# A Predictive Model of Initial Hospitalization Cost in Patients with Multiple Sclerosis

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## BACKGROUND

Recent seismic healthcare reforms are focused on curtailing rising healthcare expenditures.

In patients with multiple sclerosis(MS), limited or no data exists identifying potential modifiable targets associated with high-hospitalization cost.

## OBJECTIVE

To create a baseline predictive model of initial cost for patients in patients admitted with MS.

## METHODS

**Data Source & Cohort Definition:**
In a retrospective, observational study, the National Inpatient Sample (NIS) database for the years 2001-2014 was utilized to identify adult patients (>18 years) hospitalized with a diagnosis of MS [ICD-9-CM 340] with complete data on hospital costs.

**Outcome Measure:** Initial hospitalization costs for MS [inflation adjusted to 2017 dollar value].

**Model Variables:**
- Age, gender, race, income, payer;
- Hospital characteristics [bedsize, teaching status/location, region];
- Admission characteristics [weekend, elective, inpatient procedures(NPR)];
- Comorbidities [Stroke, seizures, hypertension, congestive heart failure (CHF), chronic renal failure (CRF), obesity, alcohol abuse, smoking, DM, peripheral vascular diseases (PVD), osteoporosis, anemia, coagulopathy, plegia, bowel/bladder dysfunction, myelopathy, visual loss, slurred speech, lack of coordination and gait abnormalities]; and disease modifying agents.

**Statistical Analysis:**
A split-sample approach (1:1 randomization) created a derivation (model) and validation (training) cohort.

Logarithmically transformed hospital cost data was modelled using ordinary least square to identity potential drivers impacting initial hospitalization cost. Subsequently, the model was applied to the validation cohort for internal validation.

Model validation was tested by assessing the difference in the variance explained by the models

## RESULTS

- Overall 314,251 patients with MS with complete data on costs were registered in the NIS [2001-2014].
- Mean age: 45.2 years; 58% were female
- Median hospitalization cost was $7,726 (IQR: $3,179-$12,273).

**Table 1: Factors Associated with Increased Costs**

| | % change in cost | P |
|---|---|---|
| **Patient demographics** | | |
| Age (in years) | +0.3% | **<0.001** |
| African Americans ‡ | +6.6% | **<0.001** |
| Hispanics‡ | +9.8% | **<0.001** |
| Asians ‡ | +10.0% | **<0.001** |
| Other races‡ | +5.2% | **<0.001** |
| Second income quartile† | +1.8% | **0.001** |
| Third income quartile † | +3.7% | **<0.001** |
| Highest income quartile† | +9.6% | **<0.001** |
| **Hospital specific factors** | | |
| NDX | +1.7% | **<0.001** |
| NPR | +15.9% | **<0.001** |
| Length of stay | +4.8% | **<0.001** |
| Elective admission | +7.3% | **<0.001** |
| Urban nonteaching hospitals‖ | +2.9% | **<0.001** |
| Urban teaching hospitals‖ | +5.4% | **<0.001** |
| Large bed size hospitals* | +4.7% | **<0.001** |
| West region hospitals # | +13.6% | **<0.001** |
| **Comorbidities** | | |
| Paralysis | +3.0% | **<0.001** |
| Obesity | +3.1% | **<0.001** |
| COPD | +4.1% | **<0.001** |
| CHF | +4.5% | **<0.001** |
| Seizures | +2.2% | **0.005** |
| Coagulopathy | +8.6% | **<0.001** |
| Anemia | +9.0% | **<0.001** |
| Slurred speech | +6.7% | **<0.001** |
| Previous ischemic stroke | +20.1% | **<0.001** |
| Myelopathies | +21.4% | **<0.001** |
| **In-hospital complications** | | |
| DVT | +4.9% | **<0.001** |
| ARF | +6.3% | **<0.001** |
| **Procedure/treatment related** | | |
| Lumbar puncture | +20.2% | **<0.001** |
| Plasma exchange | +46.5% | **<0.001** |

In comparison with:
§ uninsured patients;
‡ Caucasian race; and
† lowest income quartile

In comparison with hospitals:
# located in north-east region;
‖ rural hospitals; and
* small bed-size

- Pertinent drivers impacting cost include advancing age (+0.3%), female gender (-2.3%), Medicaid (-3.3%), African American (+6.6%), Hispanic (+9.8%), and Asian race (+10.0%), length of hospital stay (+4.8%/extra day hospital stay), patient comorbidities [paralysis (+3.0%), obesity (+3.1%), COPD(+4.1%), CHF(+4.5%),Seizure disorder (+2.2%), coagulopathy (+8.6%), previous ischemic stroke (+20.1%), and myelopathies (+21.4%), alcohol abuse(-14.2%)], complications[DVT(+4.9%), renal failure(+6.3%)], procedure related factors[lumbar puncture (+20.5%); plasmapheresis (+46.5%); CT scans (-18.0%); intravenous immunoglobulins(-24.0%); intravenous steroids(-26.8%)]. [Table 1 and 2]

**Table 2: Factors Associated with Decreased Costs**

| | % change in cost | P |
|---|---|---|
| **Patient demographics** | | |
| Female gender | -2.3% | **<0.001** |
| Medicaid § | -3.3% | **<0.001** |
| Other payers § | -4.1 | **<0.001** |
| **Hospital specific factors** | | |
| Weekend admission | -1.2% | **0.007** |
| Midwest region hospitals# | -9.5% | **<0.001** |
| South region hospitals# | -15.8% | **<0.001** |
| **Comorbidities** | | |
| Alcohol abuse | -14.2% | **<0.001** |
| **Procedure/treatment related** | | |
| CT scans | -18.0% | **<0.001** |
| DMT | -24.0% | **<0.001** |
| Intravenous steroids | -26.8% | **<0.001** |

- The model could explain a considerable proportion of variance ($R^2$= 0.51). A variation of less than 2.0% was noted in the derived $R^2$ following model training ($R^2$ = 0.50) from that of model testing. The model demonstrated a significant strength of association (p<0.001) to predict in an independent cohort as assessed by testing model fit by plotting predicted values against observed values using the validation cohort. (Figure 1)

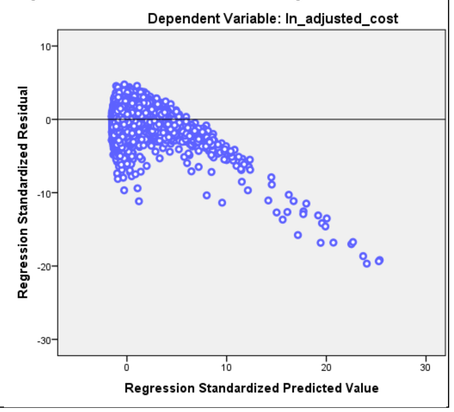


**Figure 1:** Scatterplot showing relationship of observed values with model predictive values of cost (ln transformed).

## DISCUSSION

In the backdrop of seismic healthcare reforms directed at improving value in healthcare delivery at optimal costs, several national initiatives are focused on cost-containment.

Recent studies have proposed clinical utility tools (apps) for cost-estimation risk-estimation in patients undergoing extracranial-intracranial bypass for stroke, moyamoya disease and also cerebral aneurysms.[1-3] However, limited literature exists identifying baseline drivers of costs in patients with MS.

Using an all-payer, national administrative cohort, the study quantifies risk estimates associated with initial hospitalization costs in MS patients.

**Predictive Model Application:** The identified drivers impacting hospitalization costs in MS patients could potentially be used for in-hospital auditing or budgeting, providing framework for creation of data driven policies, impact reimbursement criteria, and an adjunct in the cost containment debate.

Limitations include those pertaining the use of administrative databases and registries. This includes but not limited to coding inaccuracies, residual confounding arising from lack of functional outcomes, pharmacological and radiological parameters. Despite potential limitations, the sheer volume of patient records across diverse clinical practice settings permits generalization of outcomes and baseline assessments for future framework.

## REFERENCES

1. Sun H, Kalakoti P, Sharma K, et al. Proposing a validated clinical app predicting hospitalization cost for extracranial-intracranial bypass surgery. PLOS ONE. 2017;12(10):e0186758.
2. Bekelis K, Missios S, MacKenzie TA, et al. A predictive model of hospitalization cost after cerebral aneurysm clipping. J Neurointerv Surg. 2016; 8(3): 316–322.
3. Bekelis K, Missios S, Labropoulos N. Cerebral aneurysm coiling: a predictive model of hospitalization cost. J Neurointerv Surg. 2015; 7(7):543-548