Estimating care costs from observational data: Acute Costs of Stroke in the UK National Health Service in 2002-2004

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Background

Stroke is the second leading cause of death worldwide[1], and a major cause of death in the UK, resulting in over 64,000 deaths in 1999.[2] Additionally, stroke is the major leading cause of neurological disability in adults, with stroke patients accounting for more hospital and care-home bed days than any other condition.[3] It is therefore not surprising that the high incidence and serious consequences of stroke make it a major cause of health service use and health care expenditure. Stroke has been estimated to cost over US$420 million and Can$857 million in direct health care costs in Australia[4] and Ontario[5], respectively, and in over US$40 billion in direct and indirect costs in the USA[6]. In the UK, previous studies have also quantified the costs of stroke, and found them to be considerable[7-10]. However, as far as we are aware, no analysis has used data from a truly population-based incidence study with full case ascertainment, without which major inclusion bias is likely. Furthermore, most of these studies have only included hospitalised patients.

The objective of this study was therefore to estimate the acute care costs due to stroke during the 12 months following stroke. We used data from the Oxford Vascular Study (OXVASC), a population based incidence study in Oxfordshire, UK. As the study was administratively censored, we also investigated the role that censoring bias may have on the results using two different methods of censor adjusting costs (Lin et al.[11] and Bang and Tsiatis[12]). In the analysis we adopted the perspective of the National Health Service (NHS), and we report mean costs by severity of stroke, subtype (ischemic or haemorrhagic), presence or absence of atrial fibrillation, and whether recurrent or first event.

Methods

Study population

The OXVASC study population comprised 90,452 individuals registered with 63 general practitioners (GPs) in nine general practices in Oxfordshire. The OXVASC population was 94% white, slightly higher than the UK average (92%), and was also slightly younger than that of the UK[13]. The electoral wards containing the nine general practices

were also found to be significantly less deprived than the rest of England[14]. However, the nine practices served a broad range of areas, with two of the nine electoral wards where the practices were based ranking in the lower third nationally in terms of deprivation[14]. Registration of patients into the study began on 1 April 2002 and continued until 31 March 2004. All patients having a transient ischemic attack or stroke during the study period were included in the study, but our analysis only includes those patients who had a stroke, using the WHO definition of "rapidly developing clinical signs of focal (at times global) disturbance of cerebral function, lasting more than 24 hours or leading to death with no apparent cause other than that of vascular origin"[15].

A comprehensive method of stroke ascertainment was employed, details of which have been described in detail previously[14]. Briefly, patients were ascertained by: regular contacts with the collaborating GPs; review of computerised hospital diagnostic codes, hospital admissions and Emergency Department registers; and review of all death certificates in the study practices, and by ICD-10 vascular death codes from the local Department of Public Health.

Clinical assessment

Patients were assessed by a study clinician as soon as possible. Those patients not admitted to hospital were assessed either at a dedicated daily clinic or at home. Diagnosis of ischemic stroke, haemorrhagic stroke, and subarachnoid haemorrhage (SAH) were verified by computed tomography (CT) or magnetic resonance imaging (MRI). For the purpose of the analysis all strokes of unknown type were coded as ischemic. Pre-morbid and one-month handicap and disability were assessed with the Rankin and Barthel Score. Stroke severity was classified according to one-month handicap and disability as measured by Rankin score, with mild stroke being classified as Rankin score 0-1, moderate stroke as Rankin score 2-3, severe stroke as Rankin score 4-5, and fatal stroke as Rankin score 6, following recommendations from the study physician. OXVASC also recorded the age and gender of patients, living arrangements at one month after stroke, presence and/or history of atrial fibrillation, and pre-morbid medication from the patient hospital and GP records.

Resource use and costs

The study provided information on diagnostic tests performed on patients and total length of hospital stay. The study did not however provide information of any subsequent hospital stay related to the index event. Diagnostic tests performed included: computed tomography (CT), magnetic resonance imaging (MRI), electrocardiogram (ECG), echocardiogram (Echo), and carotid Doppler. For the purpose of the analysis we assumed that all diagnostic tests were undertaken on the day when the CT or MRI was performed on the patient. We also assumed that those patients not requiring hospitalisation or being hospitalised more than 48 hours after initial stroke visited their GP on the day of the stroke. The initial hospital stay was subdivided by type of ward: general ward, stroke unit, rehabilitation ward and long term NHS care.

Precise mode of referral to hospital was not available from the dataset for this analysis. We assumed this was distributed as in an observational study of 739 patients with suspected stroke presenting to hospital emergency department:[16] 43% as 999 ambulance calls by patient or relative, 45% as non-emergency referrals by a GP, 5% as 999 calls by a GP, and 7% by other methods such as arrival at hospital by private/public transport.

The perspective of the UK National Health Service (NHS) was adopted in the study. Costs were calculated for each patient, and all costs were standardised to 2002 prices by use of the NHS Executive hospital and community health services inflation index. Long-term NHS care was costed using the per diem costs of general ward hospitalisation. Initial assessment at hospital was costed as an emergency visit. All unit costs and sources are reported in Table 1.

(TABLE 1 HERE)

Statistical Analysis

Resource use and costs were reported as means. Chi-square tests were used to evaluate differences in hospital admission between patients with prior atrial fibrillation and those

without. To account for the skewed nature of the resource use and cost data, we calculated the 95% confidence intervals from 1000 bootstrap estimates. Bootstrapping has been found to offer a useful test and alternative method of dealing with skewed data when parametric assumptions do not hold.[17]

For this analysis, follow-up data was used up to 30 April 2004; therefore, for those patients still in hospital it was not possible to determine when they were discharged, nor was it possible to determine if patients were still alive or dead after this date. As it is widely accepted that ignoring the issue of censoring when estimating mean total costs results in biased cost estimates[18], we used two different methods to adjust for censoring. The first method - developed by Lin et al.[11] - partitions the study period (in our case one year after stroke) into smaller time periods, within each of which the mean cost incurred for all patients alive at the beginning of the period is calculated. These mean costs were then weighted by the Kaplan Meier Sample Average (KMSA) estimator, which were then summed over all periods to obtain an estimate of the mean total study cost. In our study we portioned periods both by month (i.e. 12 time periods) and by day (i.e. 365 time periods). The second method - developed by Bang and Tsiatis[12] - also partitions the study period into smaller time periods, but then weights the estimated costs of patients with complete costs for each time period by the KMSA estimator, using reverse censoring (i.e. the probability of not being censored at the beginning of each period). 95% CIs were reported around the mean censored adjusted costs using the Bang & Tsiatis method, using 1000 bootstrap estimates.

Results

Study sample

Of the 90,452 individuals registered with a GP, a total of 346 patients suffered at least one stroke during the study period. These patients were then followed up for a minimum of one month and a maximum of two years, with mean follow-up for the study sample of 393 (S.D. 209) days. 162 (46%) patients had follow-up of less than 12 months. Due to unclear hospitalisation data, four patients were excluded from the analysis, hence, results were based on the 342 remaining patients. For 1 (0.3%) patient in the study sample,

history of atrial fibrillation could not be determined. In the remaining patients, 70 (20.5%) had a history of atrial fibrillation prior to them having the stroke. Other baseline characteristics of the study sample are reported in Table 2.

(TABLE 2 HERE)

Of the 342 patients suffering a stroke, 270 (78.9%) patients suffered from a first-ever stroke, while 72 (21.1%) had already suffered a previous stroke before the study period began. Mild strokes were the most common, with 110 (32.2%) cases, followed by moderate strokes (n=102, 29.8%), severe strokes (n=66, 19.3%) and fatal strokes (n=60, 17.5%). One-month Rankin scores were not obtained for 4 (1.2%) patients. For the available 338 patients, the mean Rankin score at one-month was 2.91 $\pm$ 1.978 (median: 3). Results from CT or MRI resulted in 271 (79.2%) patients being diagnosed an ischemic stroke, 22 (6.4%) a haemorrhagic stroke and 15 (4.4%) a subarachnoid haemorrhage (SAH).

A total of 42 (12.3%) patients suffered two strokes during the study period, and a further 6 (1.8%) suffered three strokes during this same period. The mean time between the incident stroke in the study period and the second and third recurrent strokes were 54 (S.D. 93) and 214 (S.D. 122) days respectively. However, 18 patients suffered a recurrent stroke during the first week after their incident stroke in the study period. In the current analysis, the aim was to report only the costs associated with the incident stroke in the study period, however, for those patients already hospitalised when a recurrent stroke during study period occurred, this was not possible, hence all costs were combined together as part of the initial event.

Resource use

Of the 342 patients included in the analysis, 212 (62%) were admitted to hospital, with the remaining 130 (38%) being managed in an outpatient clinic. Patients with a prior history of atrial fibrillation were more likely to be admitted to hospital than those without (80% vs. 58%, $p < 0.001$). Mean length of stay in hospital was 25.1 (95% CI: 20.7 to

29.8) days, with mean length of stay for those patients with prior atrial fibrillation (37.6 days; 95 % CI: 27.7 to 53.2) being significantly higher than for those patients without (21.39 days; 95% CI: 17.08 to 26.74). As depicted in Table 3, length of stay in each type of ward (i.e. general ward, stroke unit, rehabilitation ward and NHS long term care) was higher for those patients with a history of atrial fibrillation, although this difference was not statistically significant.

(TABLE 3 HERE)

Virtually all patients underwent a CT scan (90.8%) and ECG (98.5%) and a majority of patients underwent a carotid Doppler ultrasound (61%). Patients with AF were less likely to receive Doppler tests than those without the condition (43% vs. 66%, $p < 0.001$), but more likely to undergo an echocardiogram (44% vs. 27%, $p < 0.01$). There were no statistically significant differences between the two groups in resource use of other diagnostic tests (Table 3).

Total costs

The total unadjusted cost of acute care per patient for the first incident stroke in the study period over the first year after stroke onset was £6,289 (95% CI: £5,323 to £7,426). Table 4 gives the composition of these costs, which were mainly due to inpatient hospitalisation, with rehabilitation being the major cost component, accounting for around 48% of total acute care costs. Other costs (i.e. visits to the GP, outpatient visits, assessment at hospital and ambulance services) only represented around 2.5% of stroke costs in the acute treatment phase. As hospitalisation accounts for over 90% of all acute care costs, costs for the 130 patients not admitted to hospital were significantly lower, with mean cost per patient being £302 (95% CI: £293 to £312). Hence, if we had only included costs for the 212 patients hospitalised during the study period, total acute care costs per patient would have been considerably larger at £9,960 (95% CI: £8,457 - £11,769), and costs would have been overestimated by over 35%.

(TABLE 4 HERE)

Table 5 depicts the one-year acute care costs per patient by various disease categories, and also presents the results of the different methods of adjusting costs to take into account the role of administrative censoring. Analysis for all patients in the study showed that the mean censor adjusted cost per patient, using both the Lin and Bang & Tsiatis methods, was £6,582 (95% CI: 5,307 to 7,719), when the study period was partitioned into days. Results from the analysis also demonstrated that 80% of these costs were incurred within the first 60 days after stroke onset. However, partitioning the study intervals in larger time periods, i.e. months, resulted in mean costs being lower than when partitioning by shorter time periods (£6,512 using Lin and £6,508 using Bang & Tsiatis), and in the Bang & Tsiatis method giving slightly lower costs than the Lin method. These same results are also observed when mean costs for each sub-group were also adjusted for censoring. The main notable exception was for the 60 patients suffering a fatal stroke (i.e. death occurring up to one month after index event). For this sub-group, mean costs remained at £1,601 per patient no matter if adjusted for censoring or not, and irrespective of length of time period used to partition the study period. As all patients in this group died within one month of first stroke in the study period, and no patient in the analysis was censored during the first month after index event, censor adjusting in this case became irrelevant.

(TABLE 5 HERE)

Table 5 also demonstrated that severe strokes (28-day Rankin score 4-5) were the most costly, with an associated cost (after adjusting for censoring) of £18,408 (95% CI: £15,531 to £21,075). Patients with a history of atrial fibrillation incurred significantly higher hospitalisation costs and total costs than those without. The mean censoring adjusted costs per patients with a history of AF were £9,895 compared to £5,745 for patients without AF. Again, approximately 80% all costs were incurred in the first two months after the occurrence of the stroke, both for the AF and non-AF group.
Strokes in patients with a history of stroke prior to the study period were associated with higher costs than strokes in patients with no stroke history, but these differences were not

statistically significant. Again, patients with haemorrhagic strokes had higher costs than those with ischemic strokes after adjusting for censoring, but this difference was not significant.

Discussion

This study details the acute care resource use and costs of stroke during the first 12 months after an index event. The mean total cost was found to be £6,582, with hospitalisation accounting for over 90% of the acute phase treatment of stroke even though only 62% of patients were admitted to hospital. Previous studies of the costs of stroke in the UK have also found the acute treatment costs to be high. Forbes and Dennis[9] quantified the average cost of stroke at £8,536 in 1995 prices, although this study was based only on patients being admitted to hospital. In our case, when we only included hospitalised patients in the analysis, the acute treatment costs were also considerably larger, at £9,960 per patient. Youman et al.[10], using a 5-year Markov framework quantified the costs to the NHS of a stroke case at £15,306, with 59% of these costs due to acute hospitalisation. Our study also shows that those patients with a history of atrial fibrillation prior to onset of stroke are more likely to be admitted to hospital, and once hospitalised have longer lengths of stay than those without atrial fibrillation history. On average the acute care costs for AF patients are £4,150 greater than for non-AF patients.

We demonstrated in our study that not adjusting average costs in the presence of censoring can lead to biases. When the study period was broken down into months, we found that the Lin method gave slightly higher adjusted mean costs than the Bang & Tsiatis method, probably because the Lin estimator uses more information, and in such cases might be preferred to B&T[19]. However, when study periods were reduced to the limit, both studies resulted in nearly identical results, as the loss of information from the Bang and Tsiatis estimator was small. In situations when periods are reduced to the limit, the B&T method may be recommended due to its consistency[19]. Despite the slight differences in the two methods used to adjust costs in the presence of censoring, O'Hagan et al.[19] pointed out that both methods "are demonstrably better" than not taking into account the issue of censoring.

We believe that the greatest strength of our analysis is that the results are derived from a "state-of-the art study"[20] based on a population of over 90,000 people. The exhaustive case ascertainment in the OXVASC study resulted in the study including a large proportion of patients managed in the community; these would typically not be included in such costing studies, giving rise to major inclusion bias. The OXVASC study also allowed us to estimate the costs of stroke for different disease characteristics, such as disease severity, incident or recurrent stroke, and for different stroke subtypes.

Our study had a number of limitations. First, it did not include the costs of ongoing care after the acute treatment phase. Even though the acute treatment phase is the major cost component, out-patient and community care of stroke patients may also account for a substantial proportion of costs[10;21]. Secondly, the study contained no information on the mode of referral to hospital for those admitted, obliging us to derive such information from the literature. Finally, our study only quantified the costs of a patient's first stroke during the study period, and did not include the costs of any recurrent stroke the patient might have suffered during the study period or more than one year after the first stroke. Related to this, the study did not include any subsequent hospitalisations directly related to the incident stroke in the study period.

For the future, we plan to extend our analyses as the OXVASC study progresses, incorporating additional patients and longer follow-up periods. We will in future report cost estimates for patients with transient ischemic attacks, and patients experiencing subsequent events within the follow-up period. We also plan to extract additional information from GP and other notes on medications, post-hospital care, and other types of resource use.

In summary, our study reports reliable and up-to-date estimates of acute care costs associated with stroke over the first 12 months, using data from a well conducted, state-of-the art study. Using the results from this study, we show that inclusion and censoring

biases may significantly affect the results. Our results also demonstrated that when analysis periods were sufficiently reduced, both censoring methods gave the same results.

	Unit cost (£)	Source
Inpatient care		
General ward (per day)	247.80	Caro et al. 2000
Stroke unit (per day)	286.40	Caro et al. 2000
Rehabilitation ward (per day)	221	NHS trust reference costs, 2003
ER visit	96	NHS trust reference costs, 2003
Diagnostic tests		
CT	60	NHS trust reference costs, 2003
Doppler	98	NHS trust reference costs, 2003
MRI	309.60	NHS trust reference costs, 2003
ECG	29.50	NHS trust reference costs, 2003
Echocardiogram	64.90	NHS trust reference costs, 2003
Other		
Emergency ambulance	205	Netten et al. 2004
GP visit	20	Netten et al. 2004
Out-patient visit	65	Netten et al. 2004

Table 1. Unit costs

Age, mean (SD)	74.7 (11.0)
Gender	
Female, n (%)	174 (50.9%)
Male, n (%)	168 (49.1%)
Pre-morbid Barthel, mean (SD)	18.97 (2.61)
median (n)	20 (n=322)
Pre-morbid Rankin, mean (SD)	1.33 (1.20)
median (n)	1 (n=337)
History of atrial fibrillation, n (%)	70 (20.5%)

Table 2. Characteristics of the 342 patients included in the analysis

	All patients (n=342)	AF patients (n=70)	Non-AF patients (n=241)
	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
Days in hospital			
general ward	6.5 (5.2 , 8.4)	9.6 (4.8 , 18.2)	5.7 (4.5 , 7.2)
stroke unit	3.1 (2.2 , 4.2)	5.7 (3.1 , 10.5)	2.4 (1.5 , 3.3)
rehabilitation	13.7 (10.6 , 17.6)	18.5 (12.3 , 28.2)	12.5 (9.2 , 16.2)
NHS long term care	1.8 (0.7 , 3.5)	3.8 (0.8 , 9.8)	1.3 (0.7 , 3.7)
TOTAL	25.1 (20.7 , 29.8)	37.6 (27.7 , 53.1)	21.4 (17.1 , 26.7)
Diagnostic tests			
CT scan	0.9 (0.88 , 0.94)	0.9 (0.8 , 1.0)	0.9 (0.9 , 1)
MRI	0.02 (.01 , 0.04)	0.01 (0 , 0.09)	0.02 (0.01 , 0.05)
ECG	0.99 (0.98 , 1)	1	1
Echo	0.3 (0.26 , .35)	0.4 (0.3 , 0.6)	0.27 (0.2 , 0.3)
Doppler	0.6 (0.56 , 0.66)	0.4 (0.3 , 0.6)	0.66 (0.6 , 0.7)

Table 3. Resource use

	Cost (£) per patient, mean (S.D.)
Hospitalisation	
General ward	1,610 (3,885)
Stroke unit	885 (2,802)
Rehabilitation ward	3,021 (7,044)
Long term NHS care	450 (3,327)
TOTAL	5,965 (10,579)
Diagnostic tests	170 (74)
Other costs	154 (69)
TOTAL costs	6,289 (10,587)

Table 4. Total acute care cost for all patients.

	Unadjusted costs (£) per patient (95% CIs)	Censor adjusted costs (£) per patient using Lin Method		Censor adjusted costs (£) per patient using Bang & Tsiatis Method		
		Period = month	Period = day	Period = month	Period = day	95% CIs
All patients (n=342)	6,289 (5,235 to 7,490)	6,512	6,582	6,507	6,582	5,307 to 7,719
Atrial fibrillation						
Yes (n=70)	9,372 (6,957 to 12,767)	9,785	9,896	9,759	9,895	6,957 to 13,526
No (n=271)	5,514 (4,539 to 6,588)	5,687	5,745	5,684	5,745	4,490 to 6,903
Stroke severity						
Mild (n=110)	1,133 (717 to 1,687)	1,136	1,140	1,136	1,139	695 to 1,670
Moderate (n=102)	7,021 (4,948 to 9,760)	7,475	7,558	7,470	7,470	4,894 to 10,488
Severe (n=66)	17,776 (15,355 to 20,493)	18,216	18,413	18,178	18,408	15,531 to 21,075
Fatal (n=60)	1,601 (1,211 to 2,151)	1,601	1,601	1,601	1,601	1,121 to 2,089
Stroke subtype						
Ischemic (n=271)	6,570 (5,418 to 7,773)	6,904	6,962	6,899	6,961	5,472 to 8,384
Haemorrhagic (n=22)	6,476 (2,611 to 10,977)	6,827	7,126	6,827	7,126	3,331 to 12,052
Recurrent						
Yes (n=72)	7,576 (4,639 to 11,913)	7,892	7,945	7,880	7,945	6,211 to 7,846
No (n=270)	5,945 (4,974 to 7,088)	6,091	6,156	6,088	6,156	4,947 to 7,275

Table 5. Total costs per patient by selected disease characteristics

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