU		Was patient ever trached? <input type="checkbox"/> Yes <input type="checkbox"/> No		
<input type="checkbox"/> NICU		If yes, on which HD was tracheostomy done? _____		
How many consultants saw the patient during this admission? _____		Did patient receive a feeding tube during this admission? <input type="checkbox"/> Yes <input type="checkbox"/> No		
Was a palliative care consult ordered during this admission?		If yes, on which HD was feeding tube inserted? _____		
<input type="checkbox"/> Yes <input type="checkbox"/> No		Did the patient have any of the following complications?		
		<input type="checkbox"/> CLABSI <input type="checkbox"/> CAUTI <input type="checkbox"/> DVT		

Comorbidity (check all that apply)	
<input type="checkbox"/> Myocardial infarct	<input type="checkbox"/> Dementia
<input type="checkbox"/> Congestive heart failure	<input type="checkbox"/> Hemiplegia
<input type="checkbox"/> Cerebrovascular disease (stroke)	<input type="checkbox"/> Dialysis
<input type="checkbox"/> Chronic Lung disease (COPD)	<input type="checkbox"/> Cirrhosis
<input type="checkbox"/> Chronic Liver disease	<input type="checkbox"/> Cancer w. mets
<input type="checkbox"/> Diabetes	<input type="checkbox"/> Cancer w.o. mets
<input type="checkbox"/> Mental illness	<input type="checkbox"/> HIV/AIDS

Insurance: Medicaid Medicare Commercial None
U.S. Citizen: Yes No

Activities of Daily Living (prior to admission):
Does the patient have home assistance? Yes No
Does the patient need help walking or moving? Yes No
Does the patient need help managing and taking medications? Yes No
Does the patient abuse drugs or alcohol? Yes No
Does the patient smoke? Yes No

Functional Status

MRS at admission _____
MRS at discharge _____

Disposition (upon discharge):

Living Deceased Length of stay: _____
Discharge Status:
 Home Nursing home
 Home w. assistance Other (specify):
 Sub-acute rehab facility