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The Length of Stay of In-Patient Stroke Discharges in Irish Acute Hospitals

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Abstract: Stroke imposes an important economic burden worldwide and acute in-patient care accounts for a large proportion of costs in the first year following stroke. Length of stay (LOS) is regarded as a key determinant of in-patient costs and the primary focus of this study is to examine associations between LOS of acute stroke discharges and a range of individual and system level factors. Specific focus is placed on the association between stroke units and LOS. Results indicate associations between a number of policy-relevant variables and LOS including among others, MRSA infection, availability of brain imaging and discharge destination. We find some evidence that acute stroke units are associated with lower LOS however these findings should be interpreted carefully.

I INTRODUCTION

Stroke is a leading cause of death and disability (di Carlo, 2009; Luengo-Fernandez *et al.*, 2009) worldwide. In Ireland, stroke accounts for 7.3 per cent of mortality (Government of Ireland, 2007) and approximately 7,700 new strokes occur annually. Stroke also imposes an important economic burden. In Western countries, approximately 2–5 per cent of total health-care costs are due to cerebrovascular diseases (Rossnagel *et al.*, 2005). Within the first year

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following a stroke, acute in-patient care accounts for the majority of direct health-care costs (Cadilhac *et al.*, 2009; Rossnagel *et al.*, 2005; Smith *et al.*, 2011; Spieler *et al.*, 2003). For example, in Ireland, acute care costs account for approximately 60 per cent of direct costs for incident stroke cases (Smith *et al.*, 2011).

One of the main predictors of acute in-patient care cost is length of stay (LOS) (Hakim and Bakheit, 1998; Koton *et al.*, 2010) and the primary aim of this paper is to undertake multivariate analysis of the key factors associated with acute in-patient LOS for stroke cases, in the Irish context. Previous studies have identified a number of these key factors including stroke severity, stroke type and others (Appelros, 2007; Chang *et al.*, 2002; Hakim and Bakheit, 1998; Saxena *et al.*, 2007). However, many of these studies are based on small sample sizes, and most studies undertaking multivariate analysis of stroke LOS have not paid sufficient attention to the characteristics of the dependent variable. LOS is a count variable and is positively skewed, requiring modelling approaches other than ordinary least squares regression (e.g., a generalised linear model (GLM)), (Austin *et al.*, 2002). This paper analyses LOS for a sample of more than 5,000 acute in-patient stroke cases using the GLM framework.

A secondary focus of the paper is to examine, as far as possible, the impact of stroke units on acute in-patient LOS. A stroke unit is broadly defined as an area of a hospital dedicated to stroke patient care that is provided by a multidisciplinary team of stroke specialists (Seenan *et al.*, 2007). The benefits of stroke units in terms of improved outcomes have been widely demonstrated. Patients in receipt of organised in-patient stroke unit care are more likely to survive their stroke, return home, and become independent in looking after themselves (Stroke Unit Trialists' Collaboration, 2009). Less well-defined is the impact of these units on acute in-patient LOS (Zhu *et al.*, 2009). The Cochrane Review of stroke unit trials concluded that there was "… no systematic increase in length of stay associated with organised (stroke unit) care and there may have been a modest reduction" (Stroke Unit Trialists' Collaboration, 2009). However, the authors acknowledge that the analysis was complicated by variations in data sources and methodologies. Moreover, there are different types of stroke units that vary in terms of the treatment phase covered (e.g., acute phase only; post-acute rehabilitation phase only, combined acute and rehabilitation) and there is limited evidence on the implications of each type for LOS.

Relative to other countries, the establishment of stroke units has been slow in the Irish system. Until 2005 just one Irish hospital had a defined stroke unit (Irish Heart Foundation, 2008). Expansion of stroke units is a central tenet of the national stroke programme and the number of stroke units has since been expanding. In 2010, 18 out of 33 Irish hospitals admitting stroke patients reported having an acute, combined, or rehabilitation stroke unit (Dáil Éireann, 2010; Health Service Executive and Royal College of Physicians of Ireland, 2011). Given the increasing pressures on health-care resources in Ireland, it is important to understand in more detail the implications of decisions around expansion of stroke units for acute in-patient costs and how these vary by stroke unit type.

The Irish health-care system offers a useful setting in which to examine the implications of stroke units for acute in-patient LOS. This paper exploits the differentiation between hospitals with and without stroke units in order to analyse associations between these units, controlling for other factors, and acute in-patient LOS in Irish acute public hospitals.

II DATA AND METHODOLOGY

2.1 *Data and Theoretical Framework*

The paper draws on available administrative data on stroke cases in acute public hospitals in Ireland for the year 2010. Data are taken from the Hospital In-Patient Enquiry Scheme (HIPE) which collects demographic, clinical and administrative data on discharges and deaths from acute hospitals in Ireland. Consistent with previous analysis (Smith *et al.*, 2011), stroke is defined according to the International Classification of Diseases, 10th revision, Australian Modification (ICD-10-AM) including sub-arachnoid haemorrhage (SAH), intracerebral haemorrhage (IH), cerebral infarction (CI) and stroke not specified as haemorrhage or infarction (NS) (i.e., I60, I61, I63 and I64). In 2010, 5,976 in-patient cases were discharged from acute public hospitals with a principal diagnosis of stroke. When observations with missing values on variables of interest are excluded, the sample for analysis includes 5,756 discharges. The majority of missing observations occur for the marital status variable. However, there are no significant differences in LOS between the full and the analysis samples.

2.1.1 Dependent Variable

The dependent variable is calculated as LOS (in days) in acute hospital for each in-patient stroke discharge.

2.1.2 Explanatory Variables

The explanatory variables are characterised in terms of a theoretical framework of health service utilisation focusing on individual and system determinants of health service use (Andersen and Newman, 1973). As outlined in Table 1, individual determinants include pre-disposing, enabling and illness level factors. System-level characteristics refer to resource and organisational factors.

Table 1: *Variable Definitions and Descriptive Statistics*

Variables	*Categories*	*Observations (%)*	*Mean LOS (Median)*	*Interquartile Range*
LOS		5,756 (100)	22.2 (10)	17
Pre-disposing				
Age	0-49	549 (9.5)	15.6 (7)	10
	50-59	663 (11.5)	17.7 (8)	12
	60-69	1,068 (18.6)	20.9 (9)	14
	70-79	1,560 (27.1)	23.5 (11)	19
	80-89 (Ref.)	1,567 (27.2)	24.7 (11)	20
	90 and over	349 (6.1)	27.5 (13)	23
Sex	Male (Ref.)	2,956 (51.4)	21 (10)	15
	Female	2,800 (48.6)	23.4 (10)	18
Marital Status	Single	1,182 (20.5)	23.5 (11)	17
	Married (Ref.)	2,814 (48.9)	19.7 (9)	14
	Widowed	1,493 (25.9)	25.7 (12)	20
	Other	267 (4.6)	22 (9)	16
Smoking Status	Past	680 (11.8)	20.3 (10)	15
	Current	921 (16)	18.8 (9)	14
	Never Smoked (Ref.)	4,155 (72.2)	23.2 (10)	18
Season of Admission	Spring (Ref.)	1,485 (25.8)	22 (10)	17
	Summer	1,388 (24.1)	21.4 (9)	15
	Autumn	1,429 (24.8)	21.9 (10)	16
	Winter	1,454 (25.3)	23.3 (11)	19
Illness				
Comorbidities	Diabetes	807 (14.0)	24.8 (11)	17
	Hypertension	2,567 (44.6)	24.3 (11)	17
	Hypercholesterol-aemia	661 (11.5)	23.3 (10)	14
	Asthma	49 (0.9)	23.8 (9)	19
	Charlson Index (≤1) (Ref.)	5,013 (87.1)	20.7 (10)	15
	Charlson Index (>1)	743 (12.9)	32 (14)	26
Stroke Type	CI (Ref.)	4,196 (72.9)	23.5 (11)	18
	SAH	463 (8)	12.8 (6)	11
	IH	687 (11.9)	24.6 (9)	19
	Stroke, NS	410 (7.1)	15.1 (8)	10
Stroke Severity	B70A	1,003 (17.4)	49.1 (27)	45
	B70B	1,398 (24.3)	22.5 (12)	17
	B70C (Ref.)	2,431 (42.2)	13.4 (8)	9
	Other	924 (16.1)	15.4 (3)	12

Table 1: *Variable Definitions and Descriptive Statistics (contd.)*

Variables	*Categories*	*Observations (%)*	*Mean LOS (Median)*	*Interquartile Range*
Illness (contd.)				
Dysphasia		384 (6.7)	40.6 (20)	39
Dysphagia		290 (5)	51.6 (30)	54
MRSA		174 (3)	77 (40)	63
Enabling				
Entitlement Status	Medical Card only (Ref.)	3,339 (58)	23.8 (10)	19
	No Cover	1,154 (20)	20.9 (8)	15
	Private Cover	708 (12.3)	16.9 (9)	12
	Medical Card and Private Cover	555 (9.6)	21.8 (10)	16
Resource				
Day of Admission	Sunday	760 (13.2)	23.5 (11)	20
	Monday	782 (13.6)	23.6 (10)	19
	Tuesday	875 (15.2)	21.5 (10)	16
	Wednesday (Ref.)	875 (15.2)	21.3 (9)	16
	Thursday	846 (14.7)	21.7 (9.5)	16
	Friday	851 (14.8)	22 (10)	15
	Saturday	767 (13.3)	21.7 (10)	15
Organisational				
Hospital Type	Voluntary	1,846 (32.1)	31.2 (12)	24
	County (Ref.)	2,583 (44.9)	18.1 (9)	15
	Regional	1,316 (22.9)	17.7 (9)	12.5
	Other	11 (0.2)	11.6 (10)	15
HSE Area of Hospitalisation	Dublin North-East	1,461 (25.4)	27.7 (11)	19
	Dublin Mid-Leinster	1,459 (25.3)	26.2 (10)	21
	South (Ref.)	1,513 (26.3)	17.7 (9)	13
	West	1323 (23)	16.7 (10)	14
Hospital Stroke Unit Status	Acute	968 (16.8)	20.4 (9)	13
	Combined	2,179 (37.9)	26.2 (12)	22
	Rehabiltative	362 (6.3)	27.7 (12)	24
	No stroke unit (Ref.)	2247 (39)	18.1 (9)	13
Consultant Type	Geriatric	1,608 (27.9)	27.5 (12)	22
	Neurology	420 (7.3)	34.2 (12)	29
	Other consultant (Ref.)	3,728 (64.8)	18.5 (9)	14
Scan as procedure	Yes	4,961 (86.2)	22.6 (10)	17
	No (Ref.)	795 (13.8)	19.7 (7)	14
Discharge Destination	Home (Ref.)	2,933 (51)	15.5 (9)	11
	Long Stay facility	951 (16.5)	43.7 (21)	42
	Died	916 (15.9)	17.8 (7)	13.5
	Other hospital	744 (12.9)	26.7 (11)	26
	Rehab facility	171 (3)	22.5 (14)	15
	Other destination	41 (0.7)	15.1 (6)	13

Table 1: *Variable Definitions and Descriptive Statistics (contd.)*

Variables	*Categories*	*Observations (%)*	*Mean LOS (Median)*	*Interquartile Range*
Organisational (contd.)				
Admission	Home (Ref.)	5116 (88.9)	22.1 (10)	16
Source	Long Stay facility	221 (3.8)	16.3 (10)	15
	Other hospital	394 (6.8)	26.6 (12)	19
	Other destination	25 (0.4)	14.6 (10)	10

Note: Count variables related to number of procedures and intensive care unit days (both considered organisational factors) are also included in the analysis but are not reported in this table.

Pre-disposing factors describe the pre-existing propensity of individuals to use services, prior to the onset of illness (i.e., age, sex, marital status, smoking status, season of admission). Illness level factors refer to the most immediate causes of health service utilisation including stroke type, stroke severity[1] and co-morbidities including dysphasia (speech disorder), dysphagia (difficulty swallowing), MRSA (Methicillin-resistant Staphylococcus Aureus) and others specifically thought to influence stroke outcome.[2]

Enabling factors refer to the means available for individuals to make use of health services. HIPE data do not record explicit measures of socio-economic status but two variables commonly used for this purpose include discharge status (whether a patient was treated by a consultant on a public or private basis), and medical card status.[3] While discharge and medical card status do not capture method of payment, it is reasonable to assume that there is overlap between private health insurance cover and private status (see Brick et al., 2012). Thus, taking these two variables together can give some indication of the health-care entitlement status of the discharges: medical card

[1] Stroke severity is measured using diagnosis-related groups (DRGs). DRGs group together cases which share common clinical attributes and similar patterns of resource use. Severity is measured through complication and co-morbidity (CC) weights given to all diagnoses (Government of Australia, 2008). In this analysis, the majority of stroke discharges are assigned to one of three stroke-specific Australian Refined DRGs (AR-DRGs), namely B70A (stroke with catastrophic CCs), B70B (stroke with severe CCs) and B70C (stroke without catastrophic or severe CCs).

[2] Two approaches are taken to capture the influence of additional co-morbidites on LOS. First, common co-morbidities thought to impact on stroke outcomes are identified from the literature (Chang *et al.*, 2002), namely diabetes, hypertension and hypercholesterolaemia. Second, a modified Charlson index is constructed. This index is a weighted index of co-morbidity conditions which might alter the risk of mortality. The index is modified for this analysis to take into account the specific focus on stroke outcomes (Charlson *et al.*, 1987; Goldstein *et al.*, 2004).

[3] A patient covered by a full medical card (not including a GP visit card) is entitled to free public hospital care and eligibility is largely determined on the basis of income (Brick *et al.*, 2010).

holders (medical card and treated on a public basis), privately insured (no medical card and treated on a private basis), no medical card or private health insurance (no medical card and treated on a public basis), both medical card and private health insurance (medical card and treated on a private basis). Available data suggest that these entitlement groups can be broadly ranked in terms of socio-economic status from the medical card (lowest), to the non-covered, to the privately insured (highest) (Smith and Normand, 2009).

Access to health care is influenced by characteristics of the health-care system, including availability of health-care facilities and appropriate human resources. Day of admission is included as a resource factor. Other organisational factors (including stroke units) refer to hospital type,[4] area of hospitalisation,[5] consultant specialty, a scan procedure [CT, MRI, ultrasound or angiography], count of procedures, intensive care days, discharge destination and admission source.

Three types of stroke units are identified in the Irish system (Dáil Eireann, 2010; Health Service Executive and Royal College of Physicians of Ireland, 2011) including acute (specialist care for up to one week prior to discharge to rehabilitation services), rehabilitation (rehabilitating patients following their acute treatment) and combined units (acute and rehabilitative care). 61 per cent of discharges were treated in hospitals with stroke units in 2010 and these discharges recorded longer LOS across all stroke unit types, compared with non-stroke unit hospitals without controlling for any other variables (Table 1).

2.2 *Methodology*

The nature of the dependent variable determines the methodological approach adopted for the multivariate analysis. Multivariate analysis is conducted using the Generalised Linear Models (GLM) framework, appropriate for modelling response variables with non-normal distributions and non-constant variance (McCullagh and Nelder, 1983) and increasingly used to analyse count data in health (e.g., expenditure, LOS). We model the data within the GLM framework using a gamma distribution with a square root link function. This model performs well relative to alternative choices of the distribution family and link function in a series of diagnostic tests (see Appendices, Table A1).

[4] Hospital type refers to voluntary (largely state-funded although with independent management), regional or county (owned and funded by the state), or 'other' (e.g., specialist hospitals).

[5] Area of hospitalisation refers to the administrative area into which a hospital falls as designated by the Health Service Executive (HSE): Dublin North, Dublin Mid-Leinster, South and West.

The independence (exogeneity) of certain organisational variables to be analysed cannot, a priori, be considered causal (i.e., discharge destination, scan as procedure, count of procedures, intensive care days). For robustness, the model is run with and without these variables. For a treatment of this simultaneity problem see Wooldridge (2001). Our alternative measures of co-morbidities (individual co-morbidities, modified Charlson Index) require two specifications of the model. Furthermore, the final two model specifications are analysed based on a trimmed sample (n=5,515). Following Kulinskaya *et al.*, (2005) we exclude observations (4 per cent) with a LOS greater than the upper quartile plus three times the interquartile range, with a separate 'trim point' calculated for each DRG. All statistical analysis was performed using Stata version 11.1.

III RESULTS

Table 2 presents the results from three of the GLM models, reporting average marginal effects (i.e., the change in LOS, in days, attributable to the independent effect of covariates calculated for each observation and averaged over the sample).

Models examining the two alternative measures of co-morbidity reported very similar results, with comorbidity measures in both models returning statistically insignificant results. With parsimony in mind, Table 2 presents the results of the models utilising only the modified Charlson index as a comorbidity metric. Furthermore, the season of admission and day of admission variables are not reported in Table 2 as they were statistically insignificant across all specifications. In Table 2, Models 1 and 2 exclude potentially non-causal variables. Model 3 includes all variables of interest. Models 2 and 3 are based on our trimmed sample. Model 3 performs best on key diagnostics (Table A1).

Statistically significant findings (at $p<0.05$) are highlighted here. In terms of pre-disposing factors, there is evidence that age and marital status are significantly associated with LOS. Compared to the reference category of 80-89 years, younger cohorts, predominantly in Model 3, tend to have significantly shorter LOS. Across all models, single discharges have significantly longer LOS relative to married discharges. In addition, Model 3 suggests a statistically significant relationship between LOS and widowed discharges. There is inconsistent evidence for a relationship between gender and smoking status on LOS, respectively. Model 3 however, suggest no respective relationships. Of the illness level factors, in Models 1 and 2, there is evidence of variation in LOS based on stroke type. However, once all variables of interest are included (Model 3), this relationship no longer holds. In terms of stroke severity, across all models, (relative to the reference category B70C) discharges coded with higher complexity AR-DRGs have significantly longer LOS while discharges that are not coded with one of the three main stroke AR-DRGs have significantly shorter LOS. Across all models, secondary diagnoses of dysphagia and MRSA are each associated with significantly longer LOS. Models 1 and 2 also identify a statistically significant positive relationship between LOS and dysphasia.

At the system level, LOS is significantly associated with hospital type and area of hospitalisation, however, these relationships are not consistent across all models. In Models 1 and 2, there is evidence that those treated in a hospital with a combined or rehabilitative stroke unit were hospitalised for longer relative to those treated in a hospital without. However, once all variables of interest are included in our model specification, these relationships no longer hold. Moreover, Model 3 suggests treatment in a hospital with an acute stroke unit is associated with significantly shorter LOS relative to a hospital without any stroke unit. Across all models, treatment by a geriatric consultant is associated with a significantly longer LOS. Models 1 and 2 observe a significantly longer LOS for those treated by a neurological consultant. Across all models, cases admitted from a long-stay facility have significantly shorter LOS while cases admitted from another hospital have significantly longer LOS, than cases admitted from home.

In terms of non-causal variables, cases who received a scan had a significantly shorter LOS relative to those who did not receive a scan, while LOS is likely to increase with the number of procedures performed. Days in intensive care are associated with longer LOS. Compared to those discharged to home, cases discharged to a long-stay or rehabilitation facility have significantly longer LOS, as do those transferred to another hospital.

Table 2: *Regression of Explanatory Variables on LOS (Models 1-3)*

Variables	*Categories*	*Model 1*	*Model 2*	*Model 3*
Pre-Disposing				
Age	0-49	–2.22 (1.50)	–2.10 (0.90)*	–2.39 (0.42)***
	50-59	–0.31 (1.28)	–0.08 (0.80)	–1.12 (0.43)**
	60-69	0.10 (1.13)	0.29 (0.72)	–1.05 (0.38)**
	70-79	–0.41 (0.92)	0.37 (0.57)	–0.40 (0.33)
	90 and over	2.57 (1.86)	0.79 (0.96)	0.56 (0.58)
	80-89			
Sex	Female	0.06 (0.68)	0.95 (0.44)*	0.41 (0.22)
	Male			

Table 2: *Regression of Explanatory Variables on LOS (Models 1-3)* *(contd.)*

Variables	*Categories*	*Model 1*	*Model 2*	*Model 3*
Marital Status	Single	2.86 (0.86)***	2.23 (0.56)***	0.93 (0.29)**
	Widowed	1.34 (0.91)	1.12 (0.59)	1.06 (0.32)***
	Other	–1.26 (1.23)	–0.81 (0.84)	–0.32 (0.42)
	Married			
Smoking Status	Past	–2.52 (0.80)**	–0.15 (0.58)	–0.41 (0.32)
	Current	–0.23 (0.81)	0.53 (0.53)	0.16 (0.29)
	Never smoked			
Illness level				
Charlson Index (>1)		2.16 (1.28)	1.85 (0.96)	0.30 (0.38)
Stroke Type	SAH	–4.43 (1.57)**	–6.04 (0.93)***	–0.66 (0.37)
	IH	–0.87 (1.10)	–1.61 (0.75)*	–0.08 (0.29)
	Stroke, NS	–6.06 (0.85)***	–3.51 (0.63)***	–0.83 (0.44)
	CI			
Stroke Severity	B70A	20.71 (1.35)***	19.13 (0.90)***	10.42 (0.69)***
	B70B	6.41 (0.75)***	6.25 (0.47)***	2.81 (0.39)***
	Other	–3.67 (1.26)**	–0.87 (0.99)	–6.88 (0.35)***
	B70C			
Dysphasia		7.43 (1.81)***	6.06 (1.41)***	1.03 (0.78)
Dysphagia		13.50 (2.35)***	9.56 (1.58)***	3.64 (1.01)***
MRSA		26.28 (3.69)***	13.36 (1.94)***	7.19 (1.26)***
Enabling				
Entitlement Status	No cover	–1.83 (0.96)	0.06 (0.59)	–0.56 (0.29)
	Private cover	–1.28 (1.02)	0.12 (0.66)	–0.40 (0.32)
	Medical Card and Private cover	–0.89 (0.91)	0.52 (0.70)	–0.40 (0.38)
	Medical Card only			
Organisational				
Hospital Type	Voluntary	2.88 (1.16)*	1.43 (0.76)	–2.18 (0.32)***
	Regional	0.96 (0.80)	0.21 (0.56)	–0.98 (0.32)**
	Other	–6.64 (3.50)	–3.90 (2.85)	–2.81 (2.43)
	County			
HSE Area of Hospitalisation	Dublin North-East	6.59 (1.10)***	3.79 (0.62)***	3.23 (0.35)***
	Dublin Mid-Leinster	3.30 (1.09)**	1.41 (0.67)*	0.39 (0.33)
	West	0.71 (0.79)	0.90 (0.56)	1.91 (0.32)***
	South			
Hospital Stroke Unit Status	Acute	0.20 (0.90)	–0.09 (0.56)	–1.22 (0.31)***
	Combined	4.33 (0.71)***	2.74 (0.50)***	–0.23 (0.26)
	Rehabilitative	8.23 (2.52)**	0.84 (0.91)	–0.79 (0.51)
	No Stroke Unit			

Table 2: *Regression of Explanatory Variables on LOS (Models 1-3) (contd.)*

Variables	*Categories*	*Model 1*	*Model 2*	*Model 3*
Admission Source	Long Stay facility	–4.87 (1.46)***	–3.02 (0.85)***	–1.59 (0.60)**
	Other hospital	5.46 (1.44)***	6.84 (1.07)***	1.59 (0.46)***
	Other destination	0.84 (3.03)	0.33 (2.10)	–0.22 (1.71)
	Home			
Consultant Type	Neurology	7.55 (2.01)***	3.60 (1.14)**	0.19 (0.47)
	Geriatric	3.78 (0.90)***	2.17 (0.56)***	0.93 (0.31)**
	Other			
Scan as procedure				–3.49 (0.32)***
Count of procedures				2.88 (0.08)***
Intensive care days				0.33 (0.06)***
Discharge	Died			–0.34 (0.39)
Destination	Long Stay facility			4.73 (0.49)***
	Other hospital			1.01 (0.38)**
	Rehab facility			3.76 (0.74)***
	Other destination			–1.44 (1.12)
	Home			
	N	5,756	5,515	5,515

Notes: *p<0.05, **p<0.01, ***p<0.001, standard errors in parentheses.
Reference categories, where applicable, in italics.

IV DISCUSSION

The multivariate analysis examines the relationship between a range of individual and system-level characteristics and hospital LOS for stroke discharges in 2010. The association between most of these variables and LOS is in line with expectations and we focus our discussion on findings that have implications for policy. In this context, Model 3 includes the most complete set of variables, however, it is acknowledged that certain parameter estimates in this model cannot be interpreted causally. Nevertheless, reporting on these estimates is of value as they highlight important policy-relevant associations and may motivate future analyses. Consequently, we primarily concentrate the discussion on the results on Model 3. However, endogeneity concerns mean relationships should be interpreted with care.

4.1 *Individual Factors*

Amongst the pre-disposing factors, the results show significant association between single or widowed status and longer LOS. Increasing attention is being paid in both international and national literature to the role of marital status when predicting care needs amongst older populations (Wren *et al.*, 2012). The presence of a spouse is considered an important potential source of informal care and this has implications for patterns of use of formal care. A reduction in use of both acute and long-term care utilisation has been observed in a multicountry study examining the implications for care utilisation of convergence between male and female life expectancy (i.e., reductions in widowhood and greater care-giving by spouses) (Wren, 2011). The results in this analysis are consistent with evidence in the literature, suggesting that married patients are more likely to have the necessary supports to enable them to be discharged home more quickly than others, or to have someone to assist in the process of accessing long-term care. Marital status can also be correlated with health status (Manzoli *et al.*, 2007) and it is possible that the observed results for marital status are picking up some unmeasured health status impacts. More detailed analysis using patient level data would be required for further examination of this issue.

The observed association between MRSA and longer LOS is consistent with available evidence (Guyomard *et al.*, 2009; Saez-Castillo *et al.*, 2010). Unfortunately, in this analysis it is not possible to distinguish when and where MRSA infection was acquired and it may be the case that the infection was contracted prior to the hospital admission under investigation. However, the presence of MRSA has important implications for appropriate hospital infection control processes. Reducing exposure of stroke patients to such infections could contribute to lowering LOS.

Model 3 finds no relationship between entitlement status and LOS. However, it is acknowledged that there are overlaps in the entitlement groups in terms of socio-economic status (Smith and Normand, 2009) and the income thresholds for qualifying for a medical card are higher for those aged 70 and older indicating that the income profile of medical card holders varies by age (Brick *et al.*, 2010). To better capture the association between medical card and socio-economic status, models were rerun on the sample of discharges aged 69 and younger only (see Table A2). The results for Model 3 (Table A2) indicate that those with no cover (i.e., no medical card and treated on a public basis) have a statistically significant lower LOS than those holding medical cards only. Non-medical card status may be capturing unmeasured individual level factors such as health status, better capacity to benefit from hospital treatment or to arrange post-hospital care. However, this explanation is not supported by the association between LOS and the other two entitlement groups which are assumed to be of similar and higher socio-economic status to the group with no cover. LOS for privately insured cases (i.e., no medical card and treated on a private basis) or for those with both private and medical card cover, is not significantly lower than for the medical card holders. This pattern of results is also difficult to interpret particularly in light of the incentive structures within acute hospitals (e.g., acute hospitals receive statutory in-patient fees from non-medical card public patients (see Brick et al. (2012) for further discussion of incentives in the Irish health-care system). Further examination of the associations between entitlement and socio-economic status with acute in-patient utilisation could be examined in separate analyses using available survey data (e.g., The Irish Longitudinal Study on Ageing).

4.2 *System Factors*

Our model suggests the influence of a number of policy-relevant organisational factors. The variation in LOS by area of hospitalisation and hospital type could be capturing differing administrative and managerial processes that cannot be directly measured in this analysis. Significantly lower LOS in regional and voluntary hospitals may be picking up the impact of unobserved variations in management practices, but may also be capturing the impact of higher annual case volumes or other location factors (hospitals largely located in cities). Cases admitted from a long-stay facility in this analysis have significantly shorter LOS than those admitted from home and suggests that where long-term care has already been organised, this facilitates more prompt discharge from hospital. These findings underline the importance for policymakers of addressing problems in accessing long-term and rehabilitation care facilities for stroke patients in the Irish system.[6]

4.3 *Stroke Units*

With regard to stroke units, preliminary univariate analysis (Table 1) suggests that LOS is longer in hospitals that report having a stroke unit. Model 1 suggested a positive statistically significant association is confined to hospitals with combined or rehabilitative units. In Model 2 only hospitals with combined units have a statistically significant positive association with LOS. However, after including all additional organisational variables, Model 3 finds that hospitals with acute stroke units are significantly associated with shorter LOS. This result is consistent with other Irish evidence on stroke units. A recent case study observed improved care and lower length of hospital stay following the establishment of a stroke unit in one teaching hospital (Lannon *et al.*, 2011).

[6] For example, delays in the assessment processes for accessing long-term care under the new Nursing Homes Support Scheme have been identified (Wren *et al.*, 2012) and the scheme is currently under review by the Department of Health (www.dohc.ie/press/releases/2012/20120614b.html [Accessed 11/02/13]).

In Model 3, combined and rehabilitative stroke units are also associated with shorter LOS but the results are not statistically significant. The variations in levels of significance by type of stroke unit are not surprising given that the acute stroke unit is specifically designed to cover the acute phase of care while the others are expected to cover longer phases of rehabilitation. Nevertheless, Irish policymakers need to take into account that the implications for hospital resource allocation of establishing a stroke unit are not uniform and may be influenced by the type of stroke unit considered.

Results indicate that the effect of the stroke unit variable is sensitive to model specification. The association between acute stroke units and LOS is not statistically significant in the other models and only becomes significant once all variables of interest are included in Model 3. In this context, controlling for the number of procedures plays an important role in examining the association between stroke units and LOS. Without controlling for the number of procedures, there is evidence that hospitals with certain types of stroke units (combined and rehabilitative) have longer LOS than those without stroke units. Thus, stroke units are likely to be influencing the number of procedures performed, which in turn extends LOS. These are complex patterns and need to be interpreted carefully. Many of the procedures refer to rehabilitative inputs by allied health professionals, thereby highlighting the role played by stroke units in initiating prompt rehabilitative care, a crucial element in effective stroke management (Van Peppen *et al.*, 2004). Other unobservable factors may be playing a role in the association between hospitals with stroke units and LOS. Hospitals with stroke units might be more likely to have staff with specialist stroke expertise than other hospitals and this is not controlled for in the analysis. Also, the stroke unit variable is constrained in that we can only gauge if hospitals have a stroke unit or not. We cannot determine if a discharge was actually treated in a stroke unit. We cannot observe if patients are being 'selected' for stroke unit care on the basis of specific characteristics that may make them more amenable to stroke unit interventions (and, for example, with the potential to be discharged earlier) while other stroke cases are treated elsewhere. There is sufficient variation in the data between hospitals with and without a stroke unit to justify the analysis but more detailed data on specific stroke units are needed to complement the analysis.

4.4 *Non-Causal Variables*

The results show that administering a scan (e.g., CT, MRI) is associated with significantly lower LOS. This reinforces the importance of organising hospital services to make diagnostic facilities available at short notice in order to provide the most appropriate and effective treatment. This issue has been emphasised in recent literature on stroke care in Ireland (Irish Heart Foundation, 2008). The time from symptom onset to diagnosis and subsequent treatment is particularly crucial for stroke. A proportion of stroke patients with a specific stroke type can be treated with thrombolytic therapy to restore blood flow to the brain but to be effective this treatment needs to be administered within 4.5 hours of symptom onset (Lansberg *et al.*, 2009). Further analysis of the association between brain imaging and LOS using data collected via the national stroke register[7] will be able to examine the impact on LOS of variations in time from symptom onset to scan.

Within the hospital, treatment by a geriatric consultant as opposed to other specialties is observed to increase LOS. This could be capturing some of the age effect where geriatric consultants are more likely to be treating older patients with more complex needs. However, there is also some correlation between type of consultant and the number of procedures and the individual coefficient on type of consultant needs to be interpreted with caution.

Transfers in the system also highlight important organisational factors. Cases discharged to a long-stay or rehabilitation facility record higher LOS compared to those discharged home. Given that we are controlling for stroke severity, these results suggest that there are bottlenecks in long-stay facility capacity and access in the system for these stroke cases. Concerns about limited access to long-stay facilities and the implications for delayed discharges from acute care in the Irish health-care system are well-documented (PA Consulting Group, 2007). Similar findings have been observed in the international literature (Mamoli *et al.*, 1999). In one study of six hospitals in the Netherlands in the 1990s, limited capacity of long-term facilities was found to be the most important cause of prolonged hospital stay (van Straten *et al.*, 1997). While a number of studies have analysed discharge destination as a factor associated with LOS of stroke patients (Hakim and Bakheit, 1998; Mamoli *et al.*, 1999; Somerford *et al.*, 2004) less is known about the influence of admission source on LOS.

In terms of model specification, the large size of the dataset allows us to specify and control for a number of variables. However, the use of such a database is also coupled with certain limitations. First, the constraints on the stroke unit variable are identified above. Second, the administrative nature of the data does not allow detailed measurement of stroke severity. Data from prospective stroke studies often include specific severity indices such as the National Institute of Health Stroke Scale (NIHSS) which has been shown to be a significant predictor of LOS (Chang *et al.*, 2002). Also, variables such as

[7] HSE Stroke Programme www.hse.ie [Accessed 11/02/13].

time to stroke onset and administration of thrombolytic agent which are potentially strong predictors of LOS are currently not captured in HIPE but which will be available in future via the national stroke register. Finally, these data refer to discharges rather than patients. In the absence of a unique health identifier it is not possible to identify patient-specific data within HIPE. However, it can be argued that in the case of acute stroke, within one year, the proportion of patients with multiple stroke episodes is expected to be relatively low.

V CONCLUSION

Stroke imposes an important economic burden worldwide and acute in-patient care accounts for a large proportion of costs in the first year of a stroke. Given that LOS is a key determinant of in-patients costs, we examine associations between various individual and system level factors and LOS. We focus on the Irish context which provides an opportunity to analyse the association between stroke units and LOS, exploiting the variation in availability of stroke units across hospitals in the system. Analysing a range of individual level (predisposing, illness level and enabling) and system level variables, we find a number of statistically significant relationships between policy relevant factors and LOS for stroke cases including among others, MRSA infection, availability of brain imaging and discharge destination. We find some evidence that acute stroke units are associated with significantly lower LOS although these findings need to be interpreted with care.

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APPENDICES

Table A1: *Diagnostics for Regression Models Presented in Table 2*

Link/Family		*Goodness of Fit* R^2	*RMSE*	*MAPE*	*MPE*	*AIC*	*BIC*
Log Normal	Model 1	0.24	35.28	17.34	1.08	57,452.29	57,771.88
	Model 2	0.30	20.18	11.74	0.09	48,886.16	49,203.69
	Model 3	0.53	16.55	9.65	–0.19	46,719.72	47,090.18
Log Gamma	Model 1	0.18	37.14	17.53	–0.43	44,621.30	44,940.88
	Model 2	0.26	20.87	11.66	–0.21	40,321.19	40,638.72
	Model 3	0.34	24.36	10.17	–1.42	38,590.29	38,960.74
Square Root	Model 1	0.19	36.39	17.34	0.21	44,629.33	44,948.92
Gamma	Model 2	0.26	20.65	11.61	0.04	40,314.23	40,631.76
	Model 3	0.47	17.70	9.29	0.64	38,545.08	38,915.53

Note: The Park test confirms that the Gamma distribution is the most appropriate distribution.

Pearson correlation and Preigibon link tests confirm that the Square Root is the most appropriate link.

1. Refers to the r-squared from a regression of predicted LOS on actual LOS.
2. Root Mean Squared Error.
3. Mean Absolute Prediction Error.
4. Mean Prediction Error.
5. Akaike Information Criterion.
6. Bayesian Information Criterion.

Table A2: *Coefficients for Entitlement Status Variable (Model 1-3) for Subsample of Those Aged 69 Years and Younger*

Variable	*Observations (%)*	*Model 1*	*Model 2*	*Model 3*
Entitlement Status				
No cover	829 (36.36)	–1.51 (1.05)	–0.72 (0.63)	–0.75 (0.31)*
Private cover	502 (22.02)	–0.84 (1.12)	–0.30 (0.72)	–0.56 (0.35)
Medical Card and Private Cover	55 (2.41)	–4.18 (1.91)*	–1.63 (1.50)	–1.22 (0.67)
Medical Card Only	894 (39.21)			
N	2,280 (100)	2,280	2,184	2,184