Modelling, evaluating and implementing cost-effective services to reduce the impact of stroke

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Scientific summary

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Scientific summary

Background

Stroke is the third leading cause of mortality and major cause of adult physical disability, costing over £7B a year in England. There is little information on the needs of patients after stroke, particularly longer term and in different ethnic groups.

Aims and objectives

We aimed to obtain information to underpin the implementation of national recommendations for stroke care by:

1. estimating the risk of stroke, including its underlying causes and trends over time in black and white populations
2. estimating acute and longer-term outcomes and needs after stroke and develop clinical prognostic tools for outcome prediction
3. estimating the risk of long-term stroke recurrence and develop clinical prognostic tools for recurrence
4. estimate trends and predictors of effective stroke care and associations with outcome
5. modelling cost-effective configurations of care
6. understanding users' perspectives of longer-term need, and policy-makers' and providers' perspectives of service configurations to address these needs
7. developing proposals to underpin current and future policy in stroke care.

Methods

Objective 1

The methods included estimating incidence rates age adjusted to the European population, confidence intervals (CIs) using the Poisson distribution and time trends using incidence rate ratios (IRRs) with 95% CIs; using multivariate logistic regression models to assess the significance of time trends in risk factors; and examining factors associated with risk factor diagnosis and management.

To investigate the effect of air pollution, an ecological study was undertaken. Particulate matter 10 and nitrogen dioxide (NO_2) concentrations were modelled as measures of exposure.

Objective 2

Proportions and 95% CIs for rates of disability, inactivity, cognitive impairment, anxiety, depression and quality of life up to 10 years after stroke were modelled.

Depression, anxiety, cognitive impairment and quality of life were examined in further detail using assessments up to 15 years. Incidence, cumulative incidence and prevalence of outcomes were estimated and multivariate regression was used to investigate associations between outcomes 3 months after stroke and longer-term outcomes.

A systematic review and meta-analysis estimated the natural history, predictors and outcomes of depression after stroke.

Survival curves were constructed for consecutive time periods, ethnic groups and stroke subtypes, using the Kaplan–Meier methods and log-rank tests. Multivariate survival analyses were undertaken using Cox proportional hazards models to determine the prognostic value of baseline and process of care factors on survival.

Objective 3

Kaplan–Meier estimates and Cox proportional hazards models were used to derive pooled estimates (95% CI) of cumulative risk of and predictors for recurrence. A systematic review and meta-analysis estimated cumulative risk of recurrence, employing a random-effects meta-regression Weibull model.

Objective 4

Trends in evidenced-based care were examined with the chi-squared test for trend. Multivariable logistic regression models were used to examine the impact of sociodemographic variables and case-mix on the processes of care, and examine time trends [odds ratios (ORs) (95% CIs)]. Survival functions were compared using log-rank tests.

Objective 5

Societal costs of stroke were estimated.

An economic model simulating the patient journey was developed in collaboration with the National Audit Office (NAO).

To establish the cost-effectiveness of stroke unit and early supported discharge (ESD), a Markov health state transition model was developed.

Objective 6

A national survey of stroke survivors 1–5 years post stroke was undertaken using patients recruited through Medical Research Council General Practice Research Framework (MRC GPRF) and two stroke registers. Levels and type of need were calculated and qualitative interviews of patients' and carers' perceptions of needs were conducted alongside an ethnographic study of the organisation of services provided.

Objective 7

Dissemination of outputs to stakeholders and work with stroke transformation teams nationally was undertaken.

Development of proposals to evaluate effective ways of using information generated from the programme to improve stroke care and outcome was undertaken.

Results

Objective 1

Analyses of the 1995–2004 data show that stroke incidence decreased by 18% in men and by 25% in women. A similar decline was observed in white men and women, but in the black African (BA) and black Caribbean (BC) group combined, stroke incidence was reduced only in women (52%). In the white group, the prevalence of prior-to-stroke hypertension, atrial fibrillation (AF) and smoking decreased; however, no statistically significant changes were observed in the black group.

In a subsequent analysis (1995–2010), stroke incidence continued to decline. Among white stroke patients, the incidence (per 100,000) declined from 111.78 in 1995 to 41.58 in 2010. Among BC patients, incidence declined from 138.42 in 1995 to 107 in 2010. Among BA patients, the incidence increased from 85.34 per 100,000 in 1995 to 103 per 100,000 in 2010.

The distribution of aetiological subtypes of stroke in the period 1999–2004 was as follows: large artery atherosclerosis (LAA), 109 patients (9.3%); cardioembolism (CE), 325 patients (27.8%)' small vessel occlusion (SVO), 316 patients (27.0%); other aetiology (OTH), 40 patients (3.4%); undetermined, 283 patients (24.2%); and concurrent aetiologies, 96 patients (8.2%). The annual age-adjusted incidence per 100,000 was 101.2 (95% cerebral infarction 82.4 to 122.9) for total ischaemic stroke in men and 75.1 (95% CI 59.1 to 94.1) in women; it was 10.4 (95% CI 5.1 to 18.9) for LAA in men and 6.8 (95% CI 2.7 to 14.2) in women; 23.0 (95% CI 14.6 to 34.5) for CE in men and 21.5 (95% CI 13.4 to 32.8) in women and 30.3 (95% CI 20.5 to 43.2) for SVO in men and 20.3 (95% CI 12.5 to 31.3) in women. The overall IRRs for the black group, as well as for BAs and BCs, were significantly higher for SVO in both sexes and for OTH in females.

Analysis of risk factor management in the period 1995–2010 showed that a large number of strokes occurred in people with untreated vascular risk factors. The study highlighted substantial ethnic differences in risk factors not explained by socioeconomic deprivation, with hypertension and diabetes significantly more common in black patients but AF and prior-to-stroke myocardial infarction (MI) significantly more common in white patients. There was little change in the use of primary prevention during the study period. Only a minority of stroke patients with AF or prior MI were on appropriate treatment.

Analysis of the effect of air pollution in the period 1995–2004 identified that there was no significant association between outdoor air pollutants and stroke incidence. The impact of air pollution on survival identified that a 10 $\mu g/m^3$ increase in NO_2 was associated with a 28% (95% CI 11% to 48%) increase in risk of death. A 10 $\mu g/m^3$ increase in particulate matter < 10 μm in diameter was associated with a 52% (95% CI 6% to 118%) increase in risk of death.

Objective 2

Between 1995 and 2006, 3373 first-ever strokes were registered. A total of 20–30% of survivors had 'poor' outcomes over 10 years of follow-up. The highest rate of disability (Barthel Index score < 15) was observed 7 days post stroke and remained at approximately 110 per 1000 population thereafter. Rates of inactivity [Frenchay Activity Index (FAI) score < 15] and cognitive impairment (Abbreviated Mental Test score < 8 or Mini Mental State Examination score < 24) both declined up to 1 year (280 and 180 per 1000 survivors, respectively) but then rates of inactivity remained stable until year 8, when they then increased, whereas rates of cognitive impairment fluctuated until year 8 then increased. Anxiety and depression (Hospital Anxiety and Depression Scale score > 10) showed some fluctuation over time, with a rate of 350 and 310 per 1000 population, respectively. Short form questionnaire-12 items (SF-12) scores showed little variation from 3 months to 10 years post stroke. Inactivity was higher in males at all time points and higher in white than in black stroke survivors, although black survivors reported better outcomes in the SF-12 physical domain. Increased age was associated with higher rates of disability, inactivity and cognitive impairment. Levels of inactivity were higher in males at all time points. Higher levels of inactivity were observed in white stroke survivors, although they showed a more favourable outcome in the SF-12 physical domain. Age was directly associated with rates of disability, inactivity and cognitive impairment, although there was no clear association between age and anxiety and depression and SF-12 mental and physical domains.

More detailed analyses of depression data showed that 48% of patients were not depressed at any time point, 49–55% of depressed patients at one assessment remained depressed at follow-up and 15–20% of patients at each assessment were new cases. Predictors of depression included stroke severity, inability to work and impaired cognition. The incidence of depression ranged from 7% to 21% in the 15 years following a stroke, with cumulative incidence of 55% and prevalence ranging from 29% to 39%. Most episodes of depression started within a year of the stroke, with 33% of the cases starting in the 3 months following a stroke. Fifty per cent of patients with depression at 3 months had recovered 1 year after stroke. The proportion of recurrent episodes of depression after stroke increased gradually from 38% in year 2 to 100% in years 14 and 15.

A systematic review/meta-analysis estimated the prevalence of depression to be 29% (95% CI 25% to 32%), which remained stable up to 10 years after stroke with a cumulative incidence 39–52% within 5 years of stroke. The rate of recovery from depression among patients depressed a few months after stroke ranged from 15% to 57% 1 year after the stroke.

The prevalence of cognitive impairment remained relatively unchanged at 22% [24% (95% CI 21.2% to 27.8%) at 3 months and 22% (95% CI 17.4% to 26.8%) at 5 years to 21% (95% CI 3.6% to 63.8%) at 14 years]. In multivariate analyses, the post-stroke prevalence ratio of cognitive impairment increased with older age [2% (95% CI 1% to 3%) for each year of age], ethnicity [2.2-fold (95% CI 1.65-fold to 2.89-fold) higher among black groups] and socioeconomic status [42% (95% CI 8% to 86%) increased among manual workers]. A significant, progressive trend of cognitive impairment was observed among patients with SVO and lacunar infarction.

Survival improved significantly over the 16-year period (p-value < 0.0001). BC and BA groups had a reduced risk of all-cause mortality [hazard ratio (HR) 0.85 (95% CI 0.74 to 0.98) and 0.61 (95% CI 0.49 to 0.77), respectively]. Recent stroke, being black and stroke unit admission were associated with better survival.

Objective 3

The cumulative risk of stroke recurrence at 1, 5 and 10 years was 7.1%, 16.2% and 24.5%, respectively. Factors increasing the risk of recurrence at 1 year were previous MI (HR 1.73, 95% CI 1.08 to 2.78) and AF (HR 1.61, 95% CI 1.04 to 4.27); at 5 years they were hypertension (HR 1.47, 95% CI 1.08 to 1.99) and AF (HR 1.79, 95% CI 1.29 to 2.49); and at 10 years they were older age ($p = 0.04$), hypertension (HR 1.38, 95% CI 1.04 to 1.82), MI (HR 1.50, 95% CI 1.06 to 2.11) and AF (HR 1.51, 95% CI 1.09 to 2.09).

In a meta-analysis of studies of recurrence, the pooled cumulative risk of recurrence was 3.1% (95% CI 1.7%%) at 30 days, 11.2% (95% CI 8.9% to 13.4%) at 1 year, 26.4% (95% CI 20.1% to 32.8%) at 5 years and 39.2% (95% CI 27.2% to 51.2%) at 10 years after the initial stroke.

Objective 4

Between 2007 and 2009, 5% of patients were still not admitted to hospital after a stroke and 21% of patients admitted to hospital were not admitted to a stroke unit. Rates of admission to stroke units and brain imaging (from 1995 to 2009) and thrombolysis (from 2005 to 2009) increased significantly ($p < 0.001$). Black patients had significantly increased odds of admission to a stroke unit (OR 1.76, 95% CI 1.35 to 2.29; $p < 0.001$) and of receipt of occupational therapy or physiotherapy (OR 1.90, 95% CI 1.21 to 2.97; $p = 0.01$), independent of age or stroke severity. Length of stay in hospital decreased significantly between 1995 and 2009 ($p < 0.001$). The likelihood of those with a functional deficit receiving rehabilitation increased significantly over time ($p < 0.001$). Patients managed on a stroke unit, those with deficits receiving specific rehabilitation therapies and those with ischaemic strokes receiving aspirin in the acute phase had a better 1-year survival than those who did not receive these interventions.

Objective 5

The treatment of, and productivity loss arising from, stroke results in total societal costs of £8.9B a year, with treatment costs accounting for approximately 5% of the total UK NHS costs. Direct care accounts for approximately 50% of the total, whereas informal care costs 27% and the indirect costs 24%.

Comparison of the level of stroke care in 2010 with previous provision levels demonstrates that the improvements have been cost-effective, with an incremental cost-effectiveness ratio (ICER) of £5500 per quality-adjusted life-year gained.

The ICER of stroke unit care followed by ESD is £10,661 compared with the general medical ward without ESD care and £17,721 compared with stroke unit without ESD.

Objective 6

Long-term unmet needs related to activities of daily living, social participation, aids/adaptations, housing, financial support, rehabilitation, information and transport. Needs changed over time and often were not stroke specific.

In the national survey of 1251 participants, 51% reported no unmet needs and, among the remainder, the median number of unmet needs was three (range 1–13). Proportions reporting unmet clinical needs ranged from 15% to 59%, with 54% reporting an unmet need for stroke information, 52% reporting reduction in or loss of work activities, which was reported significantly more by black ethnic groups ($p = 0.006$), 18% reporting a loss in income and 31% reporting an increase in expenses, with differences by age, ethnic group and deprivation score.

The ethnographic study suggested that patients do not simply progress through a care pathway and that quality of care can be affected by multiple factors including complexity of needs, moral evaluations, divergent staff views and patient/carer knowledge and agency.

Objective 7

Programme outputs have informed policy and practice through the NAO report on the future of stroke services. We have worked collaboratively with stroke transformation programmes in London, Manchester and the Midlands, and the east of England to provide estimates of need and modelled the cost-effectiveness of the proposed transformations to services. We have developed a proposal to evaluate effective ways of using information to improve stroke care and outcome that involves 'packaging' outputs from this programme in ways that meet the different stakeholders' needs and evaluating the effect of use on public and patient benefit.

Conclusions

The programme has provided a sustainable platform for health services research, the maintenance of a unique long-term condition register and opportunities for capacity building in health services research for health-care professionals and scientists. We have demonstrated for the first time, by systematically following a population-based cohort of patients for up to 15 years, that stroke is a very long-term condition with persisting consequences for the patient. We have produced information that has influenced national and local stakeholders and contributed to programmes that have improved stroke services nationally.

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