Current, future and avoidable costs of stroke in the UK

Technical report

Rebuilding lives after stroke

Stroke Association

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(Anita Patel, Vladislav Berdunov and Zahidul Quayyum were all employed at Queen Mary University of London when the substantial components of this work were undertaken)

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Contents

List of Tables

List of Figures

Abbreviations

A&E	Accident and Emergency
ASU	Acute stroke unit
CRT	Community rehabilitation
CI	Confidence interval
ESD	Early supported discharge
NGC	National Guideline Centre
NHS	National Health Service
OBR	Office for Budget Responsibility
ONS	Office for National Statistics
PSS	Personal Social Services
QALY	Quality-adjusted life year
RCT	Randomised controlled trial
RCP	Royal College of Physicians
SSNAP	Sentinel Stroke National Audit Programme
SLSR	South London Stroke Register
SD	Standard deviation
SU	Stroke unit
UK	United Kingdom

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Key messages

We summarise here the overall approach and key messages from this work. Further summaries are also available in the following publications:

- Current, future & avoidable costs of stroke in the UK. Summary report. London: Stroke Association, 2020.
  https://www.stroke.org.uk/sites/default/files/current_future_avoidable_costs_of_strokesummary-report.pdf

- Patel A, Berdunov V, Quayyum Z, King D, Knapp M, Wittenberg R. Estimated societal costs of stroke in the UK based on a discrete event simulation. Age and Ageing 2019; 1-7 (Online first 17 December 2019)
  https://doi.org/10.1093/ageing/afz162

- King D, Wittenberg R, Patel A, Quayyum Z, Berdunov V, Knapp M. The future incidence, prevalence and costs of stroke in the UK. Age and Ageing 2020; 1-6 (Online first 19 January 2020)
  https://doi.org/10.1093/ageing/afz163

1. The current and future burden of stroke

We assessed estimates of the current burden of stroke and forecasted the potential burden in the longer term, taking account of likely changes in demography and expert views on potential future trends in the numbers of first-time strokes (stroke incidence) and survivors after stroke (stroke prevalence) each year.

Current burden of stroke: number of strokes and stroke survivors now

Incidence: the estimated annual number of first time stroke cases (stroke incidence) ranges from 113,400 to 119,100. Using ranges of incidence rate reported by various individual studies, the

number could conceivably range from 85,800 to 147,600. We focused on the mid-point estimate of 117,600 (Stewart et al., 1999) for our various calculations.

Prevalence: The estimated number of stroke survivors (stroke prevalence) aged 45 and over in the UK ranged from 950,000 to 1.3 million in 2015. When the low and high estimates from various individual studies are considered, the number could range from 797,000 to 1.4 million. We focused on the estimate of 950,200 (Geddes et al., 1996) for our various calculations.

Future burden of stroke: potential number of strokes and stroke survivors in the future

Experts had differing views on whether stroke incidence would decrease or increase in the future. Their views on prevalence were more similar, pointing towards no change or modest increases in prevalence among people aged 40-74 years and a modest or high increase among people aged 75- 100 years. Alongside estimates of demographic trends, applying these views to current rates of incidence and prevalence points to a substantial future burden of stroke.

Incidence: first-time strokes among people aged 45 and over in the UK will rise from 117,600 in 2015 to 148,700 in 2025 and 187,000 in 2035, an increase of 59% over 20 years. This is based on the assumption from expert views that incidence rates will stay the same up to 2035 for those aged 45 to 84, and rise by 0.5% per year for those aged 85 and over. If incidence rates change by 1% per year more or 1% less than under this assumption, incidence would be 228,000 or 153,000 respectively in 2035.

Prevalence: the number of stroke survivors among people aged 45 and over in the UK will rise from 950,000 in 2015 to 1,425,000 in 2025 and 2,120,000 in 2035, an increase of 123% over 20 years. This is based on the assumption from the expert views that prevalence rates will rise by 1% per year for those aged 45 to 64, 1.5% per year for those aged 65 to 74, 2.0% per year (2.5% after 2025) for those aged 75 to 84 and 2.5% per year (3.0% after 2025) for those aged 85 and over. If prevalence rates change by 1% per year more or 1% less than under this central set of assumptions, prevalence would be 2,575,000 or 1,740,000 respectively in 2035.

2. The current and future societal costs of stroke and potential return from investment in research

We updated estimates for the current societal costs of stroke and examined potential future costs of stroke over the next 10 and 20 years (2015 prices). We accounted for costs falling upon: the National Health Service (NHS), personal social services (PSS) e.g. care homes (public and private payers), informal (unpaid) carers such as family and friends, and broader society in terms of productivity losses associated with lost/reduced employment among stroke survivors.

Our starting point was recent work by the National Guideline Centre at the Royal College of Physicians to estimate NHS and social care costs for stroke now and over the next five years (NGC & SSNAP, 2016; Xiang-Ming et al., 2017). We modified and built on that work, to estimate costs from a broader perspective and for a longer period of time. We also gathered expert views on what research areas should be prioritised to reduce the future burden of stroke in the UK and investigated potential savings from investing in these research areas.

Current average costs per person

The average societal cost of stroke per person is £45,409 in the first 12 months after stroke (cost of incident stroke), plus £24,778 in each subsequent year (cost of prevalent stroke). The average cost of NHS and PSS care in the first year after a severe stroke is almost double that for a minor stroke (£24,003 compared to £12,869). More generally, average NHS and PSS costs varied little between males and females, and between those with ischaemic versus haemorrhagic stroke, but were significantly higher for those aged 85 years and older compared to younger adults. However, lower informal care costs among older adults led to a balance in total average costs across age groups.

Current aggregate costs for the UK

The per-person costs translate into a substantial £25.6 billion aggregate cost of stroke in the UK per year. Of note, we estimate that £15.8 billion of this is the value of care contributed by informal/unpaid carers, which is almost double the NHS and PSS care costs of £8.6 billion. Of the NHS and PSS costs, the cost attributed to NHS-funded care (including secondary care, early supported discharge and community rehabilitation) is £3.4 billion (13% of cost to society). Formal

social care contributes more at £5.2 billion (20%). Although the majority of stroke survivors are of older age, lost productivity amounts to £1.6 billion per year.

Breaking this down into incident and prevalent stroke, the aggregate annual cost to society of new cases of stroke is £5.3 billion, of which £1.6 billion (30%) is NHS care. As the majority of NHS care is received in the acute phase while the person is in hospital, NHS costs level off in subsequent years to 9%. In contrast, the contribution of formal social care increases from 11% in the first year after stroke to 22% (£4.6 billion) in subsequent years. Furthermore, the informal care sector contributes a vast £12.8 billion per year in subsequent years, leading to an aggregate annual cost of £20.6 billion for prevalent stroke. The main driver for the difference in incident and prevalent stroke costs is the much larger number of stroke survivors (950,200) compared to new stroke cases each year (117,600).

The largest source of uncertainty for our estimates of current aggregate costs is the annual rate of stroke prevalence that we apply, followed by the value we use for the average cost of informal care and the rate we use for annual incidence of stroke.

Future costs

We project that the overall costs of stroke in the UK for those aged 45 years and over will rise from £26 billion in 2015 to £43 billion in 2025 and £75 billion in 2035, i.e. almost tripling over 20 years, based on constant 2015 prices. There are several key drivers for such a substantial increase: first, predictions that the number of older people (especially those aged 85 years and over) in the population will increase substantially due partly to rising life expectancy and partly to the 'baby boom' cohorts reaching old age; second, our assumption that because care is highly labour intensive, the cost per hour of care will rise in line with average earnings, which in turn are expected to rise by 2% per year after accounting for inflation (Office for Budget Responsibility, 2017); and finally, the experts we consulted expect stroke survival rates to improve. The projected increase is highest for social care because of high use of social care in late old age by survivors of severe strokes.

Changing our rates for trends in incidence, prevalence and costs of care per person show a wide range of cost projections. For example, higher or lower rates of future incidence and prevalence result in estimates of aggregate annual costs of stroke in the UK in 2035 rising to £91.5 billion or only to £61.8 billion respectively. Therefore, the total burden remains high even under more conservative assumptions.

Potential return from investment in research

Experts initially suggested 56 different research topics. After a ranking process, the top five were as follows (in rank order): improved rehabilitation strategies, rehabilitation for cognitive difficulties, vascular dementia, thrombectomy and evidence-based practice. Estimated societal savings by 2035 from investing in each of these research areas range between £400 million (0.5% saving) for further research related to thrombectomy and £4 billion (5.3% saving) for research related stroke prevention.

3. The economic case for wider implementation of effective interventions

There is already evidence of various beneficial interventions, but such interventions are not yet fully implemented. We therefore explored potential future economic gains from their wider implementation.

We conducted a series of focused and pragmatic literature reviews to identify interventions with evidence of potential economic gains as well as evidence of effectiveness. We looked for interventions spanning three overarching areas of the stroke care pathway: rehabilitation/long-term care, acute care and prevention.

Rehabilitation/long term care

A significant body of evidence related to various types of physical rehabilitation indicates its effectiveness for recovery of function and mobility after stroke (Pollock et al., 2014). In comparison, the evidence base for occupational therapy interventions is smaller but suggests improved outcomes from interventions focussing on activities of daily living (Legg et al., 2007). Evidence for rehabilitation therapy in the longer term is limited (Aziz et al., 2009).

A fifth of people with ischaemic stroke are likely to suffer from dysphagia and a fifth of these are likely to develop pneumonia (Arnold et al., 2016). This means that around 4700 people annually experience pneumonia following an ischaemic stroke in the UK, incurring an annual treatment cost of approximately £2.5 million.

NHS England estimates for extending provision of early supported discharge schemes following a stroke suggest that 170 lives could potentially be saved in England and a saving of £15,100 per 100,000 people realised (NHS England, 2014).

It is thus difficult to draw robust conclusions on effectiveness or cost-effectiveness of psychological support for stroke patients because evidence is limited in extent, quality and nature. Also, screening for psychological state after stroke remains hampered by clinician uncertainty about which screening tools to use.

Acute care

Major acute system reconfiguration to increase delivery of effective urgent care has been successful in London and Greater Manchester (Morris et al., 2015). In London, a significantly higher proportion of patients received care compliant with care processes and the new model delivered a 5% relative reduction in mortality at 90 days. Both areas saw reductions in length of hospital stay. The West Midlands is another major urban region with a population size broadly equivalent to Greater Manchester's so could potentially achieve similar gains to the Greater Manchester reconfiguration i.e. ~18,000 hospital days/£5 million saving over 2 years.

Delivering thombolysis within three hours of stroke is effective in reducing death or dependency (Wardlaw et al., 2014). We estimate that for the 2,000 eligible patients who do not receive the drug each year the NHS incurs £8.2 million in avoidable costs over 5 years.

Thrombectomy is highly cost-effective, with an incremental cost per QALY gained of £7,061 (over 20 year horizon) – significantly lower than many other NHS interventions (Ganesalingam et al., 2015). Guijarro et al. (2017) suggest that on average one extra patient receiving thrombectomy

would save the NHS £47,000 over 5 years, thus representing potential annual savings of millions. The benefits of thrombectomy are substantial: for every 100 patients treated, 38 have a less disabled outcome than with best medical management, and 20 more achieve functional independence (mRS 0–2) (Goyal et al., 2016). Thus higher treatment costs in the short term can be offset in the longer term (Lobotesis et al., 2016).

Prevention

As indicated by our estimates related to potential returns on research investment, the greatest scope for savings comes from better stroke prevention. We estimate that an atrial fibrillation screening programme could avoid 500 new strokes each year. This corresponds to £10.7 million of savings to NHS & social care or £28.4 million of savings in broader societal costs. Accounting for longer term post-stroke survival rates, potential cost savings to society (excluding costs of implementing the intervention) over a 5 year period amount to £233 million, £147 million of which relates to the opportunity cost of unpaid care and lost employment opportunities.

Appropriate anticoagulant management of atrial fibrillation in all eligible patients could avert an estimated 4,551 strokes each year. This translates to £97 million savings in NHS & social care costs or £259 million savings in societal costs in the first year. Over 5 years, corresponding savings would be 22,755 fewer new strokes, 8,727 fewer prevalent cases of stroke and societal savings of £2 billion, including £691 million savings to NHS & social care.

Increasing time spent within the therapeutic range for warfarin from 60% to 70% can potentially result in societal cost savings of £908 million within 5 years of implementation.

A successful strategy to increase the proportion of diagnosed hypertension cases by 15% could potentially avoid 10,790 new cases and 4,138 prevalent cases of stroke over 5 years, yielding potential cost savings of £772 million to society, £284 million of which is attributed to NHS & social care.

A strategy to increase the proportion of patients on treatment for hypertension who achieve blood pressure <140/90 mm Hg from 63% to 78% would allow an additional 1.3 million patients to benefit from a reduced risk of stroke. Improved blood pressure control can avoid an estimated 2,000 new stroke cases each year.

Increasing the proportion of individuals with diagnosed hypertension who achieve blood pressure <140/90 mm Hg by 15% could potentially save £36.1 million in NHS & social care for first-time stroke each year. A further £51.8 million of informal care and £2.9m of lost employment costs could be avoided. Over 5 years, 9995 new cases and 3833 prevalent cases of stroke could be avoided, yielding potential cost savings of £715 million to society, £263 million of which is attributed to NHS & social care.

Conclusions

We estimated aggregate annual costs of stroke, now and over the next two decades. Our results point towards a substantial economic burden on society associated with stroke (£25.6 billion each year). Even accounting for the caveats related to our estimates, it is clear that informal carers are significant contributors to stroke care and that social care costs will increase substantially by 2035. Therefore, the burden of stroke extends well beyond that obviously shouldered by people with stroke and health care services.

The economic burden of stroke will almost treble within 20 years, due to predicted rises in the number of older people in the population, the number of stroke survivors and costs of formal care. This will present real societal challenges in future. There is great potential to alleviate some of these costs through increased investment in research and greater priority in care funding and policy support.

Limitations

There are of course caveats surrounding these findings, the main being that our estimates are based on modelling, rather than actual observations, and that we include projections for an unknown future. A significant uncertainty is the number of new strokes that are expected to occur

each year and the number of people that will live with stroke. Experts have divergent views on this, and this uncertainty impacts on the cost predictions.

More broadly, 'costs of illness' studies like this are necessarily context-specific and can vary in their approach. For example, data sources reflect the availability/quality/outcomes of care at that point in time and such factors may vary and have different impacts at other times. Data availability is generally improving over time and estimates of aggregate costs are naturally influenced by the range of costs considered relevant or measurable. For example, our estimates of health care costs cover those relating to Accident and Emergency (A&E) departments, acute and regular stroke units and early supported discharge. But they do not include any primary care costs or costs associated with other illnesses occurring at the same time as stroke (comorbidities). These variations naturally create challenges for drawing comparisons with other estimates. To illustrate, our estimate of the aggregate annual cost of stroke is substantially larger than previously estimated by Saka et al. (2009). They estimated direct medical care costs at £4.4 billion compared to our estimate of £8.6 billion. More strikingly, they calculated informal care costs to be £2.4 billion per year, compared to our estimate of £15.8 billion. Such a difference may be driven by several factors. For instance, we valued some of the informal care inputs using a different approach and our data sources differed greatly - we used two large trials of post-stroke care as the basis of our informal care calculations which, although detailed and from a national sample, may have included a more selective sample of people with stroke compared to the more localised but routine data source used by Saka et al. (2009) (the South London Stroke Register). Moreover, both trials collected data on informal care inputs from all resident and non-resident caregivers, rather than just a primary caregiver. While we use plausible estimates throughout this work, our extensive sensitivity analyses clearly show that alternative values and assumptions can generate different specific estimates. As is the case for all cost of illness studies, our figures thus represent an indicative, rather than definitive, estimate of the economic burden of stroke. Estimates of returns from investment in research are similarly indicative.

1. Introduction

Stroke is the second largest cause of death worldwide and fourth in the United Kingdom (UK). There are upwards of 113,000 strokes annually in the UK (Rothwell et al., 2004); while there are over 950,000 stroke survivors (Geddes et al., 1996), many experience significant and long-term residual physical and psychological impacts, repeat strokes/transient ischaemic attacks and/or death within a year of stroke (Stroke Association, 2016). Stroke prevention and treatment, and its morbidity and mortality impacts, carry economic consequences across society (Saka et al. 2009; National Audit Office, 2010). A quarter of all strokes in the UK are among the under-65s (Stroke Association, 2016); this suggests significant economic impacts on employment/productivity as well on formal and unpaid care sectors.

Despite significant progress in prevention, treatment and rehabilitation, there is great capacity for further improvement, and thus for reductions in economic burdens. This is ever more important given current and likely ongoing pressures being experienced by many health and care systems, as well as pressures on family and other unpaid carers. Understanding the scale and range of associated economic impacts for a condition as prevalent as this, not only now but also in the future, can be of enormous value to help prioritise scarce resources. We seek here to update estimates of the current economic burden of stroke to ensure future service and policy responses are based on timely and relevant data. We also seek to further inform such responses by examining potential future costs over the next 10 and 20 years, accounting for expert views on the potential trajectories for stroke incidence and prevalence.

Estimates of burden of illness do not in themselves offer solutions so it is also important to identify how some of these future costs could be mitigated. Increased investments in research and interventions would likely pay for themselves many times over in resultant savings later. Despite this potential for economic gain, stroke has received considerably less research investment compared to conditions with similar burdens e.g. UK annual medical research spend per stroke patient is £48, compared with £241 per cancer patient and £118 per dementia patient

(Stroke Association, 2016). Thus we also seek to explore the potential return to be had from greater investment in stroke research.

We report five streams of work addressing the gaps highlighted above:

- Estimation of the current societal costs of stroke in the UK
- Elicitation of expert views on future trends in stroke incidence and prevalence, and on research priorities (to inform the subsequent work streams)
- Projection of societal costs of stroke to the next 10 and 20 years based on scenarios of likely changes in demography, epidemiology and other factors likely to influence costs of stroke
- Estimation of the potential returns on investment in increased spending on stroke research
- Examination of the economic case for more widely implementing interventions already established as effective.

2. Current costs of stroke

Key messages

- This study aims to estimate the current annual cost of stroke in the UK from the perspective of the NHS & personal social services and society.
- Average cost per person in the first 12 months after stroke is £45409 from the societal perspective, plus £24778 in each subsequent year.
- In aggregate terms across the UK, this translates into a substantial £26 billion per year attributed to stroke from a societal perspective.
- The largest proportion of cost is attributed to ongoing care and lost productivity in stroke survivors, which amounts to over £20 billion per year. The largest single cost driver is inputs provided by informal carers, which is estimated to cost £12.8 billion.
- The total annual cost to the NHS is £3.4 billion. Of this, the majority relates to NHS care received in the acute phase, whilst the patient is in secondary care, and NHS costs level off in subsequent years after stroke. Much of the burden in subsequent years after stroke falls on formal social care (i.e. care homes) (£4.6 billion) and the informal care sector (£12.7 billion).
- Although the majority of stroke sufferers are largely of older age, lost productivity amounts to £1.6 billion per year.
- Our estimate of the aggregate annual cost of stroke is substantially larger than previous estimates produced by Saka et al. (2009). For example, our estimate for direct medical care is £8.6 billion, compared to Saka et al.'s £4.4 billion. This may be explained by several methodological differences, for example: i) our costs refer to 2014/15 prices and thus account for cost inflation; ii) our estimate includes additional services that reflect current stroke care, such as early supported discharge; and iii) Saka et al.(2009) relied primarily on SLSR data, whilst the current study links SLSR to SSNAP data to provide a broader picture of use/length of stay for hospital, community and social care services.

- The most notable difference between our estimates and Saka et al.'s (2009) is for informal care costs: Saka et al. (2009) calculated these at £2.4 billion per year, while we estimate these at £15.8 billion. This difference may be driven by several factors: i) we use patient-level self-reported data from two large, nationally generalisable trials of post-stroke care as the basis of our calculations, whilst Saka et al. (2009) used the South London Stroke Register (SLSR); ii) we used a combined approach of assuming some of types of informal care inputs involve a loss of opportunities to carers (e.g. to work), whilst others are roles that could be done by professionals; so we assume that informal carer inputs to personal care activities are equivalent to professional care and apply hourly wages of a professional carer to these inputs (i.e. a replacement cost approach) – this generates higher total informal care costs than if we assume that all informal care inputs involve only an opportunity cost to carers (i.e. potential lost earnings); and finally both trials collected data on informal care inputs from all resident and non-resident caregivers, rather than just a primary caregiver.

2.1 Methods

2.1.1 Annual cost of stroke to NHS & personal social services

Our estimate of the current annual cost of stroke to the National Health Service (NHS) and personal social services (PSS) builds upon modelling based work conducted by the National Guideline Centre (NGC) and the Sentinel Stroke National Audit Programme (SSNAP) at the Royal College of Physicians (RCP). They simulated the cost of care of new-onset ischaemic and haemorrhagic stroke based on data from SSNAP (for England, Wales and Northern Ireland) and the South London Stroke Register (SLSR). That model consisted of an individual-level simulation of patients through a post-stroke NHS and social care pathway (e.g. hospital admissions, acute and regular stroke units, early supported discharge, community rehabilitation). The patients progress through the model until stroke recurrence (at which point they return to the start of the pathway), death or when they reach a pre-determined model horizon. The type of stroke services

included in the model are summarised in Table 2.1. The cost was estimated for patient groups according to age, sex, type and severity of stroke. For further detail on the technical aspects of the model, the reader should refer to the original NGC report (NGC & SSNAP, 2016).

The RCP model design is known as a discrete event simulation (DES), which predicts the progression of individuals through a disease pathway using discrete time intervals (e.g. length of stay, time to event), rather than transition probabilities. This offers a number of advantages over a standard Markov model built around health states. The explicit handling of time allows simulation of length of stay in hospital units, as well as the timing of significant events, such as stroke recurrence and death, based on time-to-estimates from empirical data. In a DES, prior events may influence future outcomes, in contrast to a Markov model in which transitions are independent of past health states. This allows a more realistic portrayal of a stroke pathway, when a change in physical functioning post-stroke influences survival and likelihood of a second stroke. The individual-level design allows for a heterogeneous model population in which characteristics such as age, sex and initial stroke severity determine the parameters which dictate progression through the pathway.

The structure of their model is illustrated in Figures 2.1 and 2.2 below. It is a discrete event simulation model, meaning that it samples the initial patient characteristics from empirical distributions from SSNAP data, which were representative of the population of patients with new onset stroke in the UK. The resulting heterogeneity in the sampled model population thus allowed mean cost of NHS and social care in first and subsequent years post-stroke to be estimated across a number of subgroups according to patient characteristics: age (40-64, 65-74, 75-84, ≥85 years), sex, type of stroke (ischaemic or haemorrhagic) and severity of stroke. For the purposes of stratifying by severity, they categorised National Institutes of Health Stroke Scale (NIHSS) scores as follows: 1=no stroke (NIHSS score of 0); 2=minor stroke (scores 1-4); 3=moderate stroke (scores 5-15); 4=moderate/severe stroke (scores 16-20); and 5= severe stroke (scores 21-42). We continued with this categorisation for our purposes.

We use the NGC model's estimates of the cost of NHS and social care in the first year post-stroke to estimate the per-patient and aggregate cost of incident (new-onset) stroke. We estimate the cost of long-term care of patients who have previously had stroke (prevalent stroke) from cost estimates in years 2-4 post-stroke obtained from the NGC model, adjusting for mortality.

The modelling work carried out by NGC aimed to estimate the per-patient cost of NHS and personal social services incurred within the first 12 months and 5 years after a stroke episode. The aim of the current project is to derive an estimate for the mean cost of incident stroke (value of services used in the first 12 months after stroke) and prevalent stroke (value of services used within a 12 month period by stroke survivors). To generate these new estimates, we needed to modify the design of the GCGC model as follows:

(i) The cross-sectional data collection points were changed from 1 and 5 years post-stroke to 1, 2, 3 and 4 years post-stroke.
(ii) The cost of services used in the first 12 months was used as a proxy for the mean cost of incident stroke.
(iii) The average of the cost of services used in years 2, 3 and 4 was used as a proxy for the mean cost of prevalent stroke.
(iv) Cost incurred in years 2, 3 and 4 post-stroke were adjusted for the proportion of patients alive at the start of the corresponding year to avoid underestimating the true cost of follow-up care of stroke survivors.
(v) Unit costs were updated to 2014/15 prices (the most recent version of published costs available at the time of analysis).

The NGC model is a discrete event simulation which simulates the journey of individual patients through a post-stroke pathway which includes acute hospital care, community care and social care in care homes. Values for parameters which determine the pathway, including length of stay in each service, probability of stroke recurrence and death, are sampled from probability distributions in each individual run of the model. Costs incurred by individuals are then aggregated for all patients within a run, and a large number of runs are carried out to minimise

individual-level uncertainty due to outliers, produce stable estimates of mean cost and adequately characterise uncertainty around the mean values. As this is a stochastic process which produces a new value each time, no two model runs (or sets of runs) produce exactly the same estimates.

Estimates of mean costs generated by the NGC work and the current study vary, despite using an identical estimation method. This difference is explained by the use of updated unit costs in the current analysis and residual individual-level uncertainty (Monte Carlo error) introduced by the modelling process. The costs of individual episodes of care incurred within the model are dependent on length of stay in each unit. Unit costs used in the model are summarised in Table 2.2.

Table 2.1: Summary of NHS & personal social services included in the model

Service	Description	Transition from
General medical ward (GMW)	Some patients are admitted to a general medical ward before being transferred to a stroke unit	Initial stroke admission
Acute stroke unit (ASU)	Acute stroke care	Initial stroke admission & GMW
Stroke unit (SU)	In-patient stroke rehabilitation	ASU
Early supported discharge (ESD)	Treatment by an ESD team at home	ASU & SU
Community rehabilitation	Treatment by a community rehabilitation team, it could happen either at their own home or care home	ASU, SU & ESD
Care home	Patients are discharged and staying at care home	ASU, SU, ESD & community rehabilitation

Figure 2.1: Initial part of the NGC model pathway

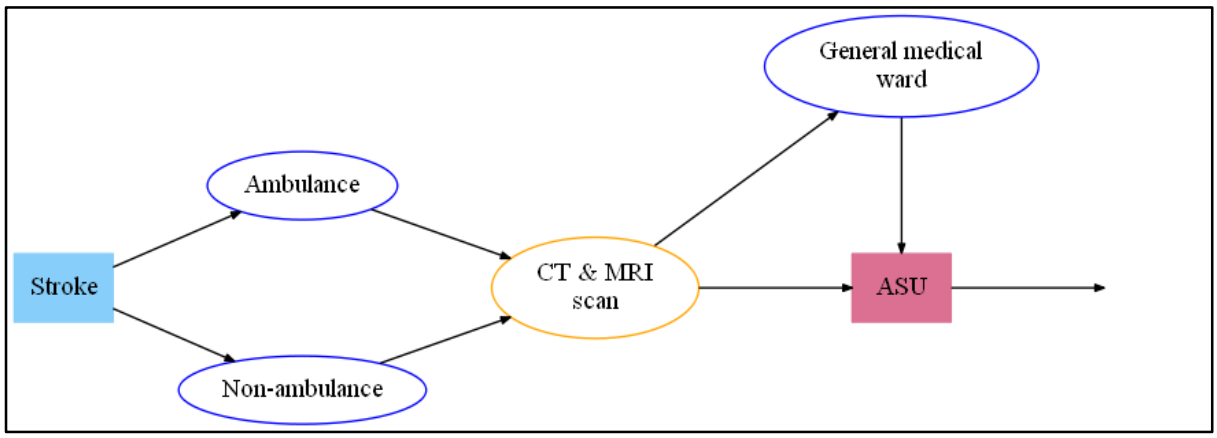


Figure. 2.2: Structure of the ASU pathway of the NGC model

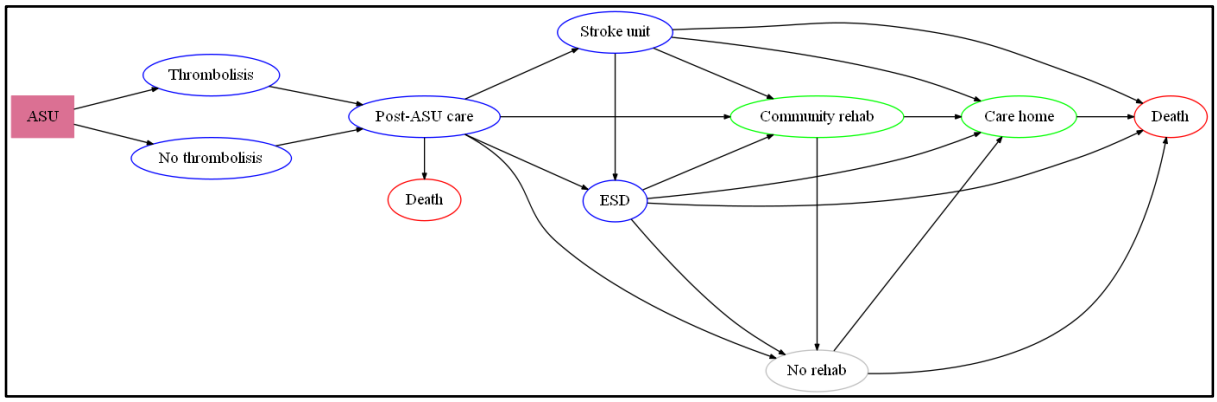


Table 2.2: Unit costs used in the model

Item	Source	Code/reference	Mean (£)
Ambulance[‡]	PSSRU 2015 Section 7.1	N/A	231
MRI scan[‡]	NHS Reference costs 2014/15	HRG RD01A	137
CT scan[‡]	NHS Reference costs 2014/15	HRG RD20A	93
Thrombolysis[†]	NHS Reference costs 2014/15	HRG YR23B (day case)	1284

Acute stroke unit[†]	NHS Reference costs 2014/15	HRG AA35A-AA35F (weighted average of non-elective short stay)	685
Stroke unit[†]	NHS Reference costs 2014/15	HRG AA35A-AA35F (weighted average of non-elective long stay excess day cost)	283
General medical ward[†]	National Audit Office (inflated using HCHS index)	N/A	212
Occupational therapy[‡]	NHS Reference costs 2014/15	HRG A06A1	73
Physiotherapy[‡]	NHS Reference costs 2014/15	HRG A08A1	52
Speech and language therapy[‡]	NHS Reference costs 2014/15	HRG A13A1	87
Psychologist[‡]	PSSRU 2015 Section 9	Based on band 8a hourly cost	62
Course of community rehabilitation	PSSRU 2014 Section 1.8	Item not listed in PSSRU 2015, cost inflated from 2014 using HCHS	2833

Social care†	PSSRU 2015 Section 1.3	N/A	159

† Cost per day

‡ Cost per visit/single use

2.1.2 Informal care and lost productivity costs

Informal care

We estimate the mean cost of care carried out by both unpaid and paid informal carers and lost productivity due to stroke-related morbidity and mortality using (control arm) data from the TRACS (Forster et al., 2013a) and LoTS Care (Forster et al., 2015) trials. Both were large-scale UK-wide pragmatic cluster randomised trials. TRACS investigated a training programme for caregivers of patients admitted for stroke and LoTS Care investigated a new system of post-acute care delivered in the community.

Both trials collected self-reported data caregiver inputs to personal care and other supports (e.g. transport, housekeeping) in the past 6 months from both resident and non-resident caregivers. In both trials, these were assessed at 6 and 12 months post-recruitment and did not ask for inputs specifically attributable to stroke due to the difficulties in doing so.

For the purposes of estimating the cost of informal care hours, we assume only that personal care inputs required a healthcare professional and thus use a replacement cost approach. For all other types of support (e.g. help with preparing meals or transport) we use the 'human capital approach', i.e. the value of lost productivity from work by the caregiver spending time caring rather than working. Average wages are typically used to value such lost productivity and these tend to be lower than the cost of professional carers. Therefore, taking this human capital approach for costing non-personal care estimates avoids over-estimating informal care costs. We use the total number of informal care hours over 12 months from the TRACS trial to estimate the annual cost of informal care for new stroke cases (i.e. incident stroke). LoTS Care recruited

patients at hospital discharge, thus data collected at 12 months post-recruitment (covering the previous 6 months) relates at least partially to the period beyond one year post-stroke. We therefore use informal care hours for this second 6 month period as a proxy for ongoing informal care (i.e. prevalent stroke).

Unit costs applied to the hours of informal care input were obtained from the TRACS and LoTS Care trials and are summarised in Table 2.3. Both trials assumed the opportunity cost for caregivers who were in employment prior to the patient's stroke event was equivalent to the national average hourly wage; for those who were unlikely to be in employment (e.g. retired, unable to work, students), the opportunity cost of leisure was assumed. The average of the two unit cost values was assumed for caregivers whose employment status was unknown. In case of personal care, the hourly wage of a professional carer was assumed. Further details of the TRACS and LoTS Care trials' participants, methods to measure and value informal care inputs, and results (e.g. hours of care inputs by type of activity) can be found in the trial reports (Forster et al., 2013b; Forster et al., 2014). A full summary of resource use counts can be found in Chapter 5 of the TRACS report and Chapter 3 of the LoTS Care report.

Table 2.3: Unit costs of informal care input

Value of time (per hour)	Source	Description	Unit cost (£)
National average wage (opportunity cost)	ONS, 2010	Hourly pay gross for all employees, 2010	15
Leisure time cost (opportunity cost)	Department of Transport, 2011	Inflated to 2009	5
Professional carer (replacement cost)	Curtis, 2010	Weighted average of weekday, evening and weekend hourly cost	28

A key inclusion criterion for the TRACS trial (Forster et al., 2013a), given the caregiver-targeted intervention under investigation, was the presence of a primary caregiver. Therefore, the trial cohort is not representative of the general stroke population. We therefore have to adjust the cohort by simulating the distribution of patients who do not have a primary caregiver. We use the participant inclusion flow chart reported in the trial report (Forster et al., 2013b) to determine the proportion of patients screened for the trial but excluded due to absence of a primary caregiver: 11.1% (Table 2.4).

Table 2.4: TRACS trial data: adjustment of trial population to incorporate potential participants excluded due to lack of primary caregiver

Category	**N**
Assessed	6305
No diagnosis of new stroke	732
Subtotal	***5573***
No caregiver	619
Total excluded (%)	**619 (11.1%)**

Source: Forster et al., 2013b

These additional 11.1% are added to the dataset. In order to accurately represent the breakdown of mean cost by patient subgroup, the distribution of age, sex and stroke type is imputed using descriptive statistics for the screened population (prior to application of exclusion criteria in the trial, see Table 2.5). In the absence of information on the characteristics of excluded patients, the additional simulated participants are assumed to have the same characteristics (mean and standard deviation of age, proportion of females and proportion of ischaemic stroke) as the screened population.

Table 2.5: TRACS trial data: demographic characteristics of screened and included patients

Category	**Screened**	**Included**	**Included and complete data**

N	6305	478	294
Mean age (SD)	74.7 (13.04)	71.3 (12.18)	71.5 (10.76)
Number male (%)	3036 (48.2)	262 (54.8)	170 (57.8)

Source: Forster et al., 2013b; SD: Standard deviation

The age distribution is assumed to follow a Gaussian distribution (generated by the random number generator in Stata 14). We generate an age distribution for patients included in the study and compare the observed and simulated age breakdown to validate the simulation method. The gamma distribution is applied as an alternative method. The age breakdown generated using the Gaussian distribution closely approximates the observed breakdown, apart from for the group aged 75-84 years. However, the breakdown generated using the gamma distribution performs poorly in comparison (see Table 2.6).

Table 2.6: TRACS trial data: number of patients

Age group	Number of patients				
	Observed	Simulated (Gaussian)	Simulated (gamma)	Extra simulated without caregiver (Gaussian)	Sum of observed and extra simulated without caregiver
All age groups	294	294	294	37	331
40-64	76	85	77	9	85
65-74	94	101	101	13	107

75-84	99	79	77	6	105
≥85	25	29	39	9	34

Source: Forster et al., 2013b

We assume the mean cost of informal care in simulated participants without a caregiver is 25% of that for a participant with a caregiver.

Lost productivity

We also use LoTS Care data to estimate lost productivity. Participants reported their employment status pre-stroke, at 6 months and 12 months post-recruitment. We estimate lost productivity by observing the change in employment status at 6 months (for incident cases) and 12 months (for prevalent cases). Mortality in patients who were employed prior to stroke was taken into account in the calculation of lost productivity.

We use income lost as a result of lost employment and early mortality as a proxy for lost productivity. For this purpose, we derive daily income using Office of National Statistics (ONS) data on the median gross weekly income for men and women in different age groups in the UK in 2016 (Office of National Statistics, 2016) (Table 2.7).

Table 2.7: Median gross weekly earnings by age and sex in the UK

Employee group	Men (£)	Women (£)
Full-time employment		
All employees	577.80	480.50
Aged 40-49 years	668.30	528.60
Aged 50-59 years	648.70	496.10
Aged 60 years and over	557.90	430.40
Part-time employment		
All employees	167.40	181.40

Source: Office of National Statistics, 2016

We classify patients into three categories: full-time work (≥30 hours per week), part-time work (<30 hours per week) and out of work (retired, unemployed, not looking for work or unable to work for health reasons). For the purposes of costing, we assume an average working week is 37.6 hours for full-time workers and 16.2 for part-time workers, based on actual weekly hours of work in October-December 2016 in the UK reported by ONS (Office of National Statistics, 2017). We use mortality and changes in employment status at 6 and 12 months to estimate lost income in incident and prevalent stroke cases, respectively. The date of change of employment status or death was unknown, so we assume it occurs halfway through the period e.g. a change at 6 months follow-up was assumed to occur at 3 months. We calculate the number of lost hours compared to the previous period and apply the weekly average pay to estimate lost productivity. Lost income includes actual time at work, annual leave and statutory holidays.

We use TRACS and LoTS Care data to calculate the breakdown of informal care and lost productivity by patient sub-groups: age (40-64, 65-74, 75-84, ≥85), sex and type of stroke (ischaemic or haemorrhagic). As TRACS and LoTS Care data did not include NIHSS scores, it was not possible examine total societal cost by NIHSS-rated stroke severity (as is done for health and social care costs). However, both trials administered the Barthel Index of Activities of Daily Living (by self or proxy-report) immediately after the stroke event and we instead use these data as an alternative way of categorising informal care and lost productivity costs by stroke severity. There is no single accepted method of categorising the Barthel Index, although scores below 50% of the maximum (depending on the scale) are considered to be severe disability (Shah et al., 1989). We use the following categorisation of scores for indicative purposes to examine differences in cost estimates across groups with different functional status: independent (Barthel Index score of 20), mild disability (score of 15-19), moderate disability (score of 10-14) and severe disability (score of <10). For each sub-group, we report mean cost per patient and 95% confidence intervals to represent the dispersion around these point estimates.

2.1.3 Aggregate costs

To estimate the aggregate cost of stroke in the UK, we combine our estimates of mean NHS, social care, informal care and lost productivity costs (as described above) with up-to-date estimates from the literature on absolute incidence (new cases of stroke) and prevalence (survivors after stroke) for the UK population. Details of the focused literature search on incidence and prevalence, and a description of our methods to derive the number of new stroke cases and stroke survivors in the UK from reported incidence and prevalence figures can be found in Appendix 2.1. For ease of understanding, we present further details of the methods for estimating aggregate costs in the results section (Section 2.2.4), after presenting the estimates for average costs.

The aggregate cost estimate is split according to type of cost (NHS, social care, informal care, lost productivity) to gauge relative contributions towards the overall cost burden of stroke in the UK.

2.1.4 Examining uncertainty in the cost estimates

Given the risk of estimation error, we undertake a series of analyses to explore uncertainties that may surround our cost estimates.

Probabilistic sensitivity analysis

A probabilistic sensitivity analysis aims to examine the overall uncertainty in a model by randomly sampling mean input values for all model parameters simultaneously. This process is repeated many times in order to estimate an interval within which the true value of the model output (i.e. mean cost) may lie, which is known as a confidence interval.

We undertake a probabilistic sensitivity analysis by repeatedly re-sampling our model output. We do this for two reasons:

(i) Estimates of mean cost per patient within categories can be influenced by sampling variation in cost across individuals in the simulation model, particularly in groups which contain small numbers of patients. This is known as Monte Carlo error and is a common limitation of discrete event simulation; it can result in spurious values for mean and standard error which are influenced by a large cost in one or more individuals within a small sub-group, which can mischaracterise the true uncertainty in the mean value. We minimise the effect of individual sampling variation using two approaches: a) increasing the number of hypothetical patients for subgroup estimation to increase the number of patients in each subgroup and thus limit the risk that mean cost in any one category is influenced by an outlier and b) by taking the mean cost as an average of an appropriately large number of runs to approximate the true population mean. The appropriate number of runs is reached when the standard error of mean cost in the three categories with the lowest number of patients reaches a stable value.

(ii) We conduct the probabilistic sensitivity analysis to gauge the overall impact of parametric uncertainty in the discrete event simulation model on estimates of mean and aggregate NHS and social care cost. The model results are replicated by repeatedly sampling parameter values from pre-determined probability distributions which reflect uncertainty in the resource use, unit costs and transitions within the model.

We derive the necessary number of replications to minimise first-order uncertainty and produce stable estimates of the point estimate, standard error and 95% confidence interval in each cost category by testing how these statistics behave under different combinations of sample size and number of replications in the simulation model. We determine the optimal setting for the probabilistic sensitivity analysis to be 500 runs of the model with 4000 individuals per run.

One-way sensitivity analyses

One-way sensitivity analyses are used to gauge the impact on our cost estimates if we change our parameter values or assumptions one at a time. We examine the effect of changing length of stay in a stroke unit/acute stroke unit following stroke, probability of thrombolysis in ischaemic

stroke, probability of post-stroke unit community rehabilitation and care home admission, probability of death in stroke units and stroke recurrence. Defensible ranges for model parameters are obtained from 95% confidence intervals based on probability distributions fitted to SSNAP data used in the RCP model. Where possible, distributional assumptions used in the original model are used, such as lognormal and exponential distributions used to simulate length of stay. Beta distributions are fitted using patient numbers from SSNAP to derive confidence intervals for transition probabilities. The sensitivity of model output to changes in the probability of stroke recurrence was based on ranges reported in a large retrospective cohort study of new stroke cases which used data from SLSR. The one-year cumulative recurrence risk of recurrence was 7.1% (95% CI 6.0-8.3) and the five-year risk was 16.2% (CI 14.4-18.1), which were used as the basis for the credible interval for the probability of recurrence in incident and prevalent stroke cases, respectively. The credible interval for incident stroke cases was thus assumed to be in the range -20% to +20% of the expected value, whilst the interval for prevalent stroke cases was between -10% and +10% of the expected value. A summary of parameters and corresponding distribution parameters used in the one-way analyses is included in Table 2.8.

Table 2.8 Summary of parameters and ranges used in one-way sensitivity analyses

Variable	Details	Distribution/range
Length of stay		
Acute stroke unit (ASU)	Thrombolised and non-thrombolised	95% CI based on standard error estimated using GLM regression based on SSNAP data
Stroke unit (SU)	Separate distributions for patients progressing to ESD, discharge and death	Lognormal
Early supported discharge (ESD)	Separate distributions for patients who survived and died	Died: lognormal; alive: exponential
Community rehabilitation (CRT)		Exponential

Transition probabilities		
ASU to SU	Conditional on surviving ASU	Beta
ASU to ESD	Conditional on surviving ASU	Beta
SU to ESD	Conditional on surviving SU	Beta
ASU, SU and ESD to CRT	Conditional on surviving ASU, SU or ESD	Beta
ESD, CRT and no rehabilitation to care home	Conditional on surviving ESD	Beta
Death in ASU, SU and ESD	Independent of background all-cause mortality	Beta
Thrombolysis in ASU		Beta
Stroke recurrence	Original SLSR data not available to derive sampling distribution; tested increase or decrease up to 30%, in 10% increments	-30%, -20%, -10%, +10%, +20%, +30% compared to baseline for both ischaemic and haemorrhage stroke

The sensitivity of model estimates to changes in cost inputs is gauged by varying unit costs of care for stroke obtained from published sources: per-day cost in acute stroke unit, stroke unit, per-episode costs for community rehabilitation. Defensible ranges for mean costs from published sources are based on the measure of spread around the point estimate, where one was reported. The lower and upper values for unit costs used in the one-way analyses are summarised in Table 2.9.

Table 2.9: Ranges for unit costs used in one-way sensitivity analyses

Item	Source	Code/reference	Mean	Low	High
Thrombolysis	NHS Reference costs 2014/15	HRG YR23B (day case)	1284	378	1411

Acute stroke unit (per day)	NHS Reference costs 2014/15	HRG AA35A-AA35F (weighted average of non-elective short stay)	685	396	729
Stroke unit (per day)	NHS Reference costs 2014/15	HRG AA35A-AA35F (weighted average of non-elective long stay excess day cost)	283	211	342
Community rehabilitation	PSSRU 2014 Section 1.8	Item not listed in PSSRU 2015, cost inflated from 2014 using HCHS	2833	1930	5750

We derive costs of inpatient hospital admission for thrombolysis and unit cost per day in an acute stroke unit or stroke unit come from NHS reference costs (Department of Health, 2015). Its reported lower and upper quartile estimates are used as low and high estimates for our one-way analyses. The range for the unit cost of an episode of community rehabilitation is derived from lower and upper estimates reported in PSSRU unit costs of health & social care and inflated to 2015 cost year using the Hospital and Community Health Index (Curtis & Burns, 2015).

The model results are re-run after changing individual parameter values. To minimise first-order uncertainty inherent in the discrete-event model design, we re-run the model 5 times, each time with 4000 hypothetical patients. Although adequate methods are applied to stabilise the mean, first-order uncertainty cannot be fully discounted. Additional caution has to be taken when interpreting the results of one-way analyses when changes in a parameter value over its pre-assigned range have a small effect on mean cost as such changes may be explained by first-order uncertainty built into the model design. In addition, some of the ranges produced by the one-way analyses may not contain the original mean value from the base case analysis, which may occur

if the first-order uncertainty in the model outweighs the effect of the parameter value on mean cost.

The results of the one-way sensitivity analyses are presented using tornado diagrams, which represent the change in the estimated mean cost associated with a change in the value of the parameter in question, relative to the base case estimate.

Characterising uncertainty in aggregate cost estimates

The estimate of aggregate cost of stroke is directly proportional to the assumed incidence and prevalence of stroke in the UK that we derive from literature. We examine the effect of uncertainty in the estimated number of new strokes and stroke survivors by calculating aggregate costs corresponding to the lower and upper estimates of incidence and prevalence reported in studies identified in the focused review (Appendix 2.1). The range of resulting values are broken down by cost category (NHS, social care, informal care, lost productivity) to (i) demonstrate the impact of uncertainty in underlying incidence estimates on the cost items which contributed to aggregate cost and (ii) demonstrate the resulting uncertainty from different cost perspectives.

The impact of uncertainty in the discrete event simulation model on aggregate cost is examined by applying 95% confidence intervals for mean cost in each cost category derived from the model.

2.2 Results

2.2.1 Annual cost of stroke to NHS & personal social services: average per patient

As described in Section 2.1.1, we use the NGC & SSNAP discrete event simulation model to estimate mean cost per patient in first and subsequent years post-stroke. We provide mean costs

by patient category in Table 2.10 and mean cost of incident and prevalent stroke by age group in Figures 2.3 and 2.4.

Base case estimates of mean cost of incident and prevalent stroke

The mean annual cost one year after new onset stroke from an NHS & PSS perspective is £18081 (95% confidence interval (CI) 17621-18542). This is split into the cost of NHS care (£13269, 95% CI 13058-13480) and social care (£4812, 95% CI 4434-5190) in the first year after hospital admission for a first stroke event. Mean cost of new-onset cost by stroke type is £17063 and £19099 for ischaemic and haemorrhagic stroke respectively. There is no noticeable difference between men and women (£17338 and £18824, respectively). Mean cost in different age groups ranges from £12770 amongst those aged 40-64 years to £22961 amongst those aged 85 years and over. Mean cost of care in the first year after severe stroke is almost double of that for minor stroke (£24003 compared to £12869).

Mean annual cost of NHS & PSS care for stroke survivors is £7759 (95% CI 7200-8318). The main cost driver in subsequent years after stroke is social care (£5544 per patient), with NHS care contributing £2215. Mean cost of care for survivors of haemorrhagic stroke is higher compared to ischaemic stroke (£8230 vs. £7225). Similarly to incident stroke, female patients have a higher, but overall similar, mean cost than male patients (£8287 vs. £7221). Mean cost increases monotonically with age (from £5169 in those aged 40-64 years to £10753 in the 75-84 year age group), apart from the group aged 85 years and over, who have a mean cost of £9873. Mean cost of care for stroke survivors ranges from £6052 after minor stroke to £12058 after severe stroke.

Table 2.10: Annual cost (£, 2015 prices) of stroke to NHS & personal social services, by patient category

	NHS cost	Percentile		Social care cost	Percentile		NHS & SC cost	Percentile	
Category	**Mean**	**2.5**	**97.5**	**Mean**	**2.5**	**97.5**	**Mean**	**2.5**	**97.5**
First year cost (incident stroke)									
All patients	13268.72	13057.92	13479.53	4812.30	4434.14	5190.46	18081.02	17620.52	18541.52
Type of stroke									
Ischaemic	12522.68	12227.29	12818.07	4540.64	4039.78	5041.50	17063.32	16432.22	17694.42

Haemorrhage	14014.76	13728.97	14300.55	5083.95	4537.60	5630.30	19098.72	18454.57	19742.87
Sex									
Male	12906.05	12605.93	13206.17	4431.50	3916.61	4946.39	17337.55	16725.27	17949.83
Female	13631.40	13346.38	13916.42	5193.09	4656.89	5729.29	18824.49	18198.03	19450.95
Age group									
40-64	10281.04	9910.35	10651.73	2489.05	1972.90	3005.20	12770.09	12089.13	13451.05
65-74	12159.27	11761.29	12557.25	3417.72	2749.79	4085.65	15576.99	14741.85	16412.13
75-84	14024.32	13670.79	14377.85	5986.19	5288.37	6684.01	20010.51	19200.64	20820.38
≥85	16190.57	15751.35	16629.79	6769.97	5830.74	7709.20	22960.54	21892.07	24029.01
NIHSS score									
1-2 (Mild stroke)	9261.40	9028.24	9494.56	3607.47	3129.37	4085.57	12868.88	12336.31	13401.45
3 (Moderate)	15669.14	15355.91	15982.37	5673.88	4997.78	6349.98	21343.02	20572.31	22113.73
4-5 (Severe)	18012.19	17580.44	18443.94	5990.96	4967.57	7014.35	24003.15	22877.86	25128.44
Subsequent year cost (prevalent stroke)									
All patients	2214.80	2117.19	2312.41	5544.13	5013.26	6075.00	7758.92	7199.99	8317.85
Type of stroke									
Ischaemic	2166.97	1460.21	2873.73	5057.65	4158.50	5956.80	7224.63	5749.65	8699.61
Haemorrhage	2229.21	1450.60	3007.82	6000.99	4935.77	7066.21	8230.21	6528.93	9931.49
Sex									
Male	2204.60	1499.98	2969.34	5015.96	4101.95	5929.97	7220.56	5740.62	8700.50
Female	2190.49	1411.65	2969.34	6096.28	5008.95	7183.61	8286.78	6566.23	10007.33
Age group									
40-64	2277.20	1694.08	2860.32	2891.43	2176.13	3606.73	5168.63	4056.98	6280.28
65-74	2015.49	1394.80	2636.18	3745.86	2789.73	4701.99	5761.34	4393.95	7128.73
75-84	2516.79	1628.07	3405.51	8236.21	6660.76	9811.66	10753.00	8495.22	13010.78
≥85	1897.58	948.18	2846.98	7975.72	6176.99	9774.45	9873.30	7403.94	12342.66
NIHSS score									
1-2 (Mild stroke)	2201.75	2075.10	2328.41	3850.31	3279.97	4420.65	6052.07	5443.67	6660.47
3 (Moderate)	2227.65	2054.21	2401.09	6319.73	5355.84	7283.62	8547.37	7540.30	9554.44
4-5 (Severe)	2173.03	1884.01	2462.05	9884.96	7738.86	12031.06	12057.99	9806.05	14309.93

Figure 2.3: Breakdown of mean cost of incident stroke by age group

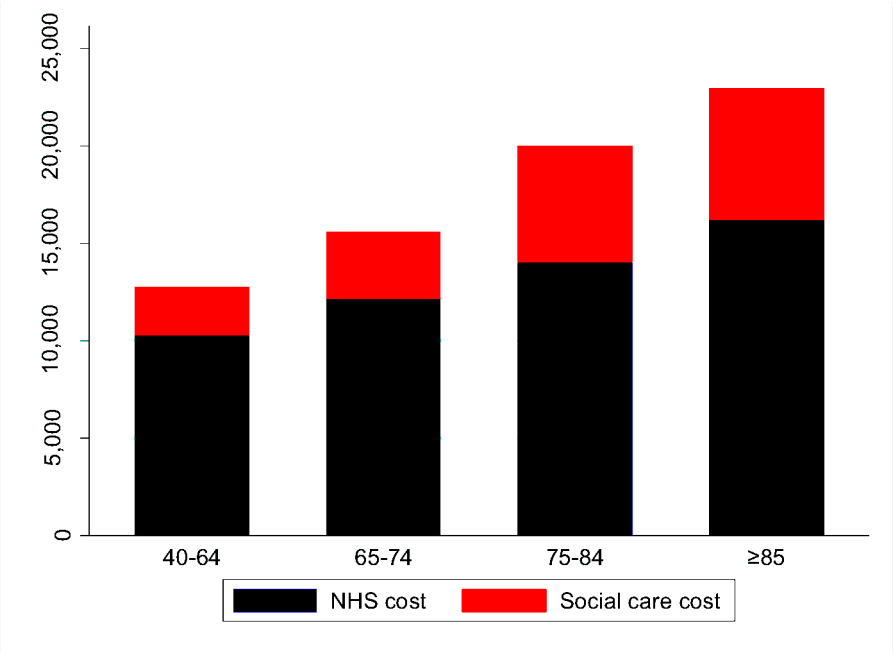
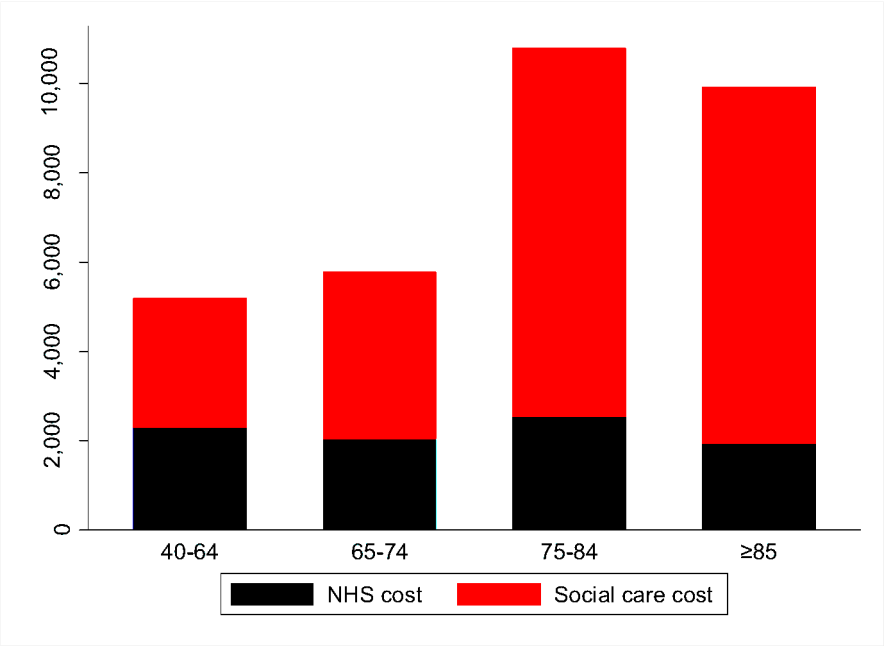


Figure 2.4: Breakdown of mean cost of prevalent stroke by age group



2.2.2 Annual informal care and lost productivity costs in the UK: average per patient

Cost of informal care, incident stroke

The estimated mean cost of informal care in the first year post-stroke is £25897 (95% CI 23621-28173; Table 2.11). There are significant differences in mean cost of informal care across age subgroups: from £18234 in those aged 85 years and above to £28019 in those aged 40-64 years. Mean cost is similar for males (£27270) and females (£24091), as well as among patients with different types of stroke: ischaemic (£25612), haemorrhagic (£27357). Informal care costs in first year post-stroke are far higher in patients with moderate (£33545) and severe (£34493) disability post-stroke compared to those with mild (£21792) and no disability (£16440).

Table 2.11: TRACS trial data: adjusted cost of informal care for incident stroke

Patient group	N	Personal care	Other activities	Total cost
		Mean (95% CI) (£)	Mean (95% CI) (£)	Mean (95% CI) (£)
All patients	331[†]	9857.59 (8674.18-11041.00)	16039.06 (14676.94-17401.18)	25896.64 (23620.73-28172.55)
Age (years)				
40-64	85	10769.70 (8791.47-12747.93)	17249.60 (14243.35-20255.85)	28019.30 (23617.20-32421.40)
65-74	107	9120.26 (7314.87-10925.66)	15902.69 (13737.81-18067.57)	25022.95 (21419.22-28626.68)
75-84	105	10429.38 (7993.61-12865.15)	17120.41 (14612.20-19628.62)	27549.79 (23110.31-31989.27)
≥85	34	8131.86 (3678.02-12585.71)	10102.39 (7011.86-13192.92)	18234.26 (11274.06-25194.46)
Sex				
Male	188	10413.58 (8802.34-12024.82)	16856.63 (14918.84-18794.42)	27270.21 (24107.51-30432.91)
Female	143	9126.62 (7390.75-10862.49)	14964.21 (13113.75-16814.67)	24090.83 (20867.43-27314.23)
Type of stroke				
Ischaemic	277	9667.26 (8325.86-11008.66)	15944.70 (14431.29-17458.11)	25611.96 (23070.82-28153.10)

Haemorrhagic	54	10833.86 (8531.45-13136.27)	16523.08 (13423.58-19622.58)	27356.95 (22355.85-32358.05)
Post-stroke Barthel index				
Independent	30	4224.37 (1671.45-6777.29)	12215.70 (9016.98-15414.42)	16440.06 (11300.45-21579.67)
Mild disability	84	7265.39 (5031.15-9499.63)	14526.63 (12397.25-16656.01)	21792.02 (18015.14-25568.90)
Moderate disability	66	13418.66 (10659.98-16177.34)	20125.85 (17401.22-23210.48)	33544.51 (28764.29-38324.73)
Severe disability	66	13453.40 (11067.22-15839.58)	21039.36 (17822.73-24255.99)	34492.75 (29418.98-39566.52)

† 246 in the Barthel category due to 85 patients with missing Barthel score. Source: Forster et al., 2013b

Cost of informal care, prevalent stroke

Estimated mean cost of informal care in subsequent years is £15354 per year (95% CI 12501-18656) (based on LoTS care trial data; Forster et al., 2015). The mean cost varies across age subgroups: from £11511 for those aged 75-84 years to £20921 for those aged 65-74 years (Table 2.12). Mean cost is £16421 for males and £13882 for females and £15393/£17116 for ischaemic and haemorrhagic stroke respectively. The cost of informal care for stroke survivors differs according to post-stroke disability, ranging from £15204 for those with no problems with activities of daily living immediately post-stroke to £20207 and £18393 for those with moderate and severe disability, respectively.

Table 2.12: Cost of informal care for stroke survivors based on LoTS Care trial (12 month follow-up)

Patient group	N	Personal care	Other activities	Total cost
		Mean (95% CI) (£)	Mean (95% CI) (£)	Mean (95% CI) (£)
All patients	264[†]	6139.62 (1090.13-8189.11)	9213.90 (7741.63-10686.17)	15353.53 (12051.48-18655.58)
Age (years)				
40-64	74	5880.37 (3470.20-8290.54)	9073.00 (7078.52-11067.48)	14953.37 (11139.88-18766.86)
65-74	72	10054.59 (3462.11-16647.07)	10866.82 (6675.99-15057.65)	20921.41 (10479.12-31363.70)
75-84	88	3067.18 (1542.36-4592.00)	8443.71 (6447.69-10439.73)	11510.89 (8453.64-14568.14)
≥85	30	6395.68 (2554.79-10236.57)	7853.69 (4907.63-10799.75)	14249.37 (7837.80-20660.94)
Sex				
Male	153	6928.12 (3654.49-10201.75)	9493.05 (7274.08-11712.02)	16421.17 (11183.91-21658.43)
Female	111	5052.77 (3208.08-6897.46)	8829.13 (7114.86-10543.40)	13881.90 (10778.77-16985.03)
Type of stroke				
Ischaemic	228	6365.18 (4038.64-8691.72)	9027.68 (7405.96-10649.40)	15392.86 (11672.53-19113.19)
Haemorrhagic	26	5610.54 (1902.73-9318.35)	11505.33 (7741.91-15268.75)	17115.86 (10548.82-23682.90)
Post-stroke Barthel index				
Independent	68	7153.67 (234.13-14073.21)	8050.31 (3784.25-12316.37)	15203.98 (4338.98-26068.99)
Mild disability	108	3424.91 (1918.40-4931.43)	8554.91 (6837.81-10272.01)	11979.82 (9180.39-14779.25)
Moderate disability	59	8767.30 (5755.27-11779.33)	11440.05 (8836.90-14043.20)	20207.34 (15245.38-25169.30)
Severe disability	29	8525.85 (4895.11-12156.59)	9867.44 (6609.65-13125.23)	18393.29 (11988.01-24798.57)

[†] 254 in the stroke type category due to 10 patients with unknown type. Source: Forster et al., 2015.

Lost productivity

A breakdown of the cost of lost productivity resulting from stroke estimated using data from the LoTS Care trial (Forster et al., 2015) is included in Tables 2.13 and 2.14. Estimated lost earnings resulting from stroke-related morbidity in the first 12 months after stroke are £1431 (95% CI 813-2049). As expected, the largest contribution towards lost productivity is by individuals aged 40-

64 years, who are most likely to be of working age (£5172 per stroke case). Lost productivity is greater in males than females (£1792 and £999, respectively) and for ischaemic (£1555) compared with for haemorrhagic stroke (£242).

Mean lost productivity in subsequent years post-stroke is £1666 (95% CI 983-2349). The group aged 40-64 years has the largest mean lost productivity (£5895). Annual lost earnings are £2260 for males and £975 for females, and higher for survivors of ischaemic (£1701) compared to haemorrhagic stroke (£1199).

Table 2.13: Lost productivity in first 12 months post-stroke based on LoTS Care trial

Category		Lost annual income per patient due to change in employment (£, 95% CI)	Lost annual income per patient due to premature death (£, 95% CI)	Total lost annual income per patient in first year post-stroke (£, 95% CI)
All patients	391[†]	1387.80 (774.49,2000.81)	43.14 (0,127.69)	1430.94 (813.07,2048.81)
Age (years)				
40-64	95	4994.19 (2783.21,7205.17)	177.54 (0,525.52)	5171.73 (2949.80,7393.66)
65-74	99	776.64 (-67.94,1621.22)	0	776.64 (-67.94,1621.22)
75-84	138	-63.08 (-186.72,60.56)	0	-63.08 (-186.72,60.56)
≥85	59	0	0	0
Sex				
Male	213	1712.63 (737.26,2688.00)	79.18 (0,234.37)	1791.82 (806.67,2776.98)
Female	178	999.10 (328.82,1669.38)	0	999.10 (328.82,1669.38)
Stroke type				
Ischaemic	335	1505.04 (812.22,2197.86)	50.35 (0,149.04)	1555.38 (856.82,2253.94)
Haemorrhagic	39	241.87 (-232.20,715.94)	0	241.87 (-232.20,715.94)
Post-stroke Barthel index				
Independent	95	2477.55 (869.51-4085.59)	0	2477.55 (869.51-4085.59)
Mild disability	152	665.77 (0-1414.16)	110.96 (0-328.44)	776.73 (0-1553.65)
Moderate disability	92	1959.44 (499.75-3419.13)	0	1959.44 (499.75-3419.13)
Severe disability	52	496.10 (0-1468.46)	0	496.10 (0-1468.46)

[†]n=374 for stroke type due to patients with unknown stroke type. Source: Forster et al., 2015.

Table 2.14: Lost productivity in stroke survivors based on LoTS Care trial

Category		Lost annual income per patient due to change in employment (£, 95% CI)	Lost annual income per patient due to premature death (£, 95% CI)	Total lost annual income per patient in subsequent years post-stroke (£, 95% CI)
All patients	370[†]	1665.90 (982.82,2348.98)	0	1665.90 (982.82,2348.98)
Age (years)				
40-69	93	5894.62 (3531.17,8258.07)	0	5894.62 (3531.17,8258.07)
70-79	94	817.95 (-71.01,1706.91)	0	817.95 (-71.01,1706.91)
80-89	129	-67.48 (-199.74,64.78)	0	-67.48 (-199.74,64.78)
≥90	54	0	0	0
Sex				
Male	199	2259.62 (1124.37,3394.87)	0	2259.62 (1124.37,3394.87)
Female	171	974.95 (323.43,1626.47)	0	974.95 (323.43,1626.47)
Stroke type				
Ischaemic	320	1700.64 (959.02,2442.27)	0	1700.64 (959.02,2442.27)
Haemorrhagic	36	1199.03 (-693.78,3091.84)	0	1199.03 (-693.78,3091.84)
Post-stroke Barthel index				
Independent	91	2586.46 (910.91-4262.01)	0	2586.46 (910.91-4262.01)
Mild disability	146	1155.22 (156.70-2153.74)	0	1155.22 (156.70-2153.74)
Moderate disability	84	2013.64 (498.13-3529.15)	0	2013.64 (498.13-3529.15)
Severe disability	49	881.77 (0-2009.73)	0	881.77 (0-2009.73)

[†]n=356 for stroke type due to patients with unknown stroke type. Source: Forster et al., 2015.

2.2.3 Annual societal costs of stroke in the UK: average per patient

Annual cost of incident and prevalent stroke from a societal perspective (combining cost of NHS, social care, informal care and lost productivity) according to patient subgroup is summarised in Table 2.15.

Table 2.15: Mean annual cost of stroke from a societal perspective (£, 2015 prices), by patient category

	NHS & SC cost		Informal care & lost productivity		Total	
Category	mean	Range	mean	Range	mean	range[†]

First year cost (incident stroke)						
All patients	18081	17621-18542	27328	24434-30221	45409	42054-48763
Age years)						
40-64	12770	12089-13451	33191	26567-39815	45961	38656-53266
65-74	15577	14742-16412	25800	21351-30248	41377	36093-46660
75-84	20011	19201-20820	27487	22924-32050	47497	42124-52870
≥85	22961	21892-24029	18234	11274-25194	41195	33166-49223
Sex						
Male	17338	16725-17950	29062	24914-33210	46400	41639-51160
Female	18824	18198-19451	25090	21196-28984	43914	39394-48435
Type of stroke						
Ischaemic	17063	16432-17694	27167	23928-30407	44231	40360-48101
Haemorrhage	19099	18455-19743	27599	22124-33074	46698	40578-52817
Subsequent year cost (prevalent stroke)						
All patients	7759	7200-8318	17019	13034-21005	24778	20234-29322
Age (years)						
40-64	5169	4057-6280	20848	14671-27025	26017	18728-33305
65-74	5761	4394-7129	21739	10408-33071	27501	14802-40199
75-84	10753	8495-13011	11443	8254-14633	22196	16749-27644
≥85	9873	7404-12343	14249	7838-20661	24123	15242-33004
Sex						
Male	7221	5741-8701	18681	12308-25053	25901	18049-33754
Female	8287	6566-10007	14857	11102-18612	23144	17668-28619
Type of stroke						
Ischaemic	7225	5750-8700	17094	12632-21555	24318	18381-30255
Haemorrhage	8230	6529-9931	18315	9855-26775	26545	16384-36706

[†] Lower and upper bound of the range is calculated using lower and upper values of NHS & SC and informal & productivity cost. It represents a feasible range of values for the total cost per patient, rather than a formal confidence interval

Figure 2.5: Breakdown of mean cost of incident stroke by service/perspective

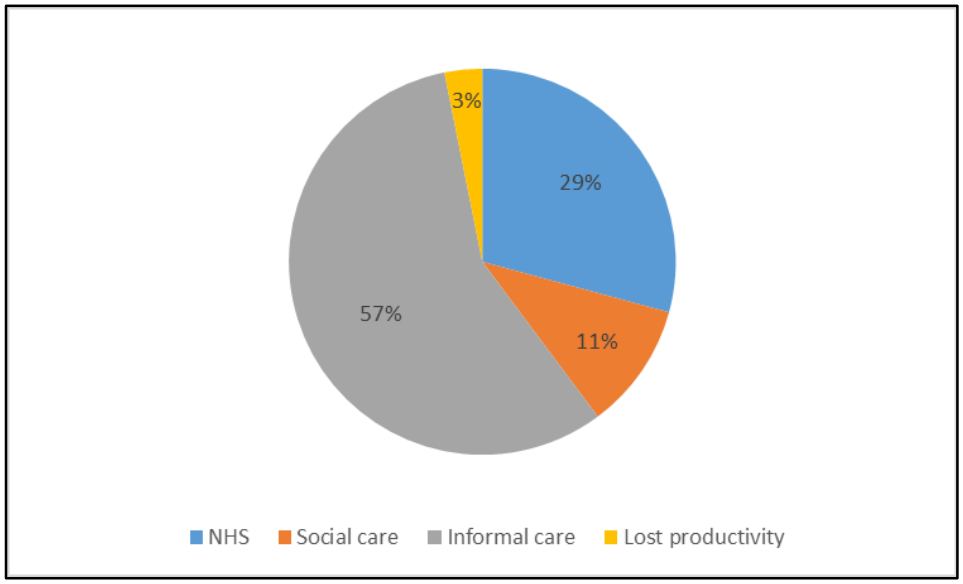
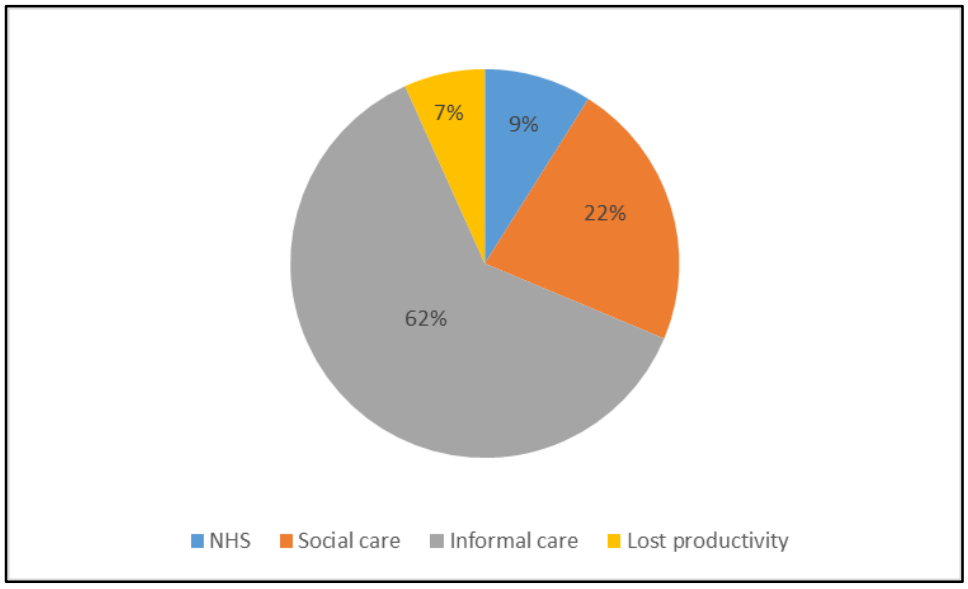


Figure 2.6: Breakdown of mean cost of prevalent stroke by service/perspective



2.2.4 Annual costs of stroke in the UK: aggregate costs for the population

The estimates of mean cost per patient of new cases of strokes and stroke survivors reported in Sections 2.2.1 and 2.2.2 are combined with findings from our focused literature search of incidence and prevalence of stroke (Appendix 2.1) to estimate the magnitude of cost impacts for the UK. Similarly to our analysis of mean costs in the previous section, we report aggregate costs of stroke separately for incident and prevalent cases, including a breakdown by type of health and social care used.

The focused literature search identifies a number of studies conducted in the UK which reported the incidence and prevalence per 1000 people in the population in the UK. To compute aggregate costs, we use those findings to derive the absolute number of new cases of stroke (Table 2.16) and stroke survivors (Table 2.17) in a given year in the UK, and combine these with the mean costs reported in Sections 2.2.1 and 2.2.2. We use reported confidence intervals from those incidence/prevalence studies to derive ranges for our estimates of aggregate costs. The annual cost of care for stroke survivors is estimated by subtracting the incidence rate from the prevalence rate to avoid double counting.

The aggregate number of stroke cases and survivors is calculated by combining age-specific incidence and prevalence rates per 1000 people reported in literature with up-to-date ONS population figures. This was done in order to account for changes in the age breakdown of the UK population. Details of the calculation can be found in Appendix 2.1.

The estimated annual number of first-time stroke cases ranges from 113.4 thousand to 119.1 thousand. Using ranges of incidence rate reported by individual studies, the number could conceivably range from 85.8 thousand to 147.6 thousand. The mid-point estimate we use in our cost calculations is 117.6 thousand.

The estimated number of stroke survivors aged 45 and over in the UK ranged from 950 thousand to 1.3 million in 2014. When the low and high estimates from individual studies are considered, the number could range from 797 thousand to 1.4 million. Given that the mid-point estimate of 1002.6 thousand reported by Jagger et al. (2006) was based on a simulation using inputs from an

old dataset (1991-94), the prevalence estimate reported by Geddes et al. (1995) (950,200) is used as the point estimate in the cost calculations – which we consider sufficiently robust due to the study size (n=18,827).

Table 2.16: Absolute number of new stroke cases in the UK estimated from incidence estimates obtained from literature

Source	UK population, whole ('000)	Number of cases in whole population ('000) (range)	UK population, aged ≥45 years, ('000)	Number of cases aged ≥45 years ('000) (range)
Rothwell et al., 2004	64597	115.2 (86.5-151.6)	27892	113.4 (85.8-147.6)
Wolfe et al., 2002	64597	123.0 (106.9-141.5)	27892	119.1 (104.4-135.2)
Stewart et al., 1999	64597	121.6 (99.6-148.6)	27892	117.6 (97.5-141.1)

Table 2.17: Absolute number of stroke survivors in the UK estimated from prevalence estimates obtained from literature

Source	Age group (years)	UK population ('000)	Number of stroke survivors ('000), using 2014 ONS figures (range)	Adjusted number of survivors ('000), aged ≥45 years (range)
Jagger et al., 2006	≥65	11406.8	809.9 (804.9-814.9)	1002.6 (895.3-1126.4)
Geddes et al., 1996	≥55	18761.2	878.0 (797.4-968.1)	950.2 (797.4-1121.5)
O'Mahony et al., 1999	≥45	27891.8	1322.1 (1285.8-1358.3)	1322.1 (1285.8-1358.3)

Base case estimates of aggregate cost

Using the above approach, we estimate the aggregate annual cost of stroke in the UK to be £8.6 billion from an NHS & PSS perspective (when using base case cost, incidence and prevalence estimates) (Table 2.18). Assuming a societal cost perspective, which includes the opportunity cost of informal care and lost productivity linked to stroke-related morbidity and mortality, these costs rise to £26 billion. The cost attributed to NHS-funded care (including secondary care, early supported discharge and community rehabilitation) is £3.4 billion (13% of cost to society); formal social care contributes more at £5.2 billion (20%). The largest cost item is informal care, valued at £15.8 billion per year (61%). Lost productivity contributes £1.6 billion (6%).

The aggregate annual cost of new cases of stroke to society is £5.3 billion, which mostly consists of direct cost for NHS care (30%). The aggregate societal cost of care and lost productivity amongst stroke survivors is £20.6 billion, with most of the cost attributed to informal care (62%). Cost of care for prevalent stroke is the main driver of aggregate stroke due to the much larger number of stroke survivors (950,000) compared to new stroke cases each year (118,000). The contribution of NHS care to aggregate societal cost is 9% in subsequent years post-stroke, compared to 30% in the first year. In contrast, the contribution of formal social care increases from 11% in the first year after stroke to 22% in subsequent years. This reflects a change in the composition of care after stroke occurrence, with a lower demand for acute hospital care and an increase in social care and informal care needs in stroke survivors over time.

Table 2.18: Aggregate cost of incident and prevalent stroke in the UK: base case, low and high cost estimates

	Aggregate cost (£ million, range[†]), base case mean cost estimates[‡]	Aggregate cost (£ million, range), low mean cost estimates[‡]	Aggregate cost (£ million, range), high mean cost estimates[‡]
First year after stroke (incident stroke)			
NHS	1560.401 (1138.456,1958.463)	1535.611 (1120.370,1927.349)	1585.193 (1156.544,1989.579)
Formal social care	565.926 (412.895,710.295)	521.455 (380.449,654.479)	610.398 (445.341,766.112)
Informal care	3045.445 (2221.932,3822.344)	2777.798 (2026.659,3486.420)	3313.092 (2417.205,4158.268)

Lost productivity	168.279 (122.775,211.207)	95.617 (69.761,120.009)	240.940 (175.788,302.404)
NHS & PSS perspective	2126.328 (1551.352,2668.759)	2072.173 (1511.841,2600.789)	2180.483 (1590.862,2736.728)
Societal perspective	5340.051 (3896.058,6702.309)	4945.588 (3608.261,6207.218)	5734.515 (4183.855,7197.401)
Survivors after stroke in previous years (prevalent stroke)			
NHS	1844.042 (1576.052,2681.458)	1762.772 (1506.592,2563.282)	1925.313 (1645.511,2799.635)
Formal social care	4616.043 (3945.203,6712.278)	4174.040 (3567.436,6069.554)	5058.045 (4322.970,7355.003)
Informal care	12783.349 (10925.572,18588.519)	10034.062 (8575.833,14590.727)	15532.636 (13275.311,22586.311)
Lost productivity	1387.028 (1185.454,2016.905)	818.296 (699.375,1189.900)	1955.761 (1671.534,2843.910)
NHS & SC perspective	6460.077 (5521.247,9393.724)	5994.712 (5123.513,8717.028)	6925.442 (5918.982,10070.421)
Societal perspective	20630.454 (17632.274,29999.148)	16847.070 (14398.721,24497.655)	24413.839 (20865.827,35500.642)
Incident and prevalent stroke			
NHS	3404.444 (2714.508,4639.921)	3298.384 (2626.962,4490.631)	3510.505 (2802.055,4789.213)
Formal social care	5181.969 (4358.098,7422.574)	4695.495 (3947.885,6724.033)	5668.443 (4768.311,8121.114)
Informal care	15828.794 (13147.504,24100.863)	12811.860 (10602.492,18077.147)	18845.728 (15692.516,26744.579)
Lost productivity	1555.307 (1308.229,2228.112)	913.913 (769.136,1309.909)	2196.701 (1847.322,3146.314)
NHS & PSS perspective	8586.405 (7072.599,12062.483)	8066.885 (6635.354,11317.817)	9105.925 (7509.844,12807.149)
Societal perspective	25970.506 (21528.332,26701.458)	21792.658 (18006.981,30704.873)	30148.353 (25049.682,42698.043)

† Range based on low and high incidence and prevalence estimates reported in Table 2.16 and 2.17. ‡ Low and high cost estimates based on range of mean cost reported in Tables 2.10-2.15.

2.2.5 Uncertainty in the cost estimates

Uncertainty in aggregate cost estimates

Uncertainty in mean cost estimates from our modelling analysis and in incidence and prevalence figures reported in the literature generate significant uncertainty in the aggregate cost estimates. Varying the estimated annual incidence of stroke over the full range of literature-sourced estimates, assuming base case mean cost values, changes aggregate societal cost of incident

stroke from £3.9 billion to £6.7 billion. Varying the assumed prevalence over its respective range changes aggregate cost of prevalent stroke from £17.6 billion to £30 billion.

Variation of parameter values generated in the discrete event simulation model is another source of uncertainty in aggregate cost estimate, although it is considerably lower than the uncertainty around incidence and prevalence estimates. The aggregate cost of NHS and formal social care (assuming base case incidence and prevalence) varies from £8.1 billion to £9.1 billion.

Uncertainty in estimates of the value of informal care and lost productivity obtained from the TRACS and LoTS Care trials was considerable. As a result, the aggregate cost of informal care in the first year post-stroke varies from £2.8 billion to £3.3 billion. Cost of informal care in stroke survivors varies over the range of £10-15.5 billion. Total informal care cost varies over the range £12.8-18.8 billion.

This study did not compute a joint distribution of cost and incidence/prevalence; this precludes estimating a formal confidence interval for aggregate cost. However, it is possible to gauge uncertainty in the aggregate cost of stroke by considering credible ranges for mean cost and incidence/prevalence estimates reported in the literature. Assuming the most conservative scenario (lower bound for mean cost, incidence and prevalence estimates), the aggregate societal cost of stroke in the UK is at least £18 billion per annum. The maximum cost (assuming that mean cost, incidence and prevalence estimates are each at the higher bound of their respective ranges) is £43 billion. Following the same approach, the credible interval for the aggregate cost assuming an NHS & PSS perspective is £6.6-12.8 billion.

The uncertainty in aggregate cost estimates is illustrated in Figure 2.7. Sensitivity of aggregate cost estimates to changes in incident/prevalence estimates and mean cost estimates derived from the discrete event model is presented in Figures 2.8 and 2.9. The largest source of uncertainty in aggregate cost both from an NHS & PSS perspective is prevalence of stroke. This is followed by the mean cost of informal care and annual incidence of stroke.

Figure 2.7: Uncertainty in aggregate cost estimates

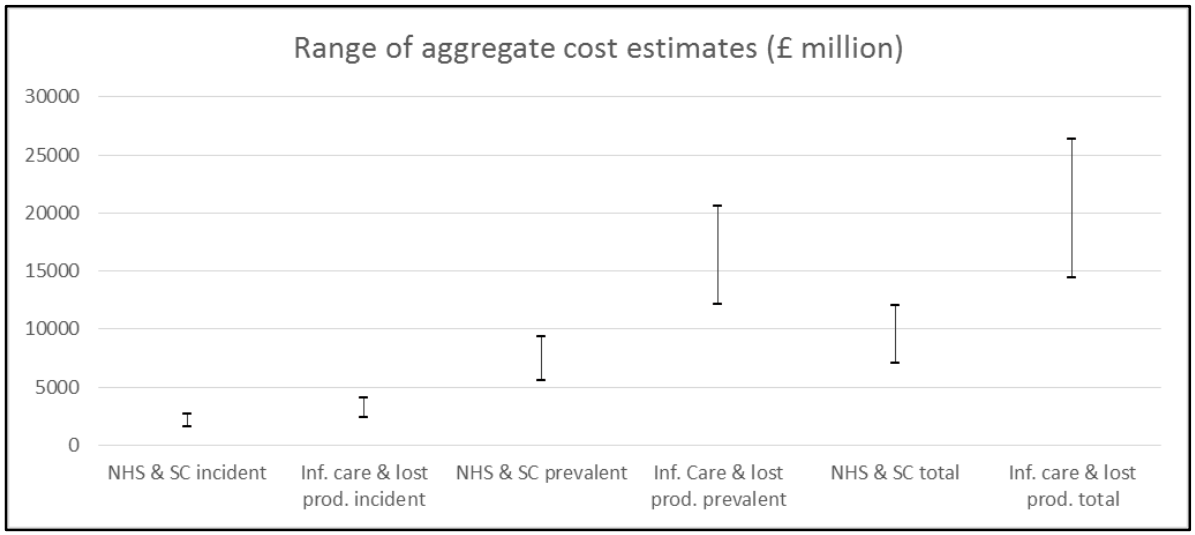


Figure 2.8: Tornado diagram demonstrating the effect of inputs on aggregate cost, societal perspective

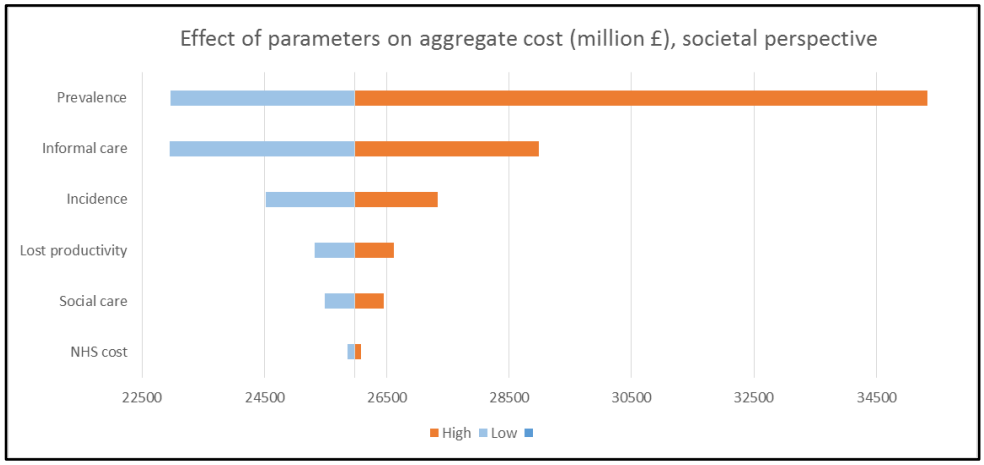
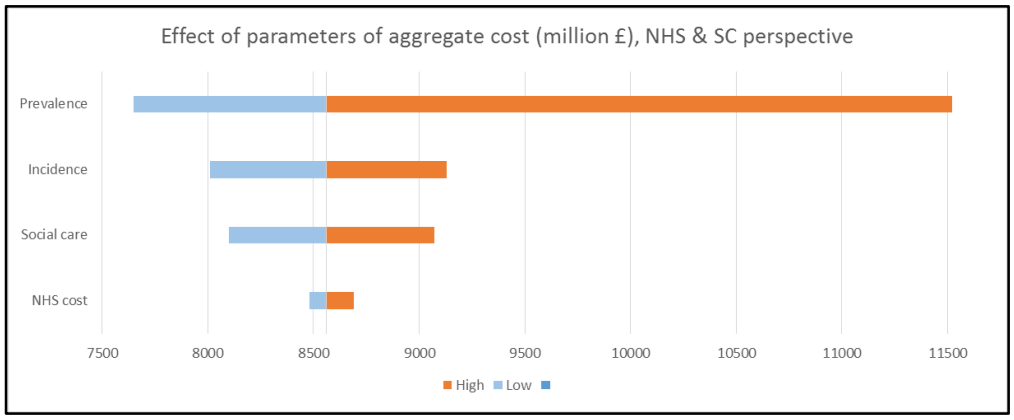


Figure 2.9: Tornado diagram demonstrating the effect of inputs on aggregate cost, NHS & PSS perspective

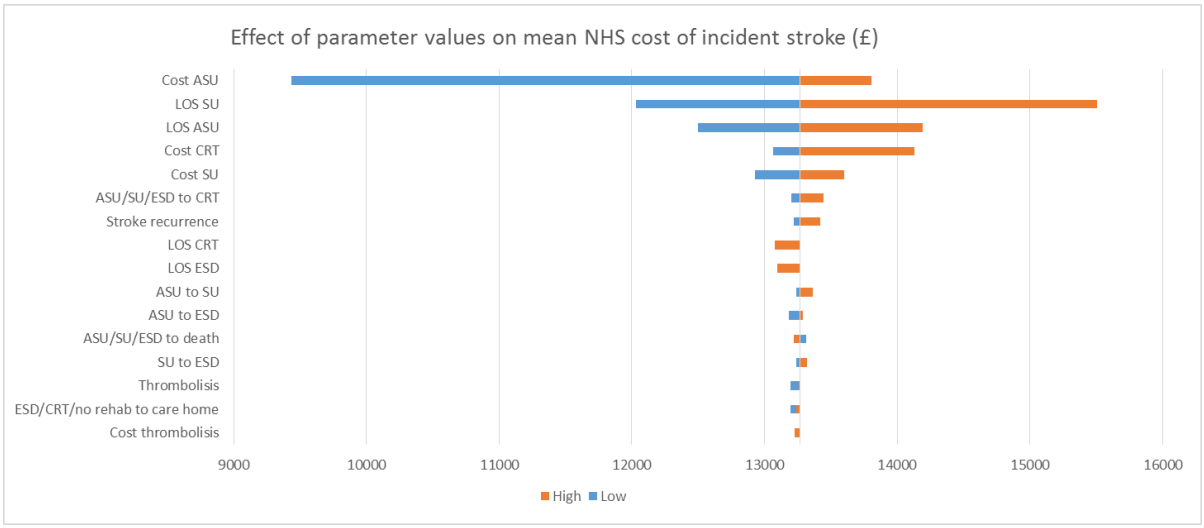


One-way sensitivity analyses

Baseline values of model parameters are varied along their respective ranges listed in Table 2.2 to examine the main sources of uncertainty in the discrete event simulation model. The impact of parametric uncertainty on estimates of mean cost from an NHS and social care perspective are summarised using tornado diagrams in Figures 2.10 to 2.13. The full summary of the results of one-way analyses are presented in Table 2.16.

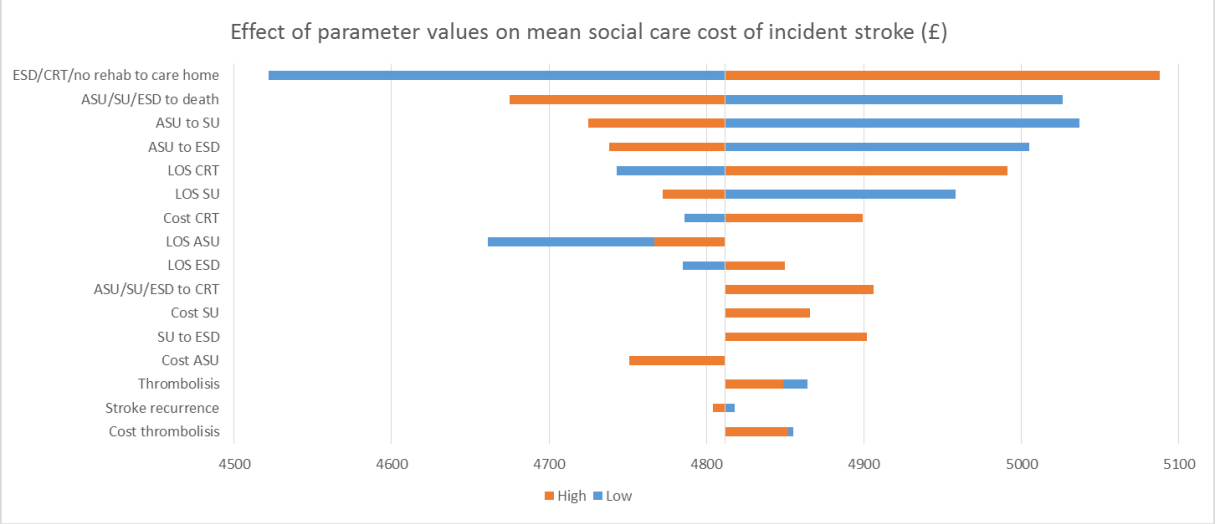
The main sources of uncertainty in the cost of incident stroke from an NHS perspective are unit cost and length of stay in acute stroke unit (ASU) and stroke unit (SU), as well as cost of community rehabilitation (Figure 2.8). Changing the assumed unit cost per day in ASU from £396 to £729 (starting from a base case value of £685) results in a mean cost of £9434 and £13805, respectively. Varying the unit cost per day in a regular stroke unit across its range (£211 to £342) results in a mean cost ranging from £12930 to £13600. Varying the cost of community rehabilitation over its feasible range results in a change of mean cost from £13064 to £14128. The assumed length of stay in ASU and SU has a large impact on estimated post-stroke care cost. Mean cost is particularly sensitive to length of stay in SU: it ranges from £12030 to £15507 depending on the assumed number of days spent in the stroke unit.

Figure 2.10: Tornado diagram of model parameter values on incident cost of stroke, NHS perspective



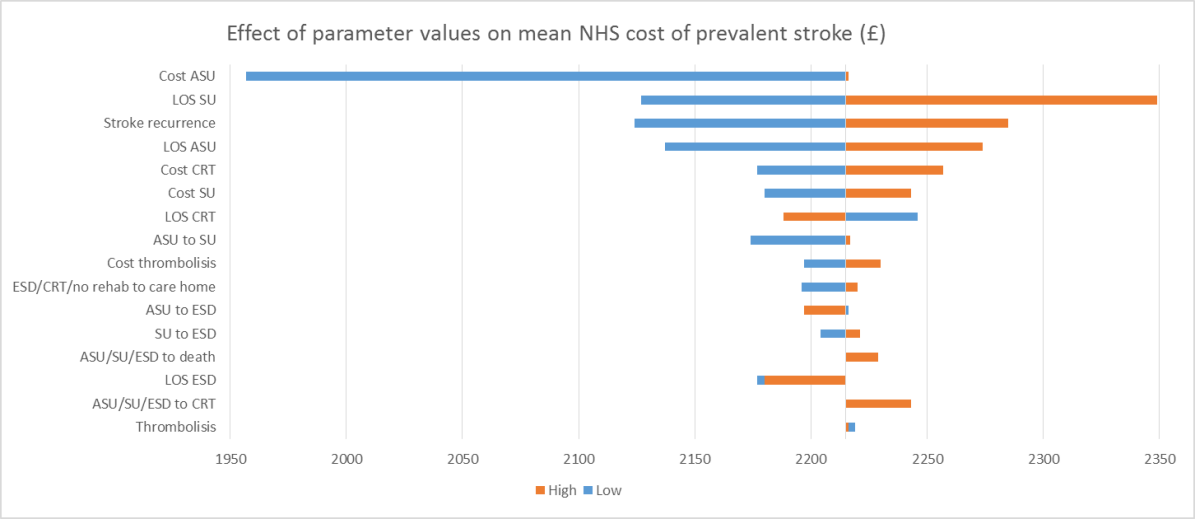
Predictably, the main source of uncertainty for cost from a social care perspective in the first 12 months following a stroke is the assumed probability of care home admission after discharge from early supported discharge (ESD), community rehabilitation or home. The mean cost of social care in the first year after stroke ranges from £4522 to £5088 depending on the probability of care admission. Increasing the probability of death in one of the stroke units, admission to SU or ESD after ASU is expected to decrease social care cost. This is also predictable, as the above events reduce the probability that the patient ends up in a care home, keeping the patient in secondary care instead, conditional on survival.

Figure 2.11: Tornado diagram of model parameter values on incident cost of stroke, social care perspective



The cost of ASU and length of stay in SU were the largest drivers of uncertainty in the mean cost of NHS-funded care in subsequent years after stroke. This is driven by the cost incurred during readmission for subsequent strokes. The probability of stroke recurrence was also a substantial driver of uncertainty.

Figure 2.12: Tornado diagram of effect of model parameter values on prevalent cost of stroke, NHS perspective



Similarly to the analysis of the cost of incident stroke, the social care cost in subsequent years post-stroke is heavily influenced by the probability of care home admission. Varying the probability across the pre-assigned range results in a change of mean cost from £5134 to £5912. Probability of admission to SU or ESD following ASU reduces the need for care home admission, resulting in a lower mean social care cost.

Figure 2.13: Tornado diagram of effect of model parameter values on prevalent cost of stroke, social care perspective

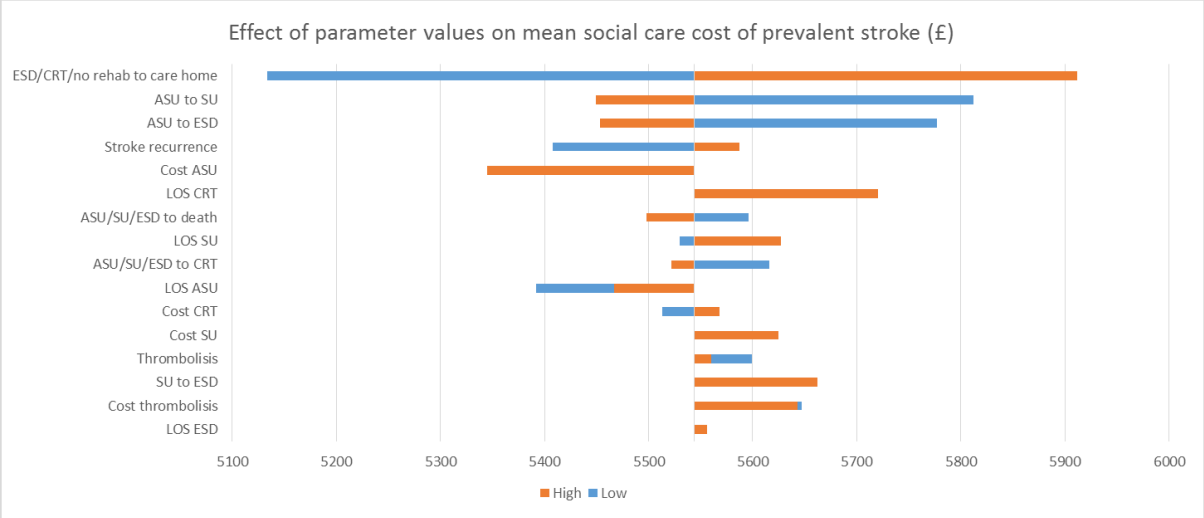


Table 2.19: Summary of one-way sensitivity analyses

Category	Incident cost: NHS†	Incident cost: social care	Incident NHS & SC cost	Prevalent cost: NHS	Prevalent: social care	Prevalent NHS & SC cost
Base case	13269	4812	18081	2215	5544	7759
Length of stay						
ASU						
Low	12499	4661	17160	2137	5392	7530
High	14194	4767	18961	2274	5467	7741
SU						
Low	12030	4958	16988	2127	5530	7656
High	15507	4772	20279	2349	5627	7977
ESD						
Low	13242	4785	18027	2177	5554	7731
High	13097	4850	17947	2180	5556	7736
CRT						
Low	13247	4743	17990	2246	5599	7844
High	13075	4991	18066	2188	5720	7908
Transition probabilities						
ASU to SU						
Low	13242	5037	18278	2174	5812	7986
High	13365	4725	18090	2217	5449	7667
ASU to ESD						
Low	13183	5005	18188	2216	5777	7993
High	13290	4738	18027	2197	5453	7650
SU to ESD						
Low	13242	4882	18125	2204	5656	7860
High	13318	4902	18220	2221	5662	7883
ASU, SU and ESD to CRT						
Low	13205	4859	18064	2240	5616	7856
High	13443	4906	18349	2243	5522	7765
Care home admission from ESD, community rehab and no rehab						
Low	13198	4522	17720	2196	5134	7330
High	13240	5088	18328	2220	5912	8133
Death during treatment in ASU, SU and ESD						
Low	13314	5026	18340	2223	5596	7819
High	13223	4675	17898	2229	5498	7728
Thrombolysis in ASU						

Low	13197	4864	18061	2219	5599	7818
High	13256	4849	18105	2216	5560	7776
Stroke recurrence						
Low (20% lower)	13223	4818	18041	2034	5634	7668
Low (10% lower)	13264	4789	18053	2124	5408	7531
High (10% higher)	13290	4796	18086	2285	5587	7872
High (20% higher)	13419	4804	18223	2453	5508	7961
Unit costs						
Thrombolysis						
Low	13249	4855	18104	2197	5647	7844
High	13227	4852	18079	2230	5643	7872
Acute stroke unit						
Low	9434	4771	14205	1957	5476	7432
High	13805	4751	18556	2216	5345	7561
Stroke unit						
Low	12930	4832	17761	2180	5582	7762
High	13600	4866	18466	2243	5625	7868
CRT						
Low	13064	4786	17851	2177	5513	7690
High	14128	4899	19027	2257	5568	7825

[†] Mean cost (£)

2.3 Strengths, limitations and assumptions

We estimate mean cost of NHS and social care using a simulation model based on inputs from a national stroke audit (SSNAP). Naturally, the resulting estimates are subject to the uncertainty in parameter values assumed in the model. We conduct extensive probabilistic and one-way sensitivity analyses to test the robustness of the findings derived from the model. Firstly, we apply distributional assumptions and repeatedly sample the model output to ensure validity of point estimates obtained. This allows us to characterise sampling uncertainty and construct credible confidence intervals for mean cost values. Secondly, we apply defensible ranges for model parameters to test the response of the model output to changes in individual parameter values. Amongst the parameters which contribute the largest amount of uncertainty are unit cost of ASU derived from NHS reference costs and assumed length of stay in acute and regular stroke units, which have a direct impact on the cost of new-onset stroke from an NHS perspective. Probability of care home admission has a significant effect on the cost of social care both in the first and subsequent years after stroke. Cost of ASU, length of stay in stroke units and probability of recurrent recurrence are the largest drivers of uncertainty in the cost of NHS care in prevalent stroke. Further research is warranted to obtain more precise estimates for these parameters to reduce uncertainty around both mean and aggregate cost estimates.

While using the NGC/SSNAP model brings many advantages to this work, there are some limitations. For example, the starting point for the model is the acute care pathway, so it does not capture the costs specifically associated with patients who are not admitted to hospital following on from stroke. Since evidence from population-based cohort studies in the UK show that some patients with minor stroke present to community based services and are referred to outpatient clinics (Rothwell et al., 2007), our estimates of costs may be over-estimated. Lancet 2007; 370: 1432-1442.

This study derives cost estimates for informal care and lost productivity using individual-level data from the standard care arm of two large multi-centre stroke trials that recruited nationally

(TRACS and LoTS Care). This approach has several advantages: it uses self or proxy-reported individual-level data on the volume and type of informal care provided to stroke patients from both resident and non-resident caregivers and includes information on employment status, which allows us to derive lost earnings attributed to stroke-related morbidity and mortality. However, this method relies on a number of assumptions. Inclusion into the TRACS trial was conditional on presence of a primary informal caregiver, thus is potentially unrepresentative of the stroke population as a whole. In an effort to adjust for this, we added simulated participants into the model (method is described in Section 2.1.2). In doing so, we assume that the mean cost of informal care in these additional patients without a primary informal caregiver are 25% of the mean cost of informal care in recruited trial population (with a primary caregiver). The cost of informal care in prevalent stroke is based on data from the LoTS Care trial. Informal care inputs in months 6-12 after discharge from the stroke unit are used as a proxy for informal care hours required in subsequent years after stroke. This may have led to an overestimate of the true cost of informal care in prevalent stroke as reliance on informal care tends to tail off over time as the patient regains mobility and independence.

Finally, while we describe a 'societal cost' for cost, this is by no means a complete cost. For example, we have excluded the value of welfare payments here since they are commonly regarded as transfer payments rather than economic costs, but they nevertheless carry a distribution cost which we have not accounted for. As an indication of the size of payments, Department for Work & Pensions expenditure on disability benefits for people whose main disabling condition was cerebrovascular disease was around £800m for Great Britain in 2015/6. This is on the basis that in November 2016, 5.8% of attendance allowance recipients, 3.0% of disability living allowance recipients and 2.8% of personal independence payment recipients had cerebrovascular disease as their main disabling condition.

3. Expert views on future incidence, prevalence and research priorities

Key messages

- To project current costs of stroke to future years, we need some sense of how many strokes will continue to occur each year and how many people will live with stroke each year.
- To hypothesise how further research could alleviate future costs, we also need some sense of what that research might consist of and what specific impacts it might have.
- To help us obtain estimates in these two areas, we formed two (overlapping) expert groups and used a Delphi-style approach to seek their views.
- Experts had divergent views on whether stroke incidence would decrease or increase in future.
- Their views on prevalence were however more uniform, pointing towards no change or modest increases in prevalence in people aged 40-74 years and a modest or high increase in people aged 75-100 years.
- In the first round of views on research priorities, experts suggested 56 different topics/questions (after allowing for duplication).
- We categorised these into different aspects of the care pathway and then asked the same experts to re-select and rank priorities from the overall list.
- This resulted in the following top five topics (in rank order):
    - Improved rehabilitation strategies
    - Rehabilitation for cognitive difficulties
    - Vascular dementia
    - Thrombectomy
    - Evidenced-based practice

3.1 Methods

Two aspects of this work concern hypothesising future trajectories for which we have no data: estimating future costs of stroke (Section 4) and estimating the potential alleviation of these costs through greater investment in research (Section 5). In the obvious absence of data about the future, such estimates require us to make a series of assumptions and we sought expert views to better inform these.

A Delphi process (for example, as used by Pollock et al. (2012) for their James Lind Alliance priority-setting work on life after stroke) is a common way of seeking such views and we used a Delphi-style approach to address two objectives of our work:

- to obtain opinions on the level of annual change in stroke incidence and prevalence rate over the next 10 years and 11-20 years given the information on current rates obtained from our targeted review; and
- to obtain opinions on research priorities and their expected benefits.

This process is detailed below. Importantly, we were not necessarily seeking to obtain a consensus view as were interested in the variation in views that might exist. The process was designed accordingly. We obtained necessary approvals from the relevant Research Ethics Committee (Proportionate Review Sub-committee of the East of England - Cambridge South Research Ethics Committee; Reference: 16/EE/0451) before starting this work.

3.1.1 Delphi group participants and process

We sought to obtain views from a range of academic experts with knowledge, expertise or a stake-holding in stroke, stroke care and/or stroke research.

Considering trends in the number of new strokes that occur each year and the number of people living with stroke is challenging. There is uncertainty in current estimates and there will likely be huge uncertainty about future trends. We therefore envisaged that expert views on

incidence/prevalence trajectories would come from those with knowledge and substantial experience of formal care sectors, epidemiological trends and/or research in these areas.

With regards to research priorities, we specifically wanted opinions on which specific or overall strategies requiring further research investment would likely lead to the most significant gains in stroke outcomes and/or save the most resources. Since we are interested in a variety of gains and perspectives, we envisaged that expert views on research priorities would come from a broader range of experts than those covering trends in incidence and prevalence.

We therefore sought to collate views from two separate, but overlapping, groups of experts. Allocations to one or both groups were based on our own judgements of their suitability.

An initial list of experts was generated from the membership list of the Royal College of Physicians Intercollegiate Stroke Working Party, which includes representatives from a range of relevant national professional bodies. Further individuals were added to the list by their national reputation for stroke research and/or by recommendation from others on the list. In total, we identified and contacted 43 potential participants; all individuals were invited to join the research priorities group but only 19 of these were additionally asked to join the incidence/prevalence group.

Potential participants were provided a participant information sheet about the study and were asked to provide written informed consent if they agreed to participate. No payment was offered for participation.

Each Delphi group was run in parallel and consisted of two rounds. We developed questionnaires for each group/round (Appendix 3.1); after Round 1, we summarised responses to include in Round 2 questionnaires. Where relevant, individual responses were treated as confidential to the research team and summary results to be shared via the questionnaires were anonymised. Round 2 questionnaires were only sent to those who returned Round 1 questionnaires because of the iterative nature of the process.

Questionnaires for the incidence/prevalence group consisted of current estimates of stroke incidence and prevalence for the four age bands considered in our estimates of current and future costs of stroke (40-64, 65-74, 75-84, and 85-100 years). In Round 1, participants were asked to indicate the level of annual change they would expect in incidence and prevalence rate over the next (a) 10 years and (b) 11-20 years (i.e. the period 2026 to 2036). They were asked to indicate these changes for each age band by selecting one of four pre-specified options: (a) increase of 2% to 3% per year, (b) increase of 1% to <2% per year, (c) increase of <1% per year/no change or (d) decrease from the current levels. In Round 2, they were provided aggregate data on Round 1 responses from the whole group and a reminder of their own Round 1 response, and given the option to either stick with or change any or all of their Round 1 responses in light of this additional information. We additionally asked them to select which of our identified sources of current incidence and prevalence rates they considered to be the most robust and to offer suggestions on any others we should consider.

Questionnaires for the research priorities group first asked participants to recommend up to three areas they would consider as priorities for future stroke research (in no particular order, open-ended responses). Then, for each, to indicate the likelihood and timing (using four pre-specified options of unlikely, likely within 10 years, likely within 11 to 20 years or likely after 21 years) of a range of pre-specified potential benefits (plus an option to add other benefits not listed) if that research was funded immediately. We examined research priority recommendations from Round 1 and organised them into five major categories broadly reflecting the clinical/care pathway: risk factors or primary prevention; acute care; long-term care or rehabilitation; secondary prevention; and cross-cutting issues across the care pathway. We used this categorisation in Round 2 to present the full range of research recommendations made in Round 1; recommendations considered to be similar were aggregated into one item but since we demarcated the individual verbatim responses and marked them with ID numbers, each participant could identify if their own responses within this list. We asked a clinical advisor to the project to check our categorisation and aggregation. Participants were then tasked with (a) ranking the five areas in priority order, (b) selecting one (aggregated) item within each area and

(c) selecting to change any, all or none of their Round 1 responses in light of this additional information.

All questionnaires were sent by email. Participants were given one week to respond to Round 1 questionnaires; reminders were sent to any non-responders. Round 2 questionnaires were sent five weeks later, with a response time of two weeks and reminders again sent to any non-responders. To maximise useable data, we examined all returned questionnaires for completion errors and, where found, notified relevant participants of these and offered an option to return a corrected version.

Of those contacted, 29/43 agreed to participate in the research priorities group and 11/19 agreed to join the incidence/prevalence group. One individual who was asked to join both groups chose to decline participation in the incidence/prevalence group due to lack of relevant expertise. Three individuals were unavailable to participate (1 who was allocated to both groups and 2 who were allocated only to the research priorities group) and 11 did not reply (6 who were allocated to both groups and 5 who were allocated only to the research priorities group). All individual data were handled anonymously using numeric identifiers. Data were entered and analysed using Microsoft Excel.

3.2 Results

Participant numbers and expertise are summarised in Appendix 3.2.

3.2.1 Incidence and prevalence

Expert views on future changes in incidence and prevalence of stroke are presented in Tables 3.1 and 3.2 respectively. Experts had divergent views on whether incidence would decrease or increase in future. There was more uniformity in responses regarding prevalence, pointing towards no change or modest increases in prevalence in the two younger age groups and a modest or high increase in the two older age bands.

Table 3.1: Incidence/prevalence Delphi group Rounds 1 and 2: Expected level of annual change in incidence (% of respondents)

		Next **10 years** n=11 Round 1	Next **10 years** n=11 Round 2	Next **11-20 years** n=11 Round 1	Next **11-20 years** n=11 Round 2
Aged 40-64 years	Increase of 2% to 3% per year	18.19%	9.09%	18.19%	9.09%
(current estimates range 114 to 147 per 100,000)	Increase of 1% to <2% per year	27.27%	36.36%	27.27%	36.36%
	Increase of <1% per year/no change	27.27%	27.27%	9.09%	9.09%
	Decrease	27.27%	27.27%	36.36%	45.46%
Aged 65-74 years	Increase of 2% to 3% per year	9.09%	9.09%	9.09%	9.09%
(current estimates range 496 to 522 per 100, 000)	Increase of 1% to <2% per year	27.27%	36.36%	27.27%	27.27%
	Increase of <1% per year/no change	18.18%	9.09%	18.18%	18.18%
	Decrease	45.46%	45.45%	36.36%	36.36%
Aged 75-84 years	Increase of 2% to 3% per year	18.18%	18.18%	18.18%	18.18%
(current estimates range 890 to 1003 per 100,000)	Increase of 1% to <2% per year	9.09%	18.18%	18.18%	18.18%
	Increase of <1% per year/no change	36.36%	27.27%	27.27%	27.27%
	Decrease	36.36%	36.36%	27.27%	36.36%

Aged 85-100 years	Increase of 2% to 3% per year	18.18%	9.09%	27.27%	9.09%
(current estimates range 1674 to 1972 per 100,000)	Increase of 1% to <2% per year	18.18%	27.27%	9.09%	18.18%
	Increase of <1% per year/no change	45.45%	54.55%	36.36	45.45%
	Decrease	18.18%	9.09%	18.18%	18.18%

Table 3.2: Incidence/prevalence Delphi group Rounds 1 and 2: Expected level of annual change in prevalence (% of respondents)

		Next **10 years** R1 N=11	Next **10 years** R2 N=11	Next **11-20 years** R1 N=11	Next **11-20 years** R2 N=11
Aged 40-64 years	Increase of 2% to 3% per year	9.09%	9.09%	9.09%	9.09%
(current estimates range 1640 to 2182 per 100,000)	Increase of 1% to <2% per year	36.36%	36.36%	36.36%	36.36%
	Increase of <1% per year/no change	45.45%	45.45%	45.45%	45.45%
	Decrease	9.09%	9.09%	9.09%	9.09%
Aged 65-74 years	Increase of 2% to 3% per year	9.09%	9.09%	9.09%	9.09%
(current estimates range 3980 to 6040 per 100,000)	Increase of 1% to <2% per year	63.64%	63.64%	81.82%	81.82%
	Increase of <1% per year/no change	27.27%	27.27%	9.09%	9.09%
	Decrease	0.00%	0.00%	0.00%	0.00%

Aged 75-84 years	Increase of 2% to 3% per year	36.36%	36.36%	54.55%	63.64%
(current estimates range 9110 to 10990 per 100,000)	Increase of 1% to <2% per year	54.55%	63.64%	36.36%	36.36%
	Increase of <1% per year/no change	9.09%	0.00%	9.09	0.00%
	Decrease	0.00%	0.00%	0.00%	0.00%
Aged 85-100 years	Increase of 2% to 3% per year	72.73%	72.73%	81.82%	90.91%
(current estimates range 9300 to 9840 per 100,000)	Increase of 1% to <2% per year	18.18%	18.18%	9.09%	9.09%
	Increase of <1% per year/no change	9.09%	9.09%	0.09%	0.00%
	Decrease	0.00%	0.00%	0.00%	0.00%

Further, given the general lack of consensus on stroke incidence and prevalence rates, in Round 2, we asked the incidence/prevalence expert group for their views on the sources we used to generate current incidence and prevalence rate ranges for the questionnaires. We first asked them to indicate which of these they would consider the most reliable. Rothwell et al. (2004) and Wolfe et al. (2002) were the most common selections (Table 3.3). We then asked them to suggest other relevant sources – text responses to this are provided in Appendix 3.3.

Table 3.3: Expert views on best of our sources of stroke incidence and prevalence rates (n=11)

	Wolfe et al., 2002	Stewart et al., 1999	Rothwell et al., 2004	Saka et al., 2009	Geddes et al., 1996

Number	6	1	9	1	3
Percentage	54.55	9.09	81.82	9.09	27.27

3.2.2 Research priorities

In Round 1, 28 responders suggested 83 research priorities; collapsing these to account for similar suggestions resulted in a list of 56 research priorities.

In Round 2, 27 of 28 Round 1 participants responded. Some questionnaires were not fully or correctly completed (e.g. two participants in Round 2 did not rank the fine broad areas as requested). We present and use all available and correctly completed data as relevant to the following analyses and reporting.

To determine a top-five list of priorities from the list of 56, we analysed the number/percentage of participants who selected each (using Round 1 responses if participants opted to stick with their original list or Round 2 responses if they modified that). Given that the distribution of research priorities across the five areas was uneven, we weighted the number of responses for each item to account for the number of items available under each category. We then further adjusted the number of responses to account for the rankings assigned to the five categories (Appendix 3.2).

During Round 2, some respondents commented on our categorisation or collapsing of research priorities, suggesting that their choices may have differed with alternative configuration of the data. We took these into account in a sensitivity analysis, which suggested slight changes in the total number of votes received for some items but did not alter ranking of items. Using this process, we identified the following as the top five research priorities from the list of 56 used in Round 2 (text is verbatim from Round 1 suggestions; weighted number of participants selecting each are given in parentheses, rounded to whole numbers):

1. Improved rehabilitation strategies (n selecting this in Round 1=5, 29%): Improved rehabilitation strategies / Stronger evidence for rehabilitation therapies / Effects of longer term access to therapy on physical, social and psychological function / Creating

an evidence base for stroke rehabilitation / Developing and evaluating services to meet the long term needs of stroke patients and their family (19).

2. Rehabilitation for cognitive difficulties (n selecting this in Round 1=5, 29%): Rehabilitation for cognitive difficulties / Improvements to cognitive and communicative aspects of recovery / Assessment, rehabilitation and pharmacological treatment of cognitive impairment after stroke / Novel treatment for cognitive decline / Cognitive function in stroke including brain structure / location - deficit associations / Long term cognitive impairment (16).
3. Vascular dementia (n selecting this in Round 1=2, 12%): Reduction of vascular dementia / Vascular cognitive impairment /dementia (12).
4. Thrombectomy (n selecting this in Round 1=3, 18%): Assessment of the options for delivery of thrombectomy in acute stroke to increase the population able to benefit / Effective implementation of thrombectomy / Research into widening thrombectomy indications using advanced brain imaging techniques combined with RCTs to determine optimum thrombectomy techniques (11).
5. Evidence based practice (n selecting this in Round 1=2, 12%): Implementation of interventions and practices for stroke care and rehabilitation that we know are effective and cessation of practices that we know are not effective/ Implementation of evidence based practice (9).

4. Future costs of stroke

Key messages

- We project that the incidence of stroke (new strokes) among people aged 45 and over in the UK will rise from 117,600 in 2015 to 148,700 in 2025 and 187,000 in 2035, an increase of 59% over 20 years.
- This is on a central set of assumptions from expert views that incidence rates will remain constant to 2035 for those aged 45 to 84 and rise by 0.5% per year for those aged 85 and over.
- If incidence rates change by 1% per year more or 1% less than under this central assumption, incidence would be 228,000 or 153,000 respectively in 2035.
- We project that the prevalence of stroke (number of stroke survivors) among people aged 45 and over in the UK will rise from 950,000 in 2015 to 1,425,000 in 2025 and 2,120,000 in 2035, an increase of 123% over 20 years.
- This is on a central set of assumptions from the expert views that prevalence rates will rise by 1% per year for those aged 45 to 64, 1.5% per year for those aged 65 to 74, 2.0% per year (2.5% after 2025) for those aged 75 to 84 and 2.5% per year (3.0% after 2025) for those aged 85 and over.
- If prevalence rates changes by 1% per year more or 1% less than under this central set of assumptions, prevalence would be 2,575,000 or 1,740,000 respectively in 2035.
- We project that total expenditure on stroke in the UK, covering health care, formal social care, unpaid social care and lost productivity, will rise from around £25.6bn in 2015 to £42.6bn in 2025 and £75.2bn 2035 (at constant 2015 prices).
- We project that health care costs will rise by 201%, social care costs by 273%, unpaid care costs by 171% and lost productivity costs by 136%. The projected increase is highest for social care because of high use of social care in late old age by survivors of severe strokes.

- This is on the central assumptions about future incidence and prevalence of stroke and an assumption, based on the OBR long term assumption for growth in productivity and earnings, that weekly costs of care will rise by 2% per year in real terms.
- Sensitivity analyses on the assumed trends in incidence and prevalence rates and on rates of increase in the real unit costs of care show a wide range of projections. For example, under the high future incidence and prevalence rates variant projected total expenditure on stroke in the UK would be £91.5bn in 2035 and under the low future incidence and prevalence rates variant projected total expenditure would be £61.8bn in 2035.

4.1 Methods

This section sets out our projections to 2035 of the future numbers of stroke survivors and future costs of stroke in the UK among people aged 45 and over. The starting point for the projections is the estimates for 2015 presented in Section 2.

The projections are produced using a cell-based simulation model in Excel similar to models we developed to produce projections of demand and associated expenditure for long-term care (Wittenberg and Hu, 2015). A description of the model is provided in the appendices.

4.1.1. Projected incidence and prevalence

Our projections are rooted in the Office for National Statistics (ONS) principal 2014-based population projections (Office of National Statistics, 2015). Between 2015 and 2035, they show the UK population aged 45 to 64 rising by 2.7%, the population aged 65 to 74 rising by 34.0%, the population aged 75 and over rising by 71.3% and the total population aged 45 and over by

22.5%. Our model starts with these population projections by gender and age group from age 45 upward (in 5 year bands up to 90 and over).

We apply to these population projections information on the current and projected future incidence and prevalence rates of stroke by age and gender. As explained in Section 2, we take as our central estimate of annual incidence 117,600 and our central estimate of current prevalence 950,200 in 2015. These estimates of incidence and prevalence by age and gender are set out in Table 4.1.

Table 4.1: Estimated incidence and prevalence of stroke in 2015 by age and gender

Age group	Incidence			Prevalence		
	Men	Women	Total	Men	Women	Total
45 to 49	2,251	1,844	4,095	26,393	1,259	27,652
50 to 54	2,153	1,755	3,908	25,245	1,199	26,444
55 to 59	5,830	2,639	8,469	42,709	23,108	65,817
60 to 64	5,281	2,432	7,713	38,685	21,296	59,981
65 to 69	10,342	8,127	18,469	84,408	64,674	149,082
70 to 74	7,470	6,141	13,611	60,964	48,868	109,832
75 to 79	8,591	10,395	18,986	112,404	96,368	208,772
80 to 84	5,832	8,089	13,921	76,301	74,989	151,290
85 to 89	6,795	11,224	18,019	30,501	64,682	95,183
90 and over	3,011	7,398	10,409	13,514	42,633	56,147
Total	57,556	60,044	117,600	511,123	439,077	950,200

We assume as our central case that:

- incidence rates will remain constant over the period 2015 to 2035 for those aged 45 to 84 and will rise by 0.5% per year for those aged 85 and over;

- prevalence rates will rise over the period 2015 to 2035 by 1% per year for those aged 45 to 64 and by 1.5% per year for those aged 65 to 74;
- prevalence rates will rise for those aged 75 to 84 by 2% per year over the period 2015 to 2025 and by 2.5% per year over the period 2025 to 2035; and
- prevalence rates for those aged 85 and over will rise by 2.5% per year between 2015 and 2025 and by 3% per year between 2025 and 2035.

These assumptions, which are later varied in sensitivity analyses, are based on our Delphi-style survey with experts described in Section 3.

On the basis of these assumptions we project that the number of strokes (incidence) will rise from 117,600 in 2015 to 148,700 in 2025 and 186,900 in 2035, an increase of 58.9% over the total 20 year period 2015 to 2035. We also project that the number of people living with stroke (prevalence) will rise from 950,200 in 2015 to 1,424,100 in 2025 and 2,119,400 in 2035, an increase of 123.1% over the 20 year period 2015 to 2035. Our central projections are set out in more detail in Table 4.2.

Table 4.2: Projections of future number of incident and prevalent cases of stroke, age 45 and over, by gender and stroke type

Gender, type of	Incidence			Prevalence		
stroke	2015	2025	2035	2015	2025	2035
Females						
Ischaemic	53,670	66,431	84,268	397,290	594,806	912,546
Haemorrhagic	6,374	7,925	9,964	41,787	62,741	96,229
Males						
Ischaemic	51,661	66,592	82,915	462,532	693,277	1,004,308
Haemorrhagic	5,895	7,749	9,770	48,591	73,325	106,347
Total						
Ischaemic	105,331	133,023	167,193	859,822	1,288,083	1,916,854
Haemorrhagic	12,269	15,674	19,734	90,378	136,066	202,576
TOTAL all strokes	117,600	148,697	186,917	950,200	1,424,149	2,119,430

To estimate the costs of stroke we break down the overall incidence and prevalence numbers by stroke type (ischaemic and haemorrhagic) and stroke severity. For these purposes, we collapsed stroke severity based on NIHSS scores into fewer categories than described for the earlier work in Section 2.1.1, as follows: low=categories 1-3 (i.e. NIHSS scores of 0-15); high=categories 4-5 (i.e. NIHSS scores of 16-42). Our breakdown of prevalence by stroke type and severity is based on figures used in the NGC & SSNAP economic modelling work (NGC & SSNAP, 2016; Table 6). In the absence of equivalent data for incidence, we assume that the breakdown by type of stroke is the same for incidence and for prevalence. We assume that the breakdown by severity however is not the same for incidence and prevalence since survival varies by severity. In the absence of information we assume that the proportion of incident strokes which are severe is twice the proportion of prevalent strokes which are severe. The breakdown which we use is set out in Table 4.3.

Table 4.3: Breakdown of incident and prevalent strokes by type of stroke and severity

Incident strokes					
		MALE		FEMALE	
Age group	Severity	Ischaemic	Haemorrhagic	Ischaemic	Haemorrhagic
40-64	Low	0.79	0.07	0.78	0.06
40-64	High	0.10	0.04	0.12	0.04
65-74	Low	0.78	0.06	0.72	0.06
65-74	High	0.14	0.02	0.18	0.04
75-84	Low	0.71	0.07	0.64	0.06
75-84	High	0.18	0.04	0.24	0.06
85+	Low	0.60	0.06	0.50	0.04
85+	High	0.28	0.06	0.40	0.06
Prevalent strokes					
		MALE		FEMALE	
Age group	Severity	Ischaemic	Haemorrhagic	Ischaemic	Haemorrhagic
40-64	Low	0.85	0.08	0.85	0.07
40-64	High	0.05	0.02	0.06	0.02
65-74	Low	0.85	0.07	0.82	0.07
65-74	High	0.07	0.01	0.09	0.02
75-84	Low	0.81	0.08	0.78	0.07
75-84	High	0.09	0.02	0.12	0.03
85+	Low	0.76	0.07	0.71	0.06
85+	High	0.14	0.03	0.20	0.03

Source: NGC & SSNAP, 2016; own calculations. Low= NIHSS scores of 0-15, High=NIHSS scores of 16-42.

4.1.2 Annual estimates of health and social care costs

Our estimates of the health and social care costs of stroke in 2015 are derived from the first work stream described in Section 2. These vary by age, gender, type of stroke and severity of stroke.

They also vary between costs in the first year following a stroke and costs in subsequent years. Data on average annual health and social care costs for selected age bands are set out in Table 2.12.

4.1.3 Cost inclusions and exclusions

It is important to note that the health care costs cover costs relating to Accident and Emergency (A&E) departments, acute and regular stroke units and early supported discharge but do not include any primary care costs or costs associated with any co-morbidities. The social care costs include the costs of both publicly and privately funded care. As we do not have a source for the breakdown between public and private social care expenditure specific to stroke patients, we use projections of social care expenditure for all older adults from the Personal Social Services Research Unit projections model (Wittenberg and Hu, 2015). Publicly funded social care includes Personal Social Services net expenditure and expenditure funded by Attendance Allowance, but excludes NHS expenditure. Private expenditure includes user charges and privately purchased social care expenditure.

4.1.4 Annual estimates of unpaid care and lost productivity

Our estimates of the costs associated with unpaid care for stroke survivors and of costs associated with lost productivity of people with stroke in 2015 are derived from the literature as discussed Section 2. These vary by age, gender and type of stroke but not by severity of stroke. They also vary between costs in the first year following a stroke and costs in subsequent years. Data on average annual unpaid care and lost productivity costs for selected age bands are set out in Table 2.12.

4.1.5 Projections labour cost changes

Since health and social care services are highly labour-intensive their costs are likely to rise broadly in line with the average earnings of their staff. We assume therefore as our central case that they will rise by 2% per year in real terms. This is based on the Office for Budget Responsibility (OBR) assumption that average earnings (in real terms) and productivity will rise by 2% per year (Office for Budget Responsibility, 2017). This assumption is varied in sensitivity analysis.

4.1.6 Sensitivity analyses

We investigate the sensitivity of the projections to three factors: trends in population mortality rates, trends in stroke incidence and prevalence rates and trends in real annual costs of care. Since there is no clear upper and lower bounds for these trends we examine plausible ranges drawing on ONS assumptions for mortality rates and the Delphi-style survey findings for incidence and prevalence rates.

4.2 Results

4.2.1 Projected costs of stroke

On the basis of these average annual costs, our central assumption on real rises in these costs and our central projections of numbers of strokes and people surviving with stroke, we project that the overall costs of stroke in the UK will rise from £26 billion in 2015 to £43 billion in 2025 and £75 billion in 2035, in constant 2015 prices. This comprises projected increases in health care costs of 201%, social care costs of 273%, unpaid care costs of 171% and lost productivity costs of 136%. It is estimated that private social care costs will rise to a slightly greater rate than public costs: 278% to 268% respectively. These projections are set out in more detail in Table 4.4.

Table 4.4: Projections of future costs of stroke – Base case, by type of cost (in £million)

AGE 45 AND OVER				
Costs (£m)	2015	2025	2035	% change
Health care	3,392	5,884	10,193	200.5%
Social care - Public	2,441	4,716	8,981	267.9%
Social care - Private	2,731	5,361	10,333	278.4%
Social care - Total	5,172	10,078	19,313	273.4%
Unpaid care	15,575	24,366	42,219	171.1%
Lost productivity	1,491	2,294	3,515	135.7%
Total	25,630	42,622	75,241	193.6%

AGE 45 to 64				
Costs (£m)	2015	2025	2035	% change
Health care	598	868	1,073	79.4%
Social care - Public	248	372	472	90.0%
Social care - Private	278	423	543	95.4%
Social care - Total	526	795	1,015	92.8%
Unpaid care	3,676	5,169	6,583	79.1%
Lost productivity	646	965	1,239	91.7%
Total	5,447	7,796	9,910	81.9%

AGE 65 AND OVER				
Costs (£m)	2015	2025	2035	% change
Health care	2,794	5,016	9,120	226.5%
Social care - Public	2,193	4,344	8,509	288.0%
Social care - Private	2,453	4,939	9,790	299.1%

Social care - Total	4,646	9,283	18,299	293.9%
Unpaid care	11,899	19,198	35,636	199.5%
Lost productivity	845	1,329	2,276	169.4%
Total	20,183	34,826	65,331	223.7%

The increase for social care services is especially high because the social care cost per person rises much more sharply with age than the health, unpaid care or lost productivity costs, and the population aged 75 and over is projected to rise more rapidly over the next 20 years than the population aged 45 to 74. In the case of people who have survived ischaemic stroke, the annual average social care cost per person at age 75 and over is more than twice the cost at ages 45 to 74. The annual average health cost, however, varies far less by age. As we would expect, with the exception of lost productivity, costs are significantly higher for the older age group.

4.2.2 Projected costs of care, by country

We first produce separate projections of number of strokes and number of stroke survivors for England, Scotland, Wales and Northern Ireland. As per the projections for the United Kingdom overall, the initial input for the modelling was the official population projections by gender and 5-year age bands for each of the constituent countries in the UK. These data are obtained for England from the Office of National Statistics (NOMIS data tool; 2017); for Wales from StatsWales (2017); for Scotland from National Records of Scotland (2017); and for Northern Ireland from the Northern Ireland Statistics and Research Agency (2017). We assume that the current and projected future incidence and prevalence rates of stroke by age and gender in each country are the same as in the UK estimates. Also, it is assumed that the break down by stroke type and stroke severity is the same in England, Wales, Scotland and Northern Ireland as for the UK. Based on these data and assumptions, we estimate current and future incidence and prevalence numbers for each constituent country in the UK, broken down by gender. The

projected numbers rise more rapidly in Northern Ireland and less rapidly in Scotland and Wales than in England (Table 4.5)

Table 4.5: Projections of stroke incidence and prevalence by country and gender

	Incidence			Prevalence		
	2015	2025	2035	2015	2025	2035
England						
Female	50,230	62,414	79,428	366,864	551,380	848,771
Male	48,252	62,481	78,194	428,122	643,833	934,496
Total	98,482	124,895	157,622	794,989	1,195,213	1,783,267
Wales						
Female	3,166	3,823	4,721	23,283	34,120	50,820
Male	3,046	3,804	4,575	27,073	39,553	54,916
Total	6,212	7,627	9,295	50,356	76,673	105,736
Scotland						
Female	5,120	6,181	7,584	37,788	54,944	82,250
Male	4,808	6,104	7,440	42,980	63,096	91,065
Total	9,928	12,285	15,024	80,768	118,041	173,315
Northern Ireland						
Female	1,523	1,935	2,498	11,138	17,094	26,939
Male	1,448	1,949	2,476	12,947	20,110	30,184
Total	2,971	3,884	4,974	24,085	37,204	57,123
UK						
Female	60,044	74,357	94,233	439,077	657,547	1,008,775
Male	57,556	74,341	92,686	511,123	766,602	1,110,655
Total	117,600	148,698	186,919	950,200	1,424,149	2,119,430

According to recent SSNAP data (Royal College of Physicians, 2017), among those stroke survivors eligible for a 6 month review and receiving it, a third had moderate to severe disability. If we assume this proportion is the same across the four nations, and apply it to our national estimates of future prevalence, approximately 590,000, 35,000, 57,000 and 19,000 people will be living with moderate to severe disability after stroke in 2035 in England, Wales, Scotland and Northern Ireland respectively. These figures are merely indicative due to the low relevant sample size available in the SSNAP dataset and uncertainty regarding whether we can extrapolate figures from that SSNAP reporting period to 2035 since the increased survival expected by the Delphi experts suggests that the breakdown by disability of the survivors will change over time.

We then produce separate projections of the costs of stroke for each of the four countries. We assume that the annual costs per person (by age, gender, type of stroke and severity of stroke) do not differ between Scotland, Wales and Northern Ireland but are 5% higher in England than in the other countries. This is to allow, on an illustrative basis, for the higher costs of health and social care and higher average earnings in London and the South East. The projected costs rise more rapidly in Northern Ireland and less rapidly in Scotland and Wales than in England (Tables 4.6)

Table 4.6: Projections of future costs of stroke – Age 45 and over, by country and type of cost (in £million)

ENGLAND				
Costs (£m)	2015	2025	2035	% change
Health care	2,983	5,189	9,015	202.2%
Social care - Public	2,148	4,163	7,936	269.4%
Social care - Private	2,403	4,733	9,130	280.0%
Social care - Total	4,551	8,896	17,066	275.0%

Unpaid care	13,675	21,453	37,300	172.8%
Lost productivity	1,305	2,012	3,106	138.0%
Total	22,514	37,550	66,487	195.3%

WALES

Costs (£m)	2015	2025	2035	% change
Health care	133	226	379	189.0%
Social care - Public	96	183	338	255.2%
Social care - Private	108	208	388	265.4%
Social care - Total	204	392	726	260.6%
Unpaid care	613	929	1,549	158.7%
Lost productivity	58	85	123	118.4%
Total	1,008	1,631	2,776	181.2%

SCOTLAND

Costs (£m)	2015	2025	2035	% change
Health care	213	361	615	188.6%
Social care - Public	152	285	542	255.7%
Social care - Private	170	324	624	265.8%
Social care - Total	323	610	1,166	261.1%
Unpaid care	988	1,515	2,574	160.7%
Lost productivity	97	149	218	124.9%
Total	1,620	2,634	4,572	182.2%

NORTHERN IRELAND

Costs (£m)	2015	2025	2035	% change
Health care	64	114	203	219.1%

Social care - Public	45	89	178	293.3%
Social care - Private	50	102	204	304.6%
Social care - Total	96	191	382	299.3%
Unpaid care	296	480	852	188.2%
Lost productivity	29	48	74	149.9%
Total	484	832	1,510	211.9%

4.2.3 Sensitivity analyses

The ONS 2014-based high and low life expectancy variant population projections show the UK population aged 45 and over rising between 2015 and 2035 by 25.9% under the high life expectancy variant and 19.0% under the low life expectancy variant in comparison with 22.5% under the principal projection (our central case). We project that the number of strokes (incidence) will rise by 65.9% under the high life expectancy variant and 52.0% under the low life expectancy variant in comparison with 58.9% under the principal projection and that the numbers of stroke survivors (prevalence) will rise by 131.6% under the high life expectancy variant and 114.4% under the low life expectancy variant in comparison 123.1% with under the principal projection. We further project that the overall costs of stroke in the UK will rise by 205% under the high life expectancy variant and 183% under the low life expectancy variant in comparison with 194% under the principal projection (Table 4.7).

Table 4.7: Projections of future cost of stroke – High and low life expectancy variants, age 45 and over, by type of cost (in £million)

	2015	2025	2035	% change
High life expectancy variant				

Incidence	117,600	150,790	195,070	65.9%
Prevalence	950,200	1,441,830	2,200,700	131.6%
Costs (£m)				
Health care	3,392	5,963	10,616	213.0%
Social care	5,172	10,221	20,154	289.7%
Unpaid care	15,575	24,644	43,697	180.6%
Lost productivity	1,491	2,311	3,584	140.3%
Total	25,630	43,139	78,051	204.5%
Low life expectancy variant				
Incidence	117,600	146,606	178,759	52.0%
Prevalence	950,200	1,406,437	2,037,368	114.4%
Costs (£m)				
Health care	3,392	5,804	9,768	188.0%
Social care	5,172	9,935	18,466	257.0%
Unpaid care	15,575	24,088	40,725	161.5%
Lost productivity	1,491	2,278	3,446	131.0%
Total	25,630	42,104	72,404	182.5%

We assume as a plausible range of uncertainty that the incidence and prevalence rates could rise by between 1 percentage point more or 1 percentage point less per year than in our central case set out above. This broadly reflects the degree of variation in the findings of the Delphi-style survey. While separate sensitivity analyses could be conducted for incidence and for prevalence rates, we have examined them together to avoid presenting large numbers of variant projections.

We project that if incidence and prevalence rates in each age band rise by 1 percentage point per year more than under our central case described above, the number of strokes will rise by 93.9%, the number of people aged 45 and over living with stroke will rise by 171.1% and the overall costs

of stroke will rise by 257% between 2015 and 2035 (Table 4.8). We estimate that if the incidence rate falls by 1 percentage point per year for those aged 45 to 84 and by 0.5 percentage point per year for those aged 85 and over and prevalence rates in each age band rise by 1 percentage point per year more than under our central case described above, the number of strokes will rise by 30.0%, the number of people aged 45 and over living with stroke will rise by 83.2% and the overall costs of stroke will rise by 141% between 2015 and 2035 (Table 4.8).

Table 4.8: Projections of future incidence, prevalence and cost of stroke – Future incidence and prevalence variants, age 45 and over

	2015	2025	2035	% change
High future incidence and prevalence variant				
Incidence	117,600	164,233	227,994	93.9%
Prevalence	950,200	1,570,369	2,575,722	171.1%
Costs (£m)				
Health care	3,392	6,491	12,402	265.7%
Social care	5,172	11,110	23,460	353.6%
Unpaid care	15,575	26,874	51,333	229.6%
Lost productivity	1,491	2,531	4,278	186.9%
Total	25,630	47,006	91,473	256.9%
Low future incidence variant				
Incidence	117,600	134,499	152,938	30.0%
Prevalence	950,200	1,290,299	1,740,628	83.2%
Costs (£m)				
Health care	3,392	5,328	8,362	146.5%
Social care	5,172	9,133	15,869	206.8%
Unpaid care	15,575	22,072	34,656	122.5%
Lost productivity	1,491	2,078	2,883	93.3%

Total	25,630	38,609	61,770	141.0%

For rises in the annual cost of care per person we assume as a plausible range to investigate that they could rise by between 1.5% and 2.5% per year in real terms. Uncertainty in this case arises from two sources: real average earnings might rise faster or slower than the OBR expect and real earnings of health and social care staff might rise faster or slower than overall average earnings in the economy. The latter point is relevant for formal services rather than for unpaid care or lost productivity, but the former point is relevant for all four types of costs.

Variant assumptions on real rises in costs per person have of course no impact on our projections of incidence and prevalence but only on our projections of aggregate costs. If costs per person rose by 2.5% per year in real terms, the overall cost of stroke would rise from £26 billion in 2015 to £83 billion in 2035, an increase of 224%, in constant 2015 prices. If costs per person rose by only 1.5% per year in real terms, the overall cost of stroke would rise from £26 billion in 2015 to £68 billion in 2035, an increase of 166%. These projections should be compared with our central case projection of a rise of 194% in overall costs between 2015 and 2035. Projections of aggregate costs over a 20 year period are inevitably highly sensitive to the assumed real annual rise in costs per person.

5. Potential return on further investment in research

Key messages

- We combine information in Section 3 (research priorities for the future) and Section 4 (projections of future costs) to estimate how the cost projections for 2035 might change if just the top five research priorities were met by investing more money in research.
- We also estimate the net benefit per person which might accrue if the investments in research on the top five priorities led to the development of new or improved treatments or preventative measures.
- Such estimations require various assumptions about what the impact of that research might be. We largely rely on the experts' views on this, but it is also necessary for us to make our own further assumptions, for example, on what the costs of that research might be, what kind of new or improved treatments that research might result in, what costs would be saved and quality of life benefits generated by these treatments and what would be the timing of any potential costs and benefits.
- We estimate that investing £10 million into each of the top five research priorities could potentially generate the following savings in 2035 (at 2015 prices):
    - physical rehabilitation: £850 million in societal costs (1.1% saving)
    - cognitive rehabilitation: £725 million in societal costs (1.0% saving)
    - vascular dementia: by £2.4 billion in societal costs (3.2% saving)
    - thrombectomy: £400 million in societal costs (0.5% saving)
    - implementing interventions evidenced to work: £4.0 billion savings due to improved stroke prevention (5.3% saving) and £1.3 billion savings due to a treatment that improves stroke survival (1.8% saving).
- Research that has the potential to reduce the number of people suffering a stroke naturally provides the greatest opportunity for averting future costs.

5.1 Methods

We set out to estimate how the cost projections set out in Section 4 might change and what net benefits might accrue if there were increased investment in stroke research. It is difficult, if not impossible, to know or estimate potential future returns from general increases in research investment. Such estimations have been produced in several clinical areas (see Appendix 5.1 for a summary of some reviews of such exercises) but tend to be retrospective rather than prospective, and all approaches carry their own limitations, not least the matter of attributing benefits/savings to research. To enable an assessment of potential savings in the future, and to make these as specific as possible, it is useful to focus on particular scenarios of research investment. To do so, we refer back to the five priority areas for future stroke research that were identified by the Delphi-style consultation with experts (as described in Section 3):

- Rehabilitation
- Cognition
- Vascular dementia
- Thrombectomy
- Implementing interventions that are evidenced to work

We focus on these five areas, rather than stroke research more broadly, to indicate some of the potential returns to be gained by investing in more stroke research.

A key task is to specify the potential impacts of addressing these five priority areas. We do so by first returning to Round 1 Delphi questionnaire data, which provides respondent views on the potential benefits of addressing these research priorities, as viewed by experts who chose these in their own list of three research priorities. See Appendix 5.2 for a full list of these expected benefits, by research priority. For each research priority in turn, we translate these expected benefits into specific changes to apply to relevant parameters in the cost projections reported in Section 4. The sections below detail these changes, plus the broader assumptions underpinning

them, and report the consequent changes to our cost projections as illustrations of potential returns from further investment in key stroke research.

We express our findings on the potential value for money of each of the research priorities in terms of the net benefit per person receiving the new intervention. We estimate the net benefit in terms of:

- costs and savings to public funds on health and social care;
- costs and savings to formal services, including privately funded social care;
- costs and savings to all forms of care, including unpaid care;
- costs and savings to society including value of assumed gains in QALYs covering both increased survival and improved quality of life.

Further details of our overall approach are provided in Appendix 5.3. We have not estimated the internal rate of return (IRR) to the five suggested research programmes because estimates of IRR – which is the rate of return that sets the net present value (NPV) of the flow of costs and benefits of an investment to zero - would be more sensitive than estimates of net benefit per person receiving the new intervention to assumptions about the number of years during which the new intervention developed as a result of the research programme remained the most cost-effective intervention available, that is the duration before it is superseded by a newer more cost-effective intervention.

To illustrate this point by way of an example, an investment costing £10 million which produces a return of £1.5 million per year (at constant prices) for 10 years has an IRR of around 12%. But if the same investment produced a return of £1.5 million per year (at constant prices) for 15 years the IRR would be around 16.5%.

5.2 Research on stroke rehabilitation (physical and cognitive): assumptions and findings

We report the priority areas of stroke rehabilitation (which we take to mean physical rehabilitation) and cognitive rehabilitation.

We assume that two programmes of research - one of each type of rehabilitation - costing £10 million each start by 2020 and that each consists of several studies to evaluate the effectiveness and cost-effectiveness of different new rehabilitation interventions. We further assume that at least one of the studies in each of the two programmes produces positive findings by latest 2025. We assume also that the new interventions are not superseded by better ones until at least 2036.

Since positive findings could, if the new rehabilitation interventions are made widely available, potentially benefit hundreds of thousands of stroke survivors over the coming years, the cost of the research per person benefiting would be low.

We assume, based on the evidence outlined in Section 2, that there are currently around 117,600 incident strokes per year and that there are 950,200 stroke survivors in the UK. This implies an average survival after a stroke of around 8 years in 2015. The Delphi experts advised that prevalence rates are likely to rise faster than incidence rates. We assume that in 2025 there will be around 148,700 incident strokes per year and that there will be some 1,424,150 stroke survivors in the UK. This implies an average survival after a stroke of around 10 years in 2025.

Analysis of South London stroke data by Chen et al. (2014) found 34% of people experiencing a stroke died with 12 months and 41% within 48 months. The average survival in 2025 of those who survive at least 12 months will on this basis be around 15 years. This in turn implies a mortality rate of around 10% in the second year after a stroke and then an average rate of around 6.5% in subsequent years. Since those who die within 12 months of a stroke (of whom most die in the first three months) are unlikely to receive the new rehabilitation intervention this mortality rate seems relevant for those receiving the intervention.

5.2.1 Rehabilitation of physical function

The five experts recommending this topic in Round 1 of the Delphi-style consultation considered that improved stroke rehabilitation would:

- have no impact on future stroke incidence or prevalence rates;
- likely improve patient quality of life and physical functioning within 10 years;
- likely improve patient psychological functioning, social functioning and employment prospects and reduce carer burden in 11-20 years; and
- likely yield savings on health and social care costs in 11-20 years.

But the experts were not unanimous on all these points.

The beneficial effects of the new intervention might not endure throughout the person's life, in particular because of comorbidities in late life. We assume therefore that they will typically last for 5 years for all those receiving rehabilitation regardless of their age

If we assume that the new intervention is offered to 10% of people experiencing a stroke from 2025 onward, there would be no (or minimal) impact in 2025 but by 2030 some 100,000 stroke survivors would have received it, around 6% of stroke survivors. If we then assume that the new intervention is offered to 20% of people experiencing a stroke (new or repeat) from 2030 onward, some 230,000 stroke survivors in 2035 would have received it, around 11% of stroke survivors.

If we assume, in the absence of robust evidence, that each person receiving the new rehabilitation intervention experiences improved quality of life in each year for 5 years averaging 0.1 on the EQ-5D tariff (Dolan et al., 1995), this would be 0.5 quality-adjusted life years (QALYs) per person with a monetary value of £10,000 if a QALY is valued at £20,000, which is the cost-effectiveness threshold used by NICE (NICE, 2013). This is of course just illustrative.

Around two-thirds of disabled older people living in the community have at least one unpaid care (authors' analysis of Health Survey for England data). If we assume that one main carer of each person with a carer receiving the intervention experiences improved quality of life in each year

for 5 years averaging 0.05 on the EQ-5D tariff, this would be 0.25 QALYs per person with a monetary value of £5,000. This is of course again just illustrative.

The new intervention is unlikely to yield any savings to health care costs in the period immediately following the stroke. To be cautious we assume savings of 10% of health care costs in years 2 to 5 after the stroke. We assume that it will yield savings of 20% of social care costs and unpaid care costs in years 1 to 5 after the stroke and savings of 10% of lost productivity costs in years 1 to 5.

To calculate an estimated net benefit for a person receiving the new intervention in 2025 we assume an illustrative cost of the research assigned to the person of £100 and cost of the intervention itself of £5,000. This estimate of £5,000, which is around twice the average cost of home care reablement, need not all be incurred in the first year after the stroke: it might be spread over the first few years if the intervention included, for example, 'refresher' rehabilitation. We assume that the costs of the intervention would be met fully by the NHS and local authorities but that around half the savings on social care would accrue to individuals funding their own care and half to local authorities. We apply a discount rate of 3.5% real.

On this basis the estimates at 2015 prices are as follows:

- Net benefit on the basis of costs and savings to public funds: -£200
- Net benefit on the basis of costs and savings to formal services: £3,100
- Net benefit including savings to unpaid carer costs: £22,100
- Net benefit including value of assumed quality of life gains: £28,300

These are of course just estimates based on the above assumptions.

Under this scenario, total expenditure on stroke in the UK, covering health care, formal social care, unpaid social care and lost productivity, would rise from around £25.6bn in 2015 and £42.6bn in 2025 to £74.3bn in 2035, as opposed to £75.2bn without this new intervention, a saving of some £850m (all at constant 2015 prices).

5.2.2 Cognitive rehabilitation

The five experts recommending this topic in Round 1 of the Delphi-style consultation considered that improved cognitive rehabilitation would have similar impacts as improved rehabilitation of physical function except that it would also result in improved stroke survival. Some of the experts considered that it would lead to fewer repeat strokes, which would presumably be one of the drivers of the improved survival.

We assume that the new cognitive rehabilitation intervention would have the same impacts in terms of savings and benefits as the new physical functioning rehabilitation intervention but would also extend survival by one year. We assume that this extra year would comprise 0.85 QALYs, since a quality of life rating of 0.85 would be typical in old age. These are of course illustrative assumptions.

We again assume an illustrative cost of the research assigned of £100 per person and cost of the intervention itself of £5,000. We assume that the costs of the intervention would be met fully by the NHS and local authorities but that around half the savings on social care would accrue to individuals funding their own care and half to local authorities. We apply a discount rate of 3.5% real, as recommended by HM Treasury (2011), to costs and benefits.

On this basis the estimates at 2015 prices are as follows:

- Net benefit on the basis of costs and savings to public funds: -£6,300
- Net benefit on the basis of costs and savings to formal services: -£5,800
- Net benefit including savings to unpaid carer costs: £8,500
- Net benefit including value of assumed quality of life gains: £18,600

These are of course just estimates based on the assumptions set out above. They are less favourable than the estimates for rehabilitation of physical function because of the assumed costs of care in the extra year of survival.

Under this scenario, total expenditure on stroke in the UK, covering health care, formal social care, unpaid social care and lost productivity, would rise from around £25.6bn in 2015 and

£42.6bn in 2025 to £74.5bn in 2035, as opposed to £75.2bn without this new intervention, a saving of some £725m (all at constant 2015 prices).

5.3 Research on vascular dementia: assumptions and findings

We assume that this research priority would involve development of better treatment of small vessel disease leading to reduced incidence of both stroke and vascular dementia. We focus on the impact on incidence rates of stroke. We assume that the intervention would reduce the incidence of stroke by 5% from 2025 onward. The improvement in quality of life and reduction in care needs relates to those whose stroke is prevented by the intervention. We also assume that the overall cost of the intervention would be £10 million; that the intervention and this cost will commence in 2022; and due to the likely need for the programme to be repeated we assume that costs of £10 million would be incurred again in 2030 and again in 2035.

Under these assumptions, the prevalence of stroke would increase from 950,200 in 2015 to 1.42 million in 2025 and 2.05 million in 2035 as compared to increases to 1.42 million in 2025 and 2.12 million in 2035 without the improvement in prevention. Thus under the assumptions set out above, the number of stroke survivors in 2035 would be around 70,000 lower than without improved prevention and the prevalence of stroke would increase by 116% between 2015 and 2035 as compared to an increase of 123% without improved prevention

On the basis of our central projections of numbers of strokes and people surviving with stroke, we project that the overall costs of stroke in the UK will rise from £25.6 billion in 2015 to £42.6 billion in 2025 and £75.2 billion in 2035, an increase of 194% over 20 years, in constant 2015 prices. Under the assumptions set out above for improved treatment of small vessel disease, the overall costs of stroke in the UK will rise from £25.6 billion in 2015 to £42.4 billion in 2025 and £72.8 billion in 2035, an increase of 184% over 20 years, at constant 2015 prices. Thus this

intervention has the potential to reduce overall projected costs of stoke in 2035 by £2.4 billion, in 2015 prices.

There are, however, caveats with these estimates. People whose strokes are prevented would gain additional life years during which they would require health and social care. Our projection does not take account of the cost of this care during the additional life years gained or the value of the quality-adjusted life years gained.

5.4 Research on thrombectomy: assumptions and findings

The three experts recommending this topic in Round 1 of the Delphi-style consultation considered that thrombectomy would:

- likely have no impact on future stroke incidence but would lead to greater stroke survival within 10 years;
- likely improve patient quality of life and physical functioning within 10 years;
- likely improve patient psychological functioning, social functioning and employment prospects and reduce carer burden within 10 years; and
- likely yield savings on health and social care costs within 10 years.

The experts were unanimous on all these points except that one expert considered that fewer subsequent strokes would occur and one that the social care savings would likely be after year 10.

We assume that the new intervention consists of a technique that enables thrombectomy be conducted safely and effectively for a wider group of stroke patients than currently. If we assume that it will be offered to (a further) 5% of people experiencing a stroke from 2025 onward, there would be no (or minimal) impact in 2025 but by 2030 some 50,000 stroke survivors would have received it, around 3% of stroke survivors. If we then assume that the new intervention is offered

to 10% of people experiencing a stroke (new or repeat) from 2030 onward, some 115,000 stroke survivors in 2035 would have received it, around 5.5% of stroke survivors.

We assume that the benefits for the patients concerned would be similar to those of cognitive rehabilitation, that is:

- one additional year of life on average, comprising 0.85 QALYs;
- improved quality of life of the person with stroke in each year for 5 years averaging 0.1 on the EQ-5D tariff;
- improved quality of life of the carer for 5 years averaging 0.05 on the EQ-5D tariff;
- savings of 10% of health care costs in years 2 to 5 after the stroke; and
- savings of 20% of social care costs and unpaid care costs and savings of 10% of lost productivity costs in years 1 to 5 after the stroke.

We again assume an illustrative cost of the research of £100 per person and cost of the intervention itself of £5,000. We assume that the costs of the intervention would be met fully by the NHS and local authorities but that around half the savings on social care would accrue to individuals funding their own care and half to local authorities.

On this basis the estimates at 2015 prices are as follows:

- Net benefit on the basis of costs and savings to public funds: -£6,300
- Net benefit on the basis of costs and savings to formal services: -£5,800
- Net benefit including savings to unpaid carer costs: £8,500
- Net benefit including value of assumed quality of life gains: £18,600

These are of course just estimates based on the assumptions set out above.

Under this scenario, total expenditure on stroke in the UK, covering health care, formal social care, unpaid social care and lost productivity, would rise from around £25.6bn in 2015 and £42.6bn in 2025 to £74.8bn in 2035, as opposed to £75.2bn without this new intervention, a saving of some £400m (all at constant 2015 prices).

5.5 Research on implementing interventions known to be effective: assumptions and findings

Twelve experts recommended this topic in Round 1 of the Delphi-style consultation. More effective implementation of evidence-based measures could relate to prevention or treatment or both. Here we consider separately improved prevention leading to reduced incidence and improved treatment leading to reduced need for ongoing care and improved quality of life.

5.5.1 Improved prevention of stroke

We assume that improvement of cardiovascular risk factors would be the mechanism to prevent strokes, resulting in a lower prevalence of stroke over time. We assume that successful evidence-based measures to reducing risk factors would have the impact of reducing the incidence of stroke by 5% beginning in 2025 and would lead to a further 5% reduction in stroke incidence from 2030 onward. We also assume that the overall cost of the intervention would be £10 million; that the intervention and its cost will commence in 2022; and due to the likely need for the prevention programme to be repeated we assume that costs of £10 million would be incurred again in 2030 and again in 2035.

Under these assumptions, the prevalence of stroke would increase from 950,200 in 2015 to 1.4m in 2025 and 2.0m in 2035 as compared with increases to 1.5m in 2025 and 2.1m in 2035 without the improvement in prevention. Thus under the assumptions set out above, the number of stroke survivors in 2035 would be around 114,000 lower than without improved prevention and the prevalence of stroke would increase by 111% by 2035 as compared to an increase of 123% without improved prevention.

On the basis of our central projections of numbers of strokes and people surviving with stroke, we project that the overall costs of stroke in the UK will rise from £25.6 billion in 2015 to £42.6 billion in 2025 and £75.2 billion in 2035, an increase of 194% over 20 years, in constant 2015 prices. Under the assumptions set out above for improved prevention, overall costs in the UK will

rise from £25.6 billion in 2015 to £42.4 billion in 2025 and £71.2 billion in 2035, an increase of 178% over 20 years, in constant 2015 prices. Thus this intervention has the potential to reduce overall projected costs of stroke in 2035 by £4.0 billion, in 2015 prices.

There are, however, caveats with these estimates. As stated for the scenario related to vascular dementia research, people whose strokes are prevented would gain additional life years during which they would require health and social care. Our projection does not take account of the cost of this care during the additional life years gained.

5.5.2 Improved treatment of stroke survivors

To model improved treatment based on evidence based interventions we sought guidance from the SSNAP 2015/16 Annual Report (Royal College of Physicians, 2016) which includes a section on putting evidence into practice. This report identifies several interventions and we select one that does not duplicate our other scenarios or those covered by the NGC/SSNAP modelling work (which examined increased implementation of thrombolysis and early supported discharge services). Intermittent Pneumatic Compression (IPC) is stated as an intervention that can reduce the risk that a person admitted to hospital with a stroke will develop a deep vein thrombosis (Royal College of Physicians, 2016). According to the report, while 50% of patients are immobile and cannot walk independently after their stroke, only 16.6% receive IPC. Further, in the few hospitals where IPC has been implemented effectively, some 64.9% of immobile patients received this intervention.

We assume that wider implementation of IPC would have impacts in terms of savings and benefits similar to those arising from a new physical functioning rehabilitation intervention outlined in Section 5.2.1, but that IPC would be implemented sooner and would extend survival.

If we assume that IPC is offered to an additional 15% of people experiencing a stroke from 2020 onward, with impact within one year, by 2025 an additional 140,000 stroke survivors would have

received it. This would represent a doubling of current IPC use. We then assume that it is offered to 25% of people experiencing a stroke (new or repeat) from 2025 onward.

We assume that the additional patients offered IPC would on average gain one additional year of survival as a result of the reduced risk of DVT. This extra year would comprise 0.85 QALYs, since a quality of life rating of 0.85 would be typical in old age. As previously, these are of course illustrative assumptions.

We again assume an illustrative cost of the research of £100 per person and cost of the intervention itself of £500, primarily to account for staff time. As previously, we assume that the costs of the intervention would be met fully by the NHS but that around half the savings on social care would accrue to individuals funding their own care and half to local authorities. We apply a discount rate of 3.5% real.

On this basis the estimates at 2015 prices are as follows:

- Net benefit on the basis of costs and savings to public funds: -£400
- Net benefit on the basis of costs and savings to formal services: £800
- Net benefit including savings to unpaid carer costs: £15,000
- Net benefit including value of assumed quality of life gains: £24,000

These are of course just estimates based on the assumptions set out above.

Under this scenario, total expenditure on stroke in the UK, covering health care, formal social care, unpaid social care and lost productivity, would rise from around £25.6bn in 2015 to £42.0bn in 2025 and £73.9bn in 2035, as opposed to £75.2bn without this new intervention, a saving of some £1.3bn (all at constant 2015 prices).

6. Economic case for wider implementation of interventions that work

Key messages

- To acknowledge and highlight the importance of investing in expansion of services as well as in research, this last section examines evidence for various existing interventions that have potential for broader implementation and the associated gains. Where appropriate, we produce new estimates to illustrate potential cost savings.
- We review evidence on various interventions related to rehabilitation/long term care, acute care and prevention: early mobilisation, physiotherapy, occupational therapy, speech and language therapy, psychological assessment and support, early supported discharge, centralisation of acute care services, thrombolysis, thrombectomy, management of atrial fibrillation and management of hypertension.
- In summary, in the broad area of rehabilitation and long-term care, we find savings potential from extending early supported discharge provision and preventing post-stroke pneumonia through better management of dysphagia. Economic evidence for effective interventions related to physiotherapy, occupational therapy and psychological support, especially in the longer term, is sparse – as also suggested by the research priorities identified by experts (Section 3). In acute care, centralising services to increase the delivery of effective urgent care offers opportunities to decrease mortality and reduce hospital stay and there is much scope to reduce costs by increasing the proportion of eligible people who receive thombolysis and thrombectomy. Better stroke prevention, in the form of greater diagnosis and treatment of atrial fibrillation and hypertension, offers significant scope for cost savings. More specifically:

Rehabilitation/long term care

- A significant body of evidence related to various types of physical rehabilitation indicates its effectiveness for recovery of function and mobility after stroke (Pollock et al., 2014). In comparison, the evidence base for occupational therapy interventions is smaller but suggests improved outcomes from interventions focussing on activities of daily living (Legg et al., 2007). Evidence for rehabilitation therapy in the longer term is limited (Aziz et al., 2009).
- A fifth of people with ischaemic stroke are likely to suffer from dysphagia and a fifth of these are likely to develop pneumonia (Arnold et al., 2016). This means that around 4700 people annually experience pneumonia following an ischaemic stroke in the UK, incurring an annual treatment cost of approximately £2.5 million.
- NHS England estimates for extending provision of early supported discharge schemes following a stroke suggest that 170 lives could potentially be saved in England and a saving of £15,100 per 100,000 people realised (NHS England, 2014).
- It is thus difficult to draw robust conclusions on effectiveness or cost-effectiveness of psychological support for stroke patients because evidence is limited in extent, quality and nature. Also, screening for psychological state after stroke remains hampered by clinician uncertainty about which screening tools to use.

Acute care

- Major acute system reconfiguration to increase delivery of effective urgent care has been successful in London and Greater Manchester (Morris et al., 2015). In London, a significantly higher proportion of patients received care compliant with care processes and the new model delivered a 5% relative reduction in mortality at 90 days. Both areas saw reductions in length of hospital stay. The West Midlands is another major urban region with a population size broadly equivalent to Greater Manchester's so could potentially achieve similar gains to the Greater Manchester reconfiguration i.e. ~18,000 hospital days/£5 million saving over 2 years.

- Delivering thombolysis within three hours of stroke is effective in reducing death or dependency (Wardlaw et al., 2014). We estimate that for the 2,000 eligible patients who do not receive the drug each year the NHS incurs £8.2 million in avoidable costs over 5 years.
- Thrombectomy is highly cost-effective, with an incremental cost per QALY gained of £7,061 (over 20 year horizon) – significantly lower than many other NHS interventions (Ganesalingam et al., 2015). Guijarro et al. (2017) suggest that on average one extra patient receiving thrombectomy would save the NHS £47,000 over 5 years, thus representing potential annual savings of millions. The benefits of thrombectomy are substantial: for every 100 patients treated, 38 have a less disabled outcome than with best medical management, and 20 more achieve functional independence (mRS 0–2) (Goyal et al., 2016). Thus higher treatment costs in the short term can be offset in the longer term (Lobotesis et al., 2016).

Prevention

- We estimate that an atrial fibrillation screening programme could avoid 500 new strokes each year. This corresponds to £10.7 million of savings to NHS & social care or £28.4 million of savings in broader societal costs. Accounting for longer term post-stroke survival rates, potential cost savings to society (excluding costs of implementing the intervention) over a 5 year period amount to £233 million, £147 million of which relates to the opportunity cost of unpaid care and lost employment opportunities.
- Appropriate anticoagulant management of atrial fibrillation in all eligible patients could avert an estimated 4,551 strokes each year. This translates to £97 million savings in NHS & social care costs or £259 million savings in societal costs in the first year. Over 5 years, corresponding savings would be 22,755 fewer new strokes, 8,727 fewer prevalent cases

of stroke and societal savings of £2 billion, including £691 million savings to NHS & social care.

- Increasing time spent within the therapeutic range for warfarin from 60% to 70% can potentially result in societal cost savings of £908 million within 5 years of implementation.
- A successful strategy to increase the proportion of diagnosed hypertension cases by 15% could potentially avoid 10,790 new cases and 4,138 prevalent cases of stroke over 5 years, yielding potential cost savings of £772 million to society, £284 million of which is attributed to NHS & social care.
- A strategy to increase the proportion of patients on treatment for hypertension who achieve blood pressure <140/90 mm Hg from 63% to 78% would allow an additional 1.3 million patients to benefit from a reduced risk of stroke. Improved blood pressure control can avoid an estimated 2,000 new stroke cases each year.
- Increasing the proportion of individuals with diagnosed hypertension who achieve blood pressure <140/90 mm Hg by 15% could potentially save £36.1 million in NHS & social care for first-time stroke each year. A further £51.8 million of informal care and £2.9m of lost employment costs could be avoided. Over 5 years, 9995 new cases and 3833 prevalent cases of stroke could be avoided, yielding potential cost savings of £715 million to society, £263 million of which is attributed to NHS & social care.

6.1 Introduction

Earlier chapters have described the sizeable current and future burden of stroke and the potential impacts to be gained through further research. While there are clearly many research gaps to address, tackling a public health issue such as stroke requires a broad set of measures working together. For example, ensuring current services and supports are configured optimally in all areas or wider roll out of interventions that are not yet fully implemented despite evidence of effectiveness and/or cost-effective. Indeed, our consultation with experts regarding research

gaps (Section 3) identified the implementation of evidence-based care as one of the priority research gaps to address. Inevitably, current resources, system pressures and practical hurdles create challenges for achieving such measures. Increased investments and a more coordinated approach could alleviate the future burden of stroke, improve outcomes and reduce variations in stroke care. To acknowledge and highlight the importance of further investing in current practice as well as in research, this last section examines evidence for various existing interventions that have potential for broader implementation and various associated gains. Where appropriate, we build on the evidence base to produce new estimates that serve as illustrations of such gains.

6.2 Methods

We conduct a series of focused literature reviews related to interventions spanning three overarching areas of the stroke care pathway: rehabilitation/long-term care, acute care and prevention. As the purpose here is to illustrate the evidence that already exists and potential gains from implementation, rather than to conduct a thorough review of evidence of stroke interventions, these reviews are pragmatic rather than systematic, and focus on identifying interventions with evidence of potential economic gains as well as evidence of effectiveness. Wherever available, we prioritise evidence from systematic reviews over that from individual studies, and on drawing out information that would enable us to highlight or estimate potential economic gains. Our methodological approaches vary across each intervention, led by the nature and strength of evidence.

6.3 Results: rehabilitation/long term care

6.3.1

The AVERT programme assessed very early mobilisation (VEM), delivered with 24 hours of stroke onset, against usual care (Langhorne et al., 2017). They defined early mobilisation as the

commencement of sitting, standing and walking using a clinical protocol tailored to the severity of the stroke. It was delivered by a team of nurses and physiotherapists. Phase III of AVERT randomised 2,104 patients (610 in the UK; Langhorne et al., 2017). The primary outcome was survival without major disability using the modified Rankin scale (a score of 0-2; Howard et al., 2012) at 3 months after stroke. Secondary outcomes included the proportion of patients achieving unassisted walking (50m) by 3 months and health-related quality of life assessed at 12 months.

The trial found that fewer patients in the VEM group survived without major disability (OR 0.73, 95% CI 0.59 to 0.90). There were no significant differences in walking ability at 3 months (VEM 75% vs UC 76%; OR 0.83, 95% CI 0.64 to 1.07) or health related quality of life at 12 months. These results were largely replicated when the analysis was restricted to UK participants only. Among UK participants, the difference between groups on the primary outcome was not statistically significant.

As part of this study, the authors conducted a systematic review of similar randomised controlled trials. They identified eight such studies (including their own) which included 2,618 participants overall. The median time to starting mobilisation after stroke across these studies was 18.5 hours. This was compared 33.3 hours for the participants in the control arms of these studies, described as 'delayed mobilisation'. The meta-analysis of these data found that at 3 months after stroke (n=2,542), early mobilisation showed a non-significant increase in the odds of death or dependency (OR 1.10, 95% CI 0.94 to 1.29). The authors conclude:

"...our high-dose frequent mobilisation protocol within 24 hours of stroke onset was less effective than (usual care) and should not be routinely applied. However, because the (usual care) protocol is also complex in nature, and increasingly featured a shift to early onset mobilisation, then it is over-simplistic to simply advise (usual care). When mobilisations are attempted early after stroke, short, frequent mobilisations are associated with better outcomes. Further exploration of this data set is essential... we propose further dose-response analyses to explore the effect of dose rehabilitation on clinical and safety outcomes."

The conclusion that early mobilisation cannot be assumed to be without benefit is, in part, justified by the authors by having observed significant positive benefit of early mobilisation in a Phase II randomised controlled trial of the same intervention. Based on 71 stroke patients recruited between 2004 and 2006, AVERT found that early mobilisation was significantly associated with returning to independent walking sooner and better Barthel Index scores at 3 months than standard care (Cummings et al., 2011).

6.3.2 Occupational therapy

A systematic review of randomised trials of occupational therapy for patients following stroke was published by Legg et al. (2007). The authors searched for randomised controlled trials in which occupational therapy focussing on activities of daily living was compared to non-routine inputs. The occupational therapy had to be delivered by, or under the supervision of, an occupational therapist. The review found nine relevant studies encompassing 1,258 participants. The participants were mostly drawn from hospital outreach and community settings. One study was set in a community nursing home. Eight of the nine studies were set in the UK and their publication spanned from 1995 to 2006. The median time to follow-up was six months and ranged from 3 to 12 months. Scores for personal activities of daily living were available for eight of the trials – six of which used the Barthel index. A standardised mean difference favouring occupational therapy was observed across these eight studies (SMD 0.18, 95% CI 0.04 to 0.32) which the authors observe as "equivalent to a one point (5%) difference on the 20 point Barthel index, assuming a population (standard deviation) of six points." No significant difference was observed on the secondary outcomes of mood or distress scores for participants and carers. The authors judged the studies to be of a good quality, though acknowledged that, "the exact nature of the interventions in each study differed according to the type of patient, the expertise of the therapist and the resources available".

Another review focussed on the effectiveness of occupational therapy for improving cognitive impairment in stroke patients (Hoffman et al., 2010). It included randomised controlled trials, quasi-randomised studies and cross-over trials; and interventions carried out, or supervised, by

an occupational therapist. The primary outcome measure was assessment of activities of daily living. Only one trial met the inclusion criteria and this was a US-based study published in 1983. It included 33 people who received rehabilitation in hospital following a stroke. The 16 participants in the intervention group received cognitive skills remediation training on an individual basis for 30 to 40 minutes three times per week for an average of three to four weeks. There was no statistically significant difference in Barthel Index score compared with rehabilitation as usual.

Sackley et al. (2016) recently published results from a randomised controlled trial of occupational therapy for care home residents with stroke–related disabilities. This study was set in England and Wales encompassing 228 care homes. Participants had to have a history of stroke or transient ischaemic attack. The intervention was a personalised, three-month course of occupational therapy by qualified therapists and the control consisted of usual care for residents. The primary outcome measure was the Barthel Index of activities of daily living score at three months. Secondary outcomes included the Barthel Index at 6 and 12 months, the Geriatric Depression Scale-15 and European Quality of Life-5 Dimensions. Data were collected from 1,042 individuals between 2010 and 2012. The non-significant adjusted mean difference in the Barthel Index score was 0.19 points higher in the intervention arm (95% CI -0.33 to 0.70). Further, no significant differences on the secondary outcome measures were observed at any of the follow-up time points. The mean cost of the intervention (including training, contact and non-contact time, travel and equipment) per participant was £399 (2010/11 prices). The mean incremental cost in the cost-utility analysis, accounting for intervention and other NHS and (personal social services) PSS costs, was £439 (95% CI -£361 to £1,238; 2010/11 prices) per participant. Inflated to 2015/16 prices, using the hospital and community health services index (Curtis and Burns 2016), the mean intervention cost and incremental cost are £428 and £471 (95% CI -£387 to £1,329) respectively. Thus, scaled up, the cost of the intervention would be £428,000 per 1,000 service users with an overall incremental cost (including intervention and service use) of £471,000 per 1,000 service users.

6.3.3 Physiotherapy

A recent review of randomised controlled trials of physical rehabilitation interventions, delivered by physiotherapists and aimed at promoting recovering balance, lower limb function or general functional ability, was conducted by Pollock et al. (2014). The primary outcomes of the review were measures of disability, including the Barthel and Katz indices; and motor function scales, including the Motor Assessment Scale and Rivermead Motor Assessment. Seven of the studies were set in the UK (or England). Eight of the included studies were published in 2010 or later.

The review identified 96 trials encompassing data from 10,401 participants. As would be expected, this number of studies included a vast range of active interventions – 122 in total. The most common intervention category was functional task training, included as a treatment component in 101 of the interventions. The control group was either no treatment (55 studies), usual care (19 studies) or another active intervention (23 studies).

Different subsets of studies were used across comparisons conducted in the review. Physical rehabilitation was found to have a positive effect on activities of daily living scales (standard mean difference 0.78, 95% CI 0.58 to 0.97) using data from 27 studies (3,423 participants). Data from nine studies were used to determine that this difference persisted beyond the length of the intervention. Pooled data from 12 studies (887 participants) found physical rehabilitation to be more effective than usual care in improving motor function (SMD 0.37, 95% CI 0.20 to 0.55). Physical rehabilitation was also more effective in improving balance (five studies including 246 participants and gait velocity (14 studies including 1,126 participants). The authors conclude that, "physical rehabilitation, comprising a selection of components from different approaches, is effective for recovery of function and mobility after stroke. Evidence related to dose of physical therapy is limited by substantial heterogeneity and does not support robust conclusions".

6.3.4 Physiotherapy and/or occupational therapy

An earlier review by Aziz et al. (2009) looked at the impact of rehabilitation therapy delivered by a physiotherapist or occupational therapist in randomised controlled trials of stroke patients resident in the community more than one year after stroke onset. The control groups were to include routine or usual care received by patients including any therapy provided in outpatient departments or day hospitals. The primary outcome measures were death or poor outcome – the latter defined as death, deterioration in ability to perform activities of daily living, being dependent (based on an activities of daily living scale) or requiring new institutional care placement; and performance of activities of daily living at follow-up.

The review identified five trials for synthesis of data for 487 participants. Two of the included studies were also included in the review by Pollock et al. (2014). Three of the studies were set in the UK but the latest was published in 2006. Two of the studies focussed on physiotherapy, one on occupational therapy and two used a multi-disciplinary rehabilitation intervention where a combination of physiotherapy and occupational therapy in an outpatient setting was used.

As in the Pollock et al. (2014) review, subsets of studies were analysed depending on the comparison and availability of data. Only one study reported poor outcome at the end of six-month follow-up. This was a UK residential care home study with an occupational therapy intervention (Sackley et al., 2006). In this study there was a significant difference in favour of rehabilitation as compared to control on the prevalence of a poor outcome (51% versus 76%, 95% CI 3% to 48%). The pooled data from two of the trials were available to assess differences across the treatment arms on Barthel Index scores (Green et al., 2002; Wade et al., 1992). Both randomised controlled trials were set in the UK and assessed a physiotherapy intervention. There was no significant difference in this outcome between the groups (SMD -0.06, 95% CI -0.32 to 0.20).

A randomised control trial of an intervention by UK NHS physiotherapists and occupational therapists found that an outdoor mobility intervention was neither clinically effective nor cost-effective (Logan et al., 2014). This study included 568 stroke patients living at home. The intervention was a targeted outdoor mobility rehabilitation programme of up to 12 sessions over

four months. The primary outcome was participant health-related quality of life, measured on the Short Form questionnaire-36 items, at six months after randomisation into the study. The median duration of the intervention sessions was 369 minutes (inter-quartile range 170 to 692 minutes). The mean, per-participant, incremental (NHS and PSS) cost of the intervention was £475 (2010/11 prices). Accounting for both intervention costs and other NHS and PSS costs, the difference in costs between groups was £3,414 (95% CI -£448 to £7,121; 2010/11 prices). Inflated to 2015/16 prices, using the hospital and community health services index (Curtis and Burns, 2016), the difference in intervention costs would be £510 and the difference in total costs would be £3,664 (95% CI -£481 to £7,643). Thus, scaled up, the cost of the intervention would be £510,000 per 1,000 service users with an incremental cost of £3,664,000 (including intervention and service use) per 1,000 service users.

6.3.5 Speech and language therapy

Aphasia

A one-year prospective, population-based study in Switzerland estimated that, annually, 43 of 100,000 inhabitants had aphasia resulting from first ischemic stroke (Engelter et al., 2006). In the UK, it has been estimated that of people affected by a stroke each year in the UK, about one third have aphasia, which may be associated with a range of psychosocial health problems that are inadequately addressed by healthcare services (https://www.stroke.org.uk/research/can-singing-group-help-improve-wellbeing-people-post-stroke-aphasia). Extrapolating this proportion to 2025, when we expect annual stroke prevalence in the UK to be 1,424,149 (Section 4), the number affected could rise from approximately 316,000 in 2015 to nearly 475,000 by 2025.

However, cost-effective interventions are still lacking. In a large trial of enhanced communication therapy after stroke for aphasia and dysarthria in the first four months after stroke compared with an attention control (unstructured social contact), the intervention provided no added benefit or savings (Bowen et al., 2012).

Dysphagia

In a prospective registry based study in Switzerland, Arnold et al. (2016) found that dysphagia affected more than a fifth of patients with ischemic stroke and persisted in half of these at hospital discharge. Importantly, severe dysphagia strongly predicted mortality (8.5-fold higher risk of death) at 3 months. Furthermore, it was independently associated with:

- in-hospital pneumonia: occurred in 22.9% of patients with dysphagia versus 1.1% without dysphagia ($p<0.001$);
- discharge destination: higher chance of transfer to a rehabilitation clinic (78.0% vs. 35.4%, $p=0.001$) and a lower chance of being discharged home (19.5% vs. 63.7%, $p=0.001$) compared to those without dysphagia; and
- institutionalisation: at 3 months, those with dysphagia were less likely to live at home (38.8% vs. 76.5%, $p<0.001$).

However, it should be noted that there are wide discrepancies in reported frequencies of dysphagia, often due to differences in screening techniques and tests (Martino et al., 2005). Screening for dysphagia before first oral intake of fluids or food after stroke can reduce aspiration/pneumonia and is recommended regardless of initial stroke severity (Bray et al., 2017; Palli et al., 2017). A registry based study in a national cohort (England and Wales) of unselected stroke patients suggests that patients with the longest delays in dysphagia screening and speech and language therapy (SALT) dysphagia assessment had a higher risk of stroke associated pneumonia, with an absolute increase of pneumonia incidence of 1% per day of delay (Bray et al., 2017). The study also suggests that "30-day mortality was 13.2% overall, 10.2% in patients screened for dysphagia, 14.7% in patients referred for SALT assessment and 34.6% in patients in whom a dysphagia screen was not carried out" (Bray et al., 2017). After adjusting for patient characteristics, there remained a modest association between screening delays in dysphagia and incidence of stroke associated pneumonia, and strong association between delays in comprehensive dysphagia assessment and incidence of stroke associated pneumonia (+3% over

the first 24 hours). Delays beyond 24 hours were associated with an additional 4% absolute increase in incidence of stroke associated pneumonia which is an approximate threefold increase in relative incidence (Bray et al., 2017).

Bray et al. (2017) conclude that "since stroke associated pneumonia is one of the main causes of mortality after acute stroke, early dysphagia assessment may contribute to preventing deaths from acute stroke and could be implemented even in settings without access to high-technology specialist stroke care".

New calculations

Assuming 117,600 new strokes per year in the UK (Section 2; based on mid-point incidence from three studies (Rothwell et al., 2004; Stewart et al., 1999; Wolfe et al., 2002), adjusted for population size and age composition in England in 2016), of which 99,960 (85%) will be ischemic stroke, using incidence figures from Arnold et al. (2016), 20,692 (20.7%) are likely to suffer from dysphagia, and 4,738 (22.9%) of these are likely to develop pneumonia. Associated treatments costs for pneumonia could be approximately £2.5m (based on a unit cost of £532 for treating pneumonia; NHS reference cost 2015-16; currency code DZ23M for non-elective shorts stay).

6.3.6 Early supported discharge

The 2016 SSNAP Acute Organisational Audit (RCP, 2016) found that 81% of hospitals had specialist early supported discharge (ESD) services available to them compared to 74% in 2014. The proportion of people discharged with stroke specialist ESD increased from 25% in 2013/14 to 33% in 2015/2016.

A recent systematic review of early supported discharge services for people with acute stroke (Langhorne et al., 2017) summarised evidence from randomised controlled trials (RCTs) which recruited stroke patients in hospital "to receive either conventional care or any service intervention that has provided rehabilitation and support in a community setting with an aim of reducing the duration of hospital care". The review findings relate to 17 trials which recruited 2,422 participants with outcomes data. The participants tended to be a selected elderly group of

stroke survivors with moderate disability. It should be noted that only 5 of the studies included in the review are post-2007 and only 4 are UK-based studies of which none are post-2007.

The review showed positive findings for appropriately resourced ESD services with co-ordinated multidisciplinary team input provided for a selected group of stroke patients but inconclusive results for services without co-ordinated multidisciplinary team input. The review found that for the ESD group, initial hospital stay was reduced by approximately five days. Also, at an average of six months after stroke, those who received ESD were more likely to be living at home ("an extra five patients living at home for every 100 receiving ESD services; moderate-quality evidence") and more likely to be independent ("an extra six patients independent for every 100 receiving ESD services; moderate-quality evidence"). No risks were identified in terms of readmission risk or patient/carer mood or quality of life. Trials based around a co-ordinated ESD team seemed to suggest the greatest disability reductions. ESD costs ranged from lower to modestly higher than usual care. The authors therefore supported appropriately resourced and co-ordinated ESD as a useful component of a comprehensive stroke service.

Fisher et al. (2015) conducted a cohort study of 293 stroke survivors recruited from two acute stroke units in Nottinghamshire ('ESD' n=135 and 'Non ESD' n=158) and 84 caregivers. The 'Non ESD' group experienced standard practices for discharge and onward referral. Outcomes (primary: Barthel) were assessed at baseline, 6 weeks, 6 months and 12 months. It found that the ESD group had significantly shorter length of hospital stay (P=0.029) and higher levels of satisfaction with services (P<0.001). In an analysis adjusting for baseline age differences, the ESD group had a greater chance of being in the ⩾90 Barthel Index category at 6 weeks (OR = 1.557, 95% CI 2.579 to 8.733), 6 months (OR = 1.541, 95% CI 2.617 to 8.340) and 12 months (OR 0.837, 95% CI 1.306 to 4.087) compared with baseline. Carers in the ESD group also showed improved mental health (P<0.01).

In terms of cost-effectiveness, a modelling study compared stroke unit care followed by ESD with stroke unit care without ESD and with general medical ward care without ESD (Saka et al.,

2009). They used data for incident ischemic stroke cases (N=844), observed between 2001 and 2006, from stroke units in the coverage area of the South London Stroke Register. Main outcome measures were societal costs (health and social care, plus lost income due to morbidity and mortality) and quality-adjusted life-years gained (QALYs). QALYs were estimated from death status and Barthel scores, and 1-year outcomes were extrapolated to a 10 year period, assuming no stroke recurrence. They found that stroke unit care followed by ESD offered the best value for money, with a cost per QALY gain over 10 years of £10,661 compared with the general medical ward without ESD care and £17,721 compared with the stroke unit care without ESD. Thus the additional quality of life benefits derived from ESD are associated with additional costs, but within the acceptable threshold of £20,000 per QALY gain. It is unclear from the paper what the cost-effectiveness ratios would be without the inclusion of lost income costs.

NHS England estimates for extending provision of Early Supported Discharge (ESD) schemes following a stroke - from 20% of patients to 40% of patients - suggest a potential 170 lives could be saved in England and a cost saving of £15,100 per 100,000 (NHS England, 2014). In turn, they cite National Audit Office modelling which suggests that "that increasing the availability of early supported discharge from its current level to all stroke units providing early supported discharge would be cost-effective over a ten-year timeframe, costing about £5,800 per QALY gained" (National Audit Office, 2010).

6.3.7 Psychological support

Treatment interventions

Few randomised controlled trials and even fewer reviews have assessed the effectiveness of psychological support for stroke patients. Those that have been researched include studies of psychotherapy, yoga and mindfulness. A number of interventions which potentially could provide psychological support for stroke patients have, as yet, been assessed for their feasibility only. For example, Simblett et al. (2017) report on the feasibility and acceptability of computerised cognitive behavioural therapy to treat depression and anxiety in stroke patients;

Ali et al. (2014) report the feasibility of art therapy, facilitated by an art psychotherapist, delivered to stroke patients receiving inpatient hospital rehabilitation; and Chan et al. (2012) report on the feasibility of yoga and exercise for improving symptoms of depression and anxiety in individuals with post stroke disability in a small pilot study. Similarly, feasibility studies of interventions to improve the psychological wellbeing of carers of individuals who have had a stroke have been reported in the literature (Woodford et al., 2014).

A recent review of interventions to treat anxiety after stroke identified three trials, including 196 participants (Knapp et al., 2017). They described the quality of the evidence as low. The first trial included was a pilot study of 21 stroke patients and the third considered pharmacological intervention only. The second trial (Wang et al., 2005), set in China, randomised 81 participants, subsequent to a first stroke, with co-morbid anxiety and depression. The intervention group received a pharmacological intervention plus psychotherapy (30 to 60 minutes once per week administered by a psychiatrist for six weeks) and the control group received standard care. The improvement in anxiety at the end of the six week follow-up period, as measured on the HAM-A anxiety scale, was significantly greater for the intervention group as compared to the control. The generalisability of the findings to England are unclear but we estimate the cost of this intervention in the UK NHS would be £948 (2015/2016 prices) per patient, based on a per attendance unit cost of psychotherapy of £158 (NHS Reference Costs, 2016).

A review of the benefits of yoga in reducing anxiety and depression in stroke patients (Thayabaranathan et al., 2017) found five papers based on four randomised controlled trials, none of which had sample sizes of over 50 participants. Although the authors found evidence that yoga was beneficial in reducing anxiety and depression they described the quality of the included trials as low to moderate and concluded that large well-designed randomised controlled trials are needed to confirm their findings.

A relatively recent review assessed the benefit of mindfulness-based interventions following transient ischemic attack or stroke (Lawrence et al., 2013). Statistical meta-analysis was not performed in this review, however, as the authors deemed the included studies to be too

heterogeneous. Of four included studies, only one was a randomised controlled trial, including only 12 participants. None of the studies were set in the UK.

Psychological assessment

Despite guideline recommendations to routinely screen stroke survivors for the presence of mood disorders, screening rates remain suboptimal. Burton and Tyson (2014) suggest that clinician uncertainty about which tool to use is one practical barrier and thus review a range of available tools. They identified a number of valid and clinically feasible tools: "the GDS-15 can detect any depressive disorder and the PHQ-9 can detect severe depression whereas the SADQ-H can be used with stroke survivors who are unable to self-report. The HADS (both the total scale and the anxiety subscale) can effectively identify anxiety post-stroke but clinical utility is limited by the costs involved." However, they were unable to identify the optimal cut-off scores for these tools (and the other tools they identified) due to the heterogeneity of studies they reviewed, thus some uncertainty surrounding screening tool choice still remains.

Forster et al. (2014) reported on a randomised controlled trial of a protocol for identifying stroke patients and their carers in need of psychological support (among other needs). The trial, set in the UK, randomised stroke patients and carers to receive either a system of care which included a structured assessment, care plan, checklist, manual containing reference guide and service information delivered by a stroke care co-ordinator, or usual care, described as current community-based care as determined by local policy and practices. The primary outcome measure was the General Health Questionnaire – 12 item (GHQ-12) assessed at 6 months after recruitment. Analysis of data from 610 patients found no significant difference on GHQ-12 scores between treatment arms at 6 months. The difference for carers (n=162) on the GHQ-12 approached statistical significance (P=0.061). There was also no evidence of cost-effectiveness of the intervention. The mean cost of the intervention in stroke care co-ordinator inputs was £277 (2010/2011 prices) and £239 for the control group. Updated to 2015/2016 prices, using the hospital and community health services index (Curtis and Burns, 2016), these costs are £297 and

£257 for the intervention and control groups, respectively. Thus the mean cost of the intervention, scaled up, would be £40,000 per 1,000 service users. The authors conclude that, "... successfully addressing the needs of a heterogeneous post-stroke population remains problematic. Future work could explore stratifying patients and targeting services towards patients (and carers) with specific needs, leading to a more specialised bespoke service".

6.4 Results: acute care

6.4.1 Acute system reconfiguration

Evidence from other countries suggests that centralised specialist stroke care can improve use of evidence based care in the first few hours after a stroke. For London, a modelling study by Hunter et al. (2013) estimated the 90-day saving to the NHS at around £800 per patient and the 10-year saving at around £3900 per patient, and that such savings would offset reconfiguration implementation costs (estimated at around £10 million) within two years (Hunter et al., 2013).

Morris et al. (2014) examined the impact of major acute system reconfiguration in London and Greater Manchester using routine data for all patients in England who had a stroke during a 51 month period. They conducted a difference in differences analysis, comparing (a) changes over time in London versus changes over time in rest of England and (b) changes over time in Manchester versus changes over time in rest of England.

In London, the reconfiguration resulted in 8 hyperacute stroke units (HASUs) operating 24/7 with capacity for immediate imaging and thrombolysis and 24 stroke units designated to provide acute rehabilitation (8 of these attached to a HASU). Five hospitals previously providing acute stroke care were no longer to do so. In Manchester, there were concerns such as transporting patients over greater distances that resulted in patients presenting only within four hours of developing stroke symptoms (the time limit for antiplatelet treatment) being taken directly to a

comprehensive stroke centre or primary stroke centre, while other patients were taken to one of 10 district stroke centres. In contrast to London, no hospitals stopped providing stroke services entirely.

A significantly higher proportion of patients received care compliant with care processes (Ramsay et al., 2015) and, consistent with evidence of better compliance being negatively correlated with mortality, the new model delivered a 5% relative reduction in mortality at 90 days in London. Although the Manchester model was not implemented as intended, both areas saw reductions in length of hospital stay: by 9% in Greater Manchester and by 7% in London, implying 17,685 fewer hospital days in Greater Manchester and 22,341 fewer in London (Morris et al., 2014).

New calculations

Although these findings may not be generalisable to less urban areas, they are likely to be relevant for other urban areas. Another major urban region in England, the West Midlands, has a population size (2.83 million in 2015) broadly equivalent to Greater Manchester's (2.76 million in 2015; ONS, 2016). Thus, we estimate that service reconfiguration just in the West Midlands alone could potentially achieve similar gains to the Greater Manchester reconfiguration i.e. ~18,000 hospital days/£5 million over 2 years (assuming a cost of £283 per day; Department of Health, 2015).

6.4.2. Thrombolysis

Approximately 20% of stroke patients are eligible to receive thrombolysis treatment and virtually all sites can now offer this at all times, through various models of implementation ranging from on-site delivery to a telemedicine service with remote advice from a stroke consultant (Royal College of Physicians, 2016).

Outcomes are better the earlier it is administered (Royal College of Physicians, 2016). A Cochrane review of 27 trials (all using a placebo control) involving 10,187 patients, found that "thrombolytic

therapy, mostly administered up to six hours after ischaemic stroke, significantly reduced the proportion of participants who were dead or dependent (modified Rankin 3 to 6) at three to six months after stroke (odds ratio (OR) 0.85, 95% confidence interval (CI) 0.78 to 0.93" (Wardlaw et al., 2014). While thrombolytic therapy was associated with increased risks of various negative outcomes (e.g. symptomatic intracranial haemorrhage, early death (generally attributable to intracranial haemorrhage) and death by three to six months after stroke) treatment *within three hours of stroke* was more effective in reducing death or dependency (OR 0.66, 95% CI 0.56 to 0.79) without any increase in death (OR 0.99, 95% CI 0.82 to 1.21; 11 trials, 2187 participants).

Various modelling studies have attempted to examine the potential gains from wider implementation of thrombolysis. Most recently, NGC/SSNAP (2016; using the original model that forms the basis of our current costs estimates in Section 2) estimated cost savings and QALY gains for each extra person thrombolysed. Their findings suggest that after 5 years, it can be expected that each extra patient thrombolysed saves £4,100 in NHS costs, £6900 in social care costs, and generates an extra 0.26 QALYs. Thus, we estimate that the 2,000 eligible patients who do not receive the drug each year incur £8.2 million in avoidable costs to the NHS over 5 years.

Using a decision tree model from an NHS and social care perspective, Penaloza-Ramos et al. (2014) attempted to establish the cost-effectiveness of increasing thrombolysis rates through a series of theoretical change strategies (drawn from the literature) designed to optimize the acute care pathway for stroke. The model's base case consisted of data for 488 consecutive stroke events following the acute stroke pathway in participating hospitals, with data on effectiveness of treatment and costs from published sources. A total of 33 patients (9%) received thrombolysis. They report that current practice resulted in 2251 QALYs per 100,000 population at a cost of £14.2 million (2010/11 prices) and that all proposed change strategies reduced costs and increased QALYs (Penaloza-Ramos et al., 2014). A strategy of computed tomography (CT) scanning immediately on arrival suggested the largest cost saving (£51,000, 5.4 additional QALYs per 100,000 population) (Penaloza-Ramos et al., 2014).

In a discrete-event simulation modelling exercise using five year retrospective data, Barton et al. (2012) suggested that the total overall cost of treating 50% of eligible patients in Northern Ireland with thrombolysis, instead of standard therapy, could decrease from £6,355 to £6,243 per appropriate patient. While increasing thrombolysis rates from 10% to 50% is associated with an additional £300 per person, there are savings elsewhere: £149 in acute care, £22 for long-stay care, £5 for rehabilitation and £213 for cost of discharge to institutional care. There would also be corresponding improvements in quality of life: the average number of QALYs per potentially clinically appropriate patient could increase from 5.442 to 5.475 - a gain of 0.033 which equates to 12 days of life in full health. Within a Northern Ireland context, the study estimates an annual gain of approximately 13 QALYs should the provision of thrombolysis be increased from 10% to 50% of patients that are clinically appropriate. Barton et al. (2012) therefore concluded that thrombolysis would produce moderate overall improvement to the service costs and outcomes assuming current levels of funding.

A further modelling study by Sandercock et al. (2004) showed that compared with standard care, treating eligible patients with recombinant tissue plasminogen activator (rt-PA) up to 6 hours is associated with a 78% probability of a gain in quality-adjusted survival during the first year, at a cost of £13,581 per QALY gained. However, they acknowledged variations in conclusions depending on the assumptions made.

6.4.3 Mechanical thrombectomy

Around 40% of ischaemic strokes are caused by a large artery occlusion (LAO), and mechanical thrombectomy is gradually being used more for the treatment of large-vessel ischemic stroke in patients arriving at the hospital outside of the 3-hour time window for thrombolysis. It is effective at preventing severe disability and increasing independence (Jovin et al., 2015) and is highly cost-effective at an incremental cost per QALY gained of £7,061 over 20 years (significantly lower than many other NHS interventions) and a 100% likelihood of being cost-effective in the UK (Ganesalingam et al., 2015). In estimating the budget impact to the NHS, Guijarro et al. (2017) suggest that on average one patient would save the NHS £47,000 over 5 years, thus representing potential annual savings of millions.

In a pooled analysis of patient-level data from five trials (1287 patients), Goyal et al. (2016) showed that modern endovascular thrombectomy led to significantly reduced disability at 90 days compared with control (adjusted cOR 2·49, 95% CI 1·76–3·53; p<0·0001). Findings held in a range of subgroups, including in patients 80 years or over, patients not eligible for intravenous alteplase, and patients randomized more than 300 minutes from symptom onset. They reported that "the degree of benefit conferred by endovascular thrombectomy is substantial: for every 100 patients treated, 38 will have a less disabled outcome than with best medical management, and 20 more will achieve functional independence (mRS 0–2) as a result of treatment" (Goyal et al., 2016).

A review by Ferri et al. (2016), which included the same five trials plus three earlier ones that showed no benefit, concluded that "patient inclusion criteria and the type of device used, as well as the timing of endovascular treatment were important aspects that might have influenced the positive results of these recent trials." They also note that a further 13 randomised controlled trials are ongoing.

After implementing the endovascular treatment (thrombectomy) pathway at University Hospitals of North Midland NHS Trust, "94% of patients with severe strokes due to large vessel occlusion were discharged to their own homes rather than to a nursing home; 23% were discharged home within 1 week. Before implementing the treatment pathway, when only intravenous tissue alteplase was used, 70% of patients were discharged to inpatient rehabilitation, with significant annual costs" (Royal Stoke University Hospital, University Hospitals of North Midlands NHS Trust, 2016). Savings amounted to £0.8 million related to reductions in length of hospital stay and £1.6 million from reductions in social care costs. Costs to commissioners (who were paying for the procedure) were estimated at £0.5million per annum and were expected to reduce as the procedure becomes established within national tariff.

In a modelling based cost-effectiveness study, Lobotesis et al. (2016) reported that higher treatment costs were offset by long-term cost savings due to improved patient health status, resulting in overall cost savings of £33,190 per patient and a net benefit of £79,402. Further, "costs saved due to improvement by one mRS [modified Rankin Scale] varied from £5,248 (moving from mRS 2 to mRS 1) and £111,209 (moving from mRS 3 to mRS 2). The cost savings

associated with stent retriever + IV t-PA [intravenous tissue-type plasminogen activator] were greatest in patients with higher functional dependence (mRS 3 +)" (Lobotesis et al., 2016).

A health technology assessment by Health Quality Ontario (2016) stated that "experts have stated that since the technology has demonstrated a beneficial effect in the RCTs examined in this report, the number of eligible patients has increased, and that as many as 10% of all acute ischemic stroke patients may have intracranial artery occlusion that could be considered for endovascular treatment". Over 8,000 people a year in England could be eligible for thrombectomy but currently only 10% of eligible patients receive it. There is also huge geographic variation in access, with 37% of sites in England having no access to the procedure locally or by referral (Royal College of Physicians, 2016).

New calculations

Given the under-implementation of thrombectomy despite promises of large economic gains, we estimate cost savings and health gains associated with increased implementation over the next three years. We assume the following accumulation in the number of eligible patients treated:

- By 2018/19, 1750 eligible patients are treated with thrombectomy
- By 2019/20, 2500 eligible patients are treated with thrombectomy
- By 2020/21, 3250 eligible patients are treated with thrombectomy

We previously estimated average care costs associated with different stroke severities (Section 2, Table 2.10). We estimated that those with moderate/severe stroke or severe stroke (NIHSS scores 16-42; referred to as NIHSS score groups 4-5 in our report) incurred NHS costs of £18,012 in their first year after stroke, and that those with minor stroke (NIHSS scores 1-4; referred to as NIHSS score groups 1-2 in our report) incurred NHS costs of £9,261. This represents a cost differential of £8,751 between those with NIHSS scores of 1-4 and those with NIHSS scores of 16-42.

Goyal et al. (2016) reported that for every 100 people treated with thrombectomy, 20 more will achieve functional independence (mRS 0–2). Assuming that the severity difference, as categorised by NIHSS scores, in the two groups described above is broadly equivalent to moving from mRS scores of 4-5 down to mRS scores of 0-2, the cost differential of £8,751 could indicate the potential NHS cost saving associated with each additional person gaining functional independence. On this basis, the overall NHS savings per 100 people treated with mechanical thrombectomy could be £175,020.

Using this approach, Table 6.1 sets out the estimated NHS, social care and combined savings (£3.9 million in 2018/19 and £7.2 million in 2020/21) associated with the aforementioned annual increases in numbers of people receiving thrombectomy. (For ease of calculation, all costs relate to 2015 prices).

Table 6.1: Estimated savings in NHS and social care costs, for different targets for thrombectomy to 2020/21

Year	Number treated	Cost savings (£, 2015, '000)		
		NHS (20% of number treated, saving average of £8,751 each)	Social care (20% of number treated, saving average of £2,383 each)	NHS & social care (20% of number treated, saving average of £11,134 each)
2018/19	1750	3,063	834	3,897
2019/20	2500	4,375	1,192	5,567
2020/21	3250	5,688	1,549	7,237

Note: numbers within table may not sum exactly due to rounding

We also estimate QALY gains and associated monetary benefits. Assuming that mean QALY gain with thrombectomy plus intravenous thrombolysis is 0.12 at one year follow-up compared

to intravenous thrombolysis only (Achit et al., 2017), we estimate QALY gains for the increased number treated. The associated monetary benefit is assumed to be £20,000 per QALY gain (i.e. the approximate willingness to pay threshold used by the National Institute for Health and Care Excellence (NICE)). Treating 1750 patients could provide a QALY gain of 210/monetary benefit of £4.2 million (Table 6.2). Increasing coverage to 3250 by 2020/21 raises these gains to 390 QALYs/monetary benefit of £7.8 million.

Table 6.2: Estimated QALY gains and net monetary benefits, for different targets for thrombectomy to 2020/21

Year	Number treated	QALY gain	Associated monetary gain (£) = QALY * £20,000
2018/19	1750	210	4,200,000
2019/20	2500	300	6,000,000
2020/21	3250	390	7,800,000

6.5 Results: stroke prevention

In Section 5, we estimated potential savings associated with further research in specific areas. Of the five research priorities we examined, developing and implementing more preventative interventions provided the greatest scope for achieving long term cost savings. For that purpose, it was sufficient to apply a set of general assumptions about the levels of change that might be achieved for various parameters in our projection models to 2025 and 2035. Here, we take a different approach to demonstrate the potential future cost savings. We (a) examine the wider implementation of existing interventions related to two specific health conditions which are risk factors for stroke, atrial fibrillation (AF) and hypertension, (b) take a shorter term view given that the focus is on implementing already available interventions and (c) rather than applying general assumptions as before, we locate our estimates in the context of relevant evidence and specific intervention targets.

6.5.1 Atrial fibrillation

There is significant scope for reduction in stroke related morbidity through timely diagnosis and management of AF, which is associated with a 5-fold increase in the risk of stroke (Wolf et al., 1991). Using anticoagulant medication has been shown to reduce the risk of stroke by 61% compared to no treatment (Aguilar & Hart, 2005) and 32% compared to antiplatelets alone (Aguilar et al., 2007) based on evidence from two Cochrane systematic reviews.

New estimates

Stroke in the presence of AF results in worse outcomes for patients, including coma, paralysis and 30 day mortality (Lin et al., 1996; Lamassa et al., 2001). This is explained by higher mean age of patients suffering AF-related stroke and higher severity of stroke on average, with a median National Institute of Health Stroke Score (NIHSS) of 3 in AF-related cases compared 2 in the general stroke population (Lopes et al., 2011). Based on the current costs of stroke estimated in Section 2, we estimate the mean cost of stroke with NIHSS score 3 (moderate stroke) to be £21,343 from the perspective of NHS & personal social services (PSS). It was also assumed that AF-related strokes lead to moderate disability on average (score of 10-14 on the Barthel scale) and incur an additional £33,545 in terms informal care and £1,959 in terms of lost employment. In subsequent years post-stroke, patients with AF are expected to incur £8,547 in NHS & PSS costs, £20,207 in informal care costs and £2,014 in lost productivity. The total societal cost of AF-related stroke is thus £56,847 in the first year and £30,768 in subsequent years conditional on survival.

We estimate, in turn, the potential economic gains associated with three implementation scenarios for AF:

- By 2020/21, reduce the number of people with undetected AF by 50%
- By 2020/21, increase proportion of known AF on anticoagulation to 89% preventing 5000 strokes
- By 2021/22, improvement in warfarin time in therapeutic range

By 2020/21, reduce the number of people with undetected AF by 50%

The Department of Health reports that 18% of AF cases remain undiagnosed, with many cases identified only upon investigation following an adverse event or complication (Department of Health, 2013). An estimated 8.1% of patients admitted for ischaemic stroke have previously undiagnosed AF (Friberg et al., 2014). Prevalence of previously diagnosed AF is 1.76% based on data from 1857 general practices in England (Cowan et al., 2013). This corresponds to 1.16 million cases based on Office for National Statistics population figures for 2016 (ONS, 2016). Given that 18% of all AF cases are undiagnosed, an estimated 254,000 people are living with undiagnosed AF in the UK.

If the number of cases of undiagnosed AF through opportunistic or targeted screening is reduced by 50% and 89% of these receive anticoagulant therapy (all those eligible for whom it is not contraindicated), 113,000 patients can benefit from a reduced risk of stroke. If we assume that these patients were not undergoing antiplatelet therapy and their risk of stroke is reduced by 61% using anticoagulant medication, an AF screening programme could avoid an estimated 500 stroke cases each year. This corresponds to £28.4 million in savings from a societal perspective, which includes £10.7 million of savings to NHS & social care. Stroke often leads to dependence on formal and informal care in future years of life, meaning that the longer-term cost savings are likely to be far higher. We modelled post-stroke survival rates for medium and severe stroke using data from SSNAP (Royal College of Physicians, 2017). The proportion of patients alive was 63% after 1 year, 52% after 2 years, 43% after 3 years and 34% after 4 years. The potential cost savings (excluding the cost of implementing the intervention) to society over a 5 year period amounts to £233 million, £137 million of which relates to informal care (Table 6.3).

Table 6.3: Estimated cost savings over 5 years (2015 prices) of a screening programme for atrial fibrillation

Year	Number of cases		Potential cost savings (£ '000)			
	incident	Prevalent	NHS & PSS	Informal care	Lost productivity	Total societal cost
1	500	0	£10,672	£16,773	£980	£28,424
2	500	315	£13,364	£23,138	£1,614	£38,115
3	500	576	£15,595	£28,412	£2,140	£46,146
4	500	790	£17,424	£32,736	£2,571	£52,730
5	500	959	£18,868	£36,151	£2,911	£57,930
Total	**2500**		**£75,922**	**£137,209**	**£10,214**	**£223,345**

The cost of implementing a strategy of opportunistic or targeted screening at the national level is unknown. One randomised controlled trial estimated the cost of screening with a 12-lead electrocardiogram (ECG) interpreted by a consultant to be £16.25 per patient and the cost of a routine pulse reading to be £1.83 per patient (Hobbs et al., 2005). These costs would need to be combined with the total number of patients who undergo screening to estimate the aggregate cost of carrying out the strategy from the NHS perspective. Additional costs, including administration and promotion of the strategy would also need to be considered.

By 2020/21, increase proportion of known AF on anticoagulation to 89%

As reported in Section 2, an estimated 117,600 new stroke cases per year occur in the UK (based on mid-point incidence from three studies (Rothwell et al., 2004; Stewart et al., 1999; Wolfe et al., 2002), adjusted for population size and age composition in the UK in 2016). Given that one in five patients admitted for stroke in England, Wales and Northern Ireland have previously diagnosed AF (Royal College of Physicians, 2017), the estimated number of AF-related stroke cases is 23,520. Based on SSNAP data, 35% of AF cases are not treated with anticoagulants, excluding patients in whom therapy was contra-indicated due to a high risk of bleeds or another

reason (Royal College of Physicians, 2017). Therefore an estimated 8,232 strokes are potentially avoidable through appropriate management of AF.

Patients with AF do not receive anticoagulant therapy for a number of reasons. As noted above, in a small proportion of patients anticoagulant therapy is contra-indicated due to a high risk of bleeding. Patients who are not given anticoagulants for one reason or another are often given antiplatelets, which is less effective at preventing stroke. The protective effect of anticoagulant therapy is higher in trials which use placebo as the control treatment compared to antiplatelets. To gauge the number of strokes which could be avoided through appropriate anticoagulant therapy of all eligible stroke patients with AF, we estimate the proportion of patients admitted for stroke with a prior diagnosis of AF who were treated with anticoagulants and antiplatelets using SSNAP data (Royal College of Physicians, 2017). We assume that all patients with a contra-indication for anticoagulant medication are treated with antiplatelets (626, 10.9% of all patients with AF). This is subtracted from the number of patients who took anticoagulants only (1022) to derive the number of stroke patients who are eligible for anticoagulants, but are given an antiplatelet instead (396). We then apply the odds ratio estimates from relevant systematic reviews (Aguilar & Hart, 2005; Aguilar et al., 2007) to work out the number of averted strokes per year. The final figure represents the estimated number of strokes which could be prevented if (a) all patients eligible for anticoagulation who are currently on antiplatelets only are switched to an anticoagulant and (b) all patients eligible for anticoagulation who are currently not medicated are given an anticoagulant. The calculations are summarised in Tables 6.4 and 6.5.

Table 6.4: Estimated proportion of patients not on anticoagulant therapy who were on antiplatelets

Patient category	**Number of patients in SSNAP**	**% of total**	**% of eligible but not taking anticoagulant**
All stroke cases	5739	100.0	
Taking anticoagulant	3099	54.0	
Ineligible for anticoagulant	626	10.9	

Eligible but not taking anticoagulant	2014	35.1	100.0
Taking antiplatelets†	**396**	**6.9**	**19.7**
Not taking antiplatelets	**1618**	**28.2**	**80.3**

† It is assumed that all patients with diagnosed AF ineligible for anticoagulant therapy are treated with antiplatelets.

Table 6.5: Estimated number of strokes avoidable through anticoagulant therapy

Patient category	**Number of strokes per year**
Number of AF-related strokes not treated with anticoagulants	8232
Taking antiplatelets (19.7%)	1622
Number of strokes avoided (OR 0.68)	519
Not taking antiplatelets (80.3%)	6610
Number of strokes avoided (OR 0.39)	4032
Total number of avoided strokes	**4551**

Appropriate anticoagulant management of AF in all eligible patients could avert an estimated 4,551 strokes each year. This translates to £97 million savings in NHS & PSS costs through avoiding the need for acute stroke treatment each year. Estimated societal cost savings are £259 million in the first year after achieving the target. Potential cost savings over a 5-year period, which incorporate savings arising from reduced burden on informal carers in subsequent years post-stroke, are summarised in Table 6.6. Over a 5 year period, appropriate management of all previously diagnosed AF cases eligible for anticoagulant medication could lead to 22,755 fewer new strokes, 8,727 fewer prevalent cases of stroke by year 5 and produce societal savings of £2 billion, including £691 million in savings to NHS & PSS. These estimates do not include the additional cost of medication and administration associated with the strategy.

Table 6.6: Estimated cost savings over 5 years (2015 prices) of appropriate anticoagulant management of all AF patients

Year	Number of cases		Potential cost savings ('000)			
	incident	prevalent	NHS & PSS	Informal care	Lost productivity	Total societal cost
1	4551	0	£97,132	£152,663	£8,915	£258,711
2	4551	2867	£121,636	£210,597	£14,690	£346,922
3	4551	5247	£141,978	£258,689	£19,483	£420,150
4	4551	7191	£158,593	£297,972	£23,398	£479,963
5	4551	8727	£171,722	£329,010	£26,492	£527,223
Total	**22755**		**£691,061**	**£1,248,931**	**£92,977**	**£2,032,970**

By 2021/22, improvement in warfarin time in therapeutic range

The effectiveness of warfarin is dependent on the quality of anticoagulation, whilst balancing the risk of haemorrhage. Optimal risk reduction occurs when the International Normalised Ratio (INR) is between 2 and 3. The proportion of time spent within this therapeutic range (TTR) during warfarin therapy is an indicator of quality of therapy and a predictor of stroke and mortality. However, evidence from large randomised controlled trials of anticoagulant medications suggest that only 60% of patients on warfarin achieve the TTR for warfarin (ACTIVE Writing Group of the ACTIVE Investigators et al., 2006; Miura et al., 2009; The SPAF III Writing Committee for the Stroke Prevention in Atrial Fibrillation Investigators, 1998).

A TTR of ≥70% is associated with a four-fifth reduction in the risk of stroke (RR 0.21, C.I. 0.18-0.25) compared to patients with a TTR of 30% or less, based on data from UK general practices (Gallagher et al., 2011). Another study used pooled data from three major randomised controlled trials of anticoagulant therapy in AF to demonstrate a statistically significant effect of TTR in warfarin therapy on the rate of stroke. They reported that for every 10% increase in TTR, stroke event rates decreased by 0.32% per year. Specifically, the rate of ischaemic stroke at 60% TTR was 1.25, 1.04 for 70% TTR, 0.83 for 80% TTR and 0.62 for 90% TTR. In case of haemorrhagic stroke, the rate was 0.44 for 60% TTR, 0.37 for 70% TTR, 0.29 for 80% TTR and 0.22 TTR for

90%. Varying TTR did not have a significant effect on the rate of major bleeding (Amin et al., 2014).

Based on these findings, we can assume that increasing TTR for warfarin from 60% to 70%, 80% and 90% would reduce the rate of stroke by an estimated 16%, 34% and 50%, respectively. Assuming that 20% of 117,600 patients admitted for stroke each year have a prior diagnosis of AF, 54% of whom are treated with anticoagulants, 12,701 stroke cases each year could be avoided by improving TTR during warfarin therapy. If we assume a modest increase in mean TTR from 60% to 70%, 16% of the above incident cases could potentially be prevented (2032 per year). This corresponds to 10,160 incident cases and 3,897 prevalent cases of stroke prevented at 5 years after implementation. If we apply the same broad logic as for the two previous scenarios to estimate potential cost savings from different cost perspectives, increasing TTR of warfarin from 60% to 70% can potentially result in societal cost savings of £908 million within 5 years of implementation Table 6.7.

This estimate is subject to certain assumptions. The distribution of TTR across the population of patients with AF is unknown; the calculation assumes that the distribution is sufficiently narrow so that improvement in anticoagulant treatment across the board results in the mean TTR value moving from 60% to 70% results in a proportional effect on the risk of stroke. In reality the risk of stroke is most likely non-linear, e.g. moving from 60% to 70% represents a larger reduction than moving from 70% to 80%.

Table 6.7: Estimated cost savings (2015 prices) at 5 years after achieving target, if time spent within therapeutic range of warfarin is increased from a reference base case of 60% to 70%.

Number of cases avoided	
Incident	10,160
Prevalent	3,897
Cost (£m)	
NHS & PSS	308.6
Informal care	557.7

Lost productivity	41.5
Total societal cost	**907.7**

6.5.2 Hypertension

Hypertension is a major modifiable risk factor for stroke. Stroke sufferers were 2.79 times more likely to have pre-existing hypertension compared to non-stroke controls in high-income countries, according to a large case-control study carried out in 22 countries (INTERSTROKE study; O'Donnell et al., 2010). Hypertension is highly prevalent in the UK population, with an estimated 13.8% of people in England with a diagnosis of high blood pressure according to data collected in the Quality and Outcomes Framework (QOF) in 2015-16 (NHS Digital, 2016). Furthermore, a large number of people in England live with high blood pressure which has not been formally diagnosed. Public Health England (PHE) estimated that a further 5.6 million people in England (9.8% of the population) lived with undiagnosed hypertension in 2014, by modelling data from Health Survey for England (Public Health England, 2016).

New calculations

A new strategy to increase the proportion of diagnosed and appropriately treated hypertension could reduce the number of new stroke cases, yield significant savings from avoided treatment costs and yield gains in quality of life and reduced stroke-related mortality. Here, we estimate such potential gains associated with two scenarios:

- By 2021/22, 15% increase in proportion of adults with blood pressure controlled to 140/90
- By 2021/22, 15% increase in hypertension diagnosis

The two scenarios are not assumed to be mutually exclusive and their economic impact would be additive to some extent if both were to be implemented. Literature-based estimates of the potential reduction in the number of new stroke cases in the UK are combined with our estimates of the mean cost of incident and prevalent stroke (Section 2). In the first year post-stroke, average per-person costs were £18,081, £25,897 and £1,431 for NHS/PSS, informal care and lost

productivity respectively; in subsequent years post-stroke, equivalent costs were £7,759, £15,354 and £1,666 respectively. Total societal cost of stroke was thus £45,409 in the first year and £24,778 in subsequent years conditional on survival.

Public Health England (PHE) estimates:

In 2014 PHE commissioned Optimity Matrix to produce a report on the cost-effectiveness of selected interventions in the prevention and management of hypertension (Optimity Matrix, 2014; Public Health England, 2014). They undertook an extensive literature review and a modelling study to estimate potential cost savings, life-year gains and QALY gains from improved management and detection of hypertension. Incremental cost-effectiveness ratios (ICERs) were computed for specific interventions. Economic benefits were presented for a range of time horizons: 1, 5, 10 years and lifetime. The main findings relevant to our scenarios are as follows:

- a 15% increase (from 59% to 74%) in the proportion of adults who have their high blood pressure diagnosed translates to 1.94 million people diagnosed, of whom 1.13 million will control their blood pressure. This translates to £33.3 million in NHS/PSS cost savings and 3317 QALYs gained at 5 years; and
- a 15% increase (from 58% to 73%) in the proportion of adults treated for hypertension controlling their blood pressure to 140/90 mm Hg or lower is equivalent to 1.14 million people controlling their blood pressure. This translates to a saving of £33.7 million in NHS/PSS cost savings and 3356 additional QALYs.

These benefits/savings estimates were based on reduced risk of four conditions associated with hypertension: coronary heart disease, stroke, vascular dementia and chronic kidney disease. To isolate the economic benefits of reducing the risk of stroke, we combine the estimates from the Optimity Matrix model relating to stroke risk reduction with our own estimates of the cost of stroke to the NHS & PSS and society (in the 2015/16 cost year).

The distribution of hypertension is assumed to be the same as in the Optimity Matrix model: 31% normotensive (systolic blood pressure <120 mm Hg), 39% pre-hypertensive (≥120 and <140), 18% with stage 1 hypertension (≥140 and <160), 12% with stage 2 hypertension (≥160). The distribution of the risk of stroke across hypertension groups is taken from the INTERSTROKE study (O'Donnell et al., 2010). It reported the population attributable risk (PAR) of 0.346 and 0.518 for patients with blood pressure ≥140/90 mm Hg and ≥160/90 mm Hg, respectively. This corresponds to a relative risk of 2.2 and 3, respectively, compared to <140/90 mm Hg (O'Donnell et al., 2010). Thus the weighted annual risk of stroke is 0.001 in individuals with blood pressure below 140/90 mm Hg and 0.0025 for ≥140/90 mm Hg, given a crude incidence rate of 1.45 per 1000 based in the OXVASC study (Rothwell et al., 2004) (details of calculation are in Table 6.8).

Table 6.8: Annual risk of stroke in different hypertension categories

Category (mm Hg systolic)	**Distribution**	**Relative risk of stroke**	**Annual risk of stroke, weighted by relative risk of stroke**
Sub-categories			
Normotensive (<120)	0.31	1	0.000996
Pre-hypertensive (120-139)	0.39	1	0.000996
Stage 1 HT (140-159)	0.18	2.2	0.002191
Stage 2+ HT (≥160)	0.12	3	0.002988
Grouped categories			
<140 mm Hg	0.7	1	0.000996
≥140 mm Hg	0.3	2.52	0.00251
Whole population	1	1.456	0.00145

Estimated cost savings associated with a 15% increase in the proportion of adults who have had their high blood pressure diagnosed (from 59% to 74%):

The benefits of increasing the proportion of patients with a blood pressure diagnosis are estimated in terms of reduced risk of stroke associated with moving from high blood pressure

(≥140/90 mm Hg) to normotensive (<140/90 mm Hg). It is assumed that 13.8% of the UK population (8.8 million) have a prior diagnosis of hypertension, which represents 58% of the total population of hypertensive adults, based on data from Quality and Outcomes Framework (NHS Digital, 2016). An absolute increase of 15% would increase the total number of hypertensive individuals eligible for treatment by 2.3 million. Given that the proportion of individuals with a prior diagnosis and on treatment for hypertension who achieve BP <140/90 mm Hg is 63% according to Public Health England data (Public Health England, 2014), the extra number who will achieve this target is 1.4 million. By applying the difference in the annual risk of stroke computed earlier, we estimate that 2,158 strokes may be avoided each year (details of the calculation are included in Table 6.9).

Table 6.9: Estimated number of stroke cases avoided through improved diagnosis of hypertension

Category	**N**	**Sources/notes**
Mid-2016 England population	63,818,387	ONS, 2016
Hypertensive	15,082,984	Sum of diagnosed and undiagnosed
Prior diagnosis of hypertension (58%)	8,802,823	≈13.8% of population in QOF (NHS Digital, 2016)
Undiagnosed hypertension (42%)	6,280,161	≈12% of those aged ≥16 (Public Health England, 2016)
Total eligible for treatment if proportion of diagnosed increased by 15%	2,262,448	Based on figures reported above
Proportion of above expected to achieve BP <140/90 mm Hg	1,425,342	63% (Public Health England, 2014)
Expected no. of strokes in this category, without treatment	3,578	Assuming annual rate 2.51 per 1000 from Table 1
Expected no. of strokes in this category with treatment	1,420	Assuming annual rate 0.996 per 1000 from Table 1

Potential no. of averted stroke cases	2,158	

The estimated number of averted stroke cases is combined with mean costs of care for incident and prevalent stroke to gauge the total cost to the NHS & PSS and society over a 5 year period (Table 6.10). Increasing the proportion of hypertensive individuals with a diagnosis by 15% could potentially save £39 million in NHS & PSS costs for first-time stroke each year (excluding the cost of implementing the intervention). A further £55.9 million of informal care and £3.1 of lost productivity could be avoided. Over a 5 year period, 10,790 new cases and 4,138 prevalent cases of stroke could be avoided, yielding potential cost savings of £772 million to society, £284 million of which is attributed to NHS & PSS.

Table 6.10: Estimated cost savings over 5 years (2015 prices) from a 15% increase (from 59% to 74%) in the proportion of adults who have their high blood pressure diagnosed

Year	**Number of cases**		**Potential cost savings ('000)**			
	incident	prevalent	NHS & PSS	Informal care	Lost productivity	Total societal
1	2158	0	£39,019	£55,886	£3,088	£97,993
2	2158	1359	£49,563	£76,752	£5,352	£131,667
3	2158	2488	£58,323	£94,086	£7,233	£159,643
4	2158	3410	£65,477	£108,243	£8,769	£182,489
5	2158	4138	£71,126	£119,421	£9,982	£200,528
Total	10790		£283,508	£454,387	£34,425	£772,320

Estimated cost savings associated with a 15% increase in the proportion of adults treated for hypertension controlling their blood pressure to 140/90 mm Hg or lower (from 63% to 78%):

The benefits of increasing the proportion of patients treated for hypertension who control their blood pressure is estimated in terms of reduced risk of stroke associated with moving from high

blood pressure (≥140/90 mm Hg) to normotensive (<140/90 mm Hg). Based on QOF data, 13.8% of the population in England have a diagnosis of hypertension (8.8 million) (NHS Digital, 2016). Given that the proportion of individuals with a prior diagnosis and on treatment for hypertension who achieve BP <140/90 mm Hg is 63% according to Public Health England data (Public Health England, 2014), currently 5.5 million people with hypertension control their blood pressure. If this proportion were to be increased by 15% to 78%, an additional 1.3 million people would benefit from a reduced risk of stroke. This translates to around 2,000 avoided stroke cases annually, by applying the annual risk estimates reported in Table 6.11.

Table 6.11: Estimated number of stroke cases avoided through improvement in control of blood pressure below 140/90 mm Hg

Category	**N**	**Sources/notes**
Mid-2016 England population	63,818,387	ONS, 2016
Prior diagnosis of hypertension	8,802,823	≈13.8% of population in QOF (NHS Digital, 2016)
No. treated for hypertension expected to achieve BP <140/90 mm Hg	5,545,779	63% (Public Health England, 2014)
Additional no. to achieve BP <140/90 mm Hg if proportion increased by 15%	1,320,424	Based on figures reported above
Expected no. of strokes in additional 15%		
Current (not achieving <140/90 mm Hg)	3,314	Assuming annual rate 2.51 per 1000 from Table 1
Future (achieving <140/90 mm Hg)	1,315	Assuming annual rate 0.996 per 1000 from Table 1
Potential no. of avoided stroke cases	1,999	Difference between future and present no. of strokes

The estimated number of averted stroke cases is combined with mean costs for incident and prevalent stroke to gauge the total cost to the NHS & PSS and society over a 5 year period (Table

6.12). Increasing the proportion of individuals with diagnosed hypertension who achieve BP <140/90 mm Hg by 15% could potentially save £36.1 million in NHS & PSS care for first-time stroke each year. A further £51.8 million in informal care costs and £2.9m in lost productivity costs could be avoided. Over a 5 year period, 9995 new cases and 3833 prevalent cases of stroke could be avoided, yielding potential cost savings of £715 million to society, £263 million of which is attributed to NHS & PSS (Table 6.12).

Table 6.12: Estimated cost savings over 5 years (2015 prices) from a 15% increase (from 63% to 78%) in the proportion of adults treated for hypertension controlling their blood pressure to 140/90 mm Hg or lower

Year	**Number of cases**		**Potential cost savings ('000)**			
	incident	prevalent	NHS & PSS	Informal care	Lost productivity	Total societal
1	1999	0	£36,144	£51,768	£2,861	£90,773
2	1999	1259	£45,913	£71,099	£4,958	£121,969
3	1999	2305	£54,028	£87,159	£6,701	£147,888
4	1999	3159	£60,655	£100,271	£8,123	£169,049
5	1999	3833	£65,884	£110,620	£9,246	£185,750
Total	9995		£262,624	£420,917	£31,889	£715,430

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Appendix 2.1: Focused literature review on stroke incidence and prevalence

To enable us to calculate aggregate costs of stroke for the UK, we conducted a focused literature review to i) to identify incidence & prevalence of stroke in the UK and ii) estimate the number of stroke incidents and stroke survivors in the UK. Those we considered appropriate for our estimates are summarised in Table A2.1.

Table A2.1: Focused review of incidence & prevalence: summary of included studies

Source	Year of estimate	Population	Method	Incidence/prevalence rate (per 1000)	Total no. of stroke survivors	Comments
Incidence						
Rothwell et al., 2004	2002-2004	All individuals registered at GP practice in Oxfordshire	GP reporting and review of electronic records; n=91106	1.45 (1.28-1.63)	Not reported	Large-scale observational studies of individuals of all ages registered at a general practice in Oxfordshire. Using data from the latest cohort collected from 2002 to 2004 (n=91,106), the overall incidence was 1.45 per 1000 individuals per year (range 1.28-1.63).
Wolfe et al., 2002	1995-1998	All individuals included in South London Stroke Register	Reporting by healthcare professionals and patients, review of electronic records; n=234533	1.33 (1.26-1.41)	Not reported	Observational study of patients of all ages included in the South London Stroke Register (SLSR). Episodes of stroke were identified using a variety of sources, including reporting by healthcare professionals and patients, A&E and hospital ward records and electronic health records. Based on data collected from 1995 to 1998, the overall incidence of stroke was 1.33 per 1000 individuals per year (range 1.26-1.41).

Stewart et al., 1999	1995-1996	All individuals included in South London Stroke Register	Reporting by healthcare professionals and patients, review of case notes and electronic records; n=234533	1.31 (1.20-1.41)	Not reported	Prospective cohort study using data from the SLSR involving patients of all ages (n=234533). First stroke events were identified during an observation period in 1995-1996 using multiple sources. Cases of stroke were found using A&E and hospital ward records, brain imaging requests, death certificates, GP records and electronic health records. Episodes with symptoms lasting <24 hours were considered TIA and excluded. The crude incidence rate was 1.31 per 1000 individuals per year (range 1.2-1.41).
Prevalence						
Jagger et al., 2006	2015 (projected)	aged ≥65, urban: Newcastle, Nottingham and Oxford, rural: Cambridgeshire and Gwynedd	Simulated using data from 1991-94 (n=13004)	Not directly observed	724000	Estimated prevalence in 2015 was a model-based extrapolation using prevalence figures obtained from the Medical Research Council Cognitive Function and Ageing Study (MRC CFAS) conducted in 1991-94 (n=13004) (Gunning-Schepers, 1989). Participants were classified as having had a stroke if they answered positively to the question "Have you ever had a stroke that required medical attention".
Geddes et al., 1996	1995	aged ≥55, North Yorkshire	Questionnaires with n=18,827	46.8 (range 42.5-51.6)	Not reported	Questionnaire-based study of 18,827 patients aged 55 years and over. Estimated prevalence of 47/1000 (96% CI 42.5-52) in patients aged 55 and above.

O'Mahony., 1999	1999	aged ≥45, Newcastle upon Tyne	Questionnaires with n=1663	47.4 (range 46.1-48.7)	Not reported	Used a questionnaire to identify stroke survivors in a sample of 1663 patients aged 45 and over. The question was as follows: "Have you ever had a stroke". Saka et al. (2009) combined the prevalence estimates from O'Mahony et al. (1999) with ONS data to estimate an absolute prevalence of 1,173,176 for the entire population and 1,126,249 for those aged ≥45 years.

Other sources of incidence and prevalence rates that are excluded

Dey et al., 2014: Incidence: Used a simulation model to extrapolate the incidence of stroke or TIA based on retrospective data on stroke morbidity between 1993 and 2006 using electronic primary care records (GPRD). Estimated number of strokes per year in 2015 was 83959 (range 79263-116396). Excluded due to inclusion of TIA and because incidence rate was based only on GPRD data with no secondary source or verification, meaning the rate of missing or inaccurate data was likely to be high, particularly in the early years of the time period.

Hajat et al., 2011: Incidence: This study was suggested by a participant in our expert panel on stroke incidence/prevalence. Excluded as it looked at ischaemic stroke only.

Lee et al., 2011:Incidence: Retrospective cohort study of 32151 patients with a diagnosis of stroke recorded in GPRD. Excluded following review of full text as no reference was found to methods to distinguish TIA from stroke. Similarly to Dey et al. (2014), it relied on solely on GPRD, therefore relied on the completeness of diagnoses in primary care records.

Stroke Association, 2017: Prevalence: Estimate number of stroke survivors in the UK at 1.2 million, citing figures from Quality and Outcomes Framework (QOF) reporting from primary care.

Methods for calculating absolute number of stroke cases and stroke survivors using incidence and prevalence rates:

1. The original prevalence and incidence rates were combined with age-specific Office of National Statistics 2014 population figures (Office of National Statistics, 2015) to provide an estimate of the total number of stroke survivors and annual number of cases of first-time stroke. This was done in order to adjust for changes in the age structure of the UK population.
2. To construct a range, estimates of the number of stroke events and stroke survivors from individual studies were adjusted to ensure they represented the same patient population. The adjustments were as follows:
    (i) Rothwell et al. (2004), Wolfe et al. (2002) and Stewart et al. (1999) estimated the incidence of stroke based on a population of patients of all ages. Breakdown of

incidence rates by age group reported in these studies were used to estimate the number of stroke cases in the population aged ≥45 (Table A2.1.2).

(ii) Geddes et al only sampled individuals aged 55 and over, and the resulting estimate was adjusted using the prevalence rate for people aged 45-54 from O'Mahony et al. (1999). Estimates from Jagger et al. (2006) reflected the population aged ≥65 years and was adjusted using prevalence figures from Geddes et al for those aged 55-64 and O'Mahony et al. (1999) for the 45-54 age group. Details of prevalence estimates for age subgroups are included in Table A2.1.3.

Summary of findings

Estimates of the number of cases of stroke and number of stroke survivors aged ≥45 are summarised in Tables A2.2 and A2.3.

Table A2.2: Estimated annual number of stroke cases in the UK based on age-specific incidence rates and ONS population figures.

Stewart et al	**Low rate**	**High rate**	**No. of cases**	**Low no. of cases**	**High no. of cases**
	0	0.06	114	0	684
	0.01	0.13	327	82	1062
	0.08	0.22	1137	700	1924
	0.16	0.46	2348	1342	3857
	0.61	1.21	7944	5570	11048
	1.78	2.72	16253	13091	20004
	4.43	5.98	31968	27445	37048
	7.64	10.32	33040	28331	38269
	15.33	23.11	28441	23044	34739
			121571	**99604**	**148635**
			117646	**97481**	**141108**

Rothwell et al				Wolfe et al						
High rate	No. of cases	Low no. of cases	High no. of cases	Rate (per 1000)	Low rate	High rate	No. of cases	Low no. of cases	High no. of cases	Rate (per 1000)
				0.01	0	0.06	114	0	684	0.01
				0.03	0	0.07	245	0	572	0.04
				0.12	0.08	0.18	1050	700	1574	0.13
0.47	1845	671	3941	0.3	0.21	0.42	2515	1761	3522	0.28
1.05	5844	3287	9587	0.87	0.68	1.1	7944	6209	10044	0.87
2.47	12944	8899	18166	2.19	1.88	2.53	16106	13826	18607	2.21
6.63	32588	25525	41075	4.96	4.44	5.51	30729	27507	34136	5.16
12.37	37268	29925	45871	9.34	8.41	10.34	34635	31186	38343	8.91
21.91	24758	18189	32935	19.72	17.08	22.65	29643	25675	34048	18.92
	115245	**86495**	**151574**				**122981**	**106864**	**141529**	
	113400	**85825**	**147633**				**119057**	**104403**	**135177**	

Age group	UK population (ONS)		Rate (per 1000)	Low rate
		<15	0	
		15-24	0	
		25-34	0	
		35-44	0.22	0.08
		45-54	0.64	0.36
		55-64	1.76	1.21
		65-74	5.26	4.12
		75-84	10.05	8.07
		≥85	16.47	12.1
Total	**64596752**			
Total (≥45)	**27891767**			

Table A2.3: Estimated number of stroke survivors in the UK

Source	Age subgroup (years)	UK population ('000)	Number of stroke survivors ('000), using 2014 ONS figures (range)	Adjusted number of survivors ('000), aged ≥45 (range)
Jagger et al. 2006	≥65	11406.8	809.9 (804.9-814.9)	1002.6 (895.3-1126.4)
Geddes et al. 1996	≥55	18761.2	878.0 (797.4-968.1)	950.2 (797.4-1121.5)
O'Mahony et al. 1999	≥45	27891.8	1322.1 (1285.8-1358.3)	1322.1 (1285.8-1358.3)

Appendix 2.2: Focused literature review on informal care and lost productivity costs

Aim of the review

The aim of this targeted literature review was to identify up-to-date estimates of the mean cost of informal care and lost productivity resulting from stroke from previously published studies. This evidence was combined with estimates of formal care cost derived from the NGC model to compute the aggregate cost of stroke from a societal perspective in accordance with the research objectives of WP1.

Methods

Relevant economic studies of stroke from the last 10 years were identified using the NHS Economic Evaluation Database (EED) and Health Technology Assessment Database (HTA) using established methods for literature searching and reviewing. This search was complemented by an additional search of articles and citations using PubMed and Google Scholar. The search was conducted using the following medical subject headings (MeSH): "stroke", "informal care", "cost" for studies of the cost of informal care; "stroke", "productivity", "earnings" for studies of lost productivity and earnings resulting from stroke.

Abstracts were reviewed to identify relevant studies, using the following criteria as a guide, rather than strict inclusion/exclusion criteria: inclusion of new cases of stroke or stroke survivors; reported point estimate of informal care and/or productivity losses linked to stroke; reported measure of dispersion around the point estimate (e.g. standard deviation, standard error or 95% confidence interval); description of cost estimation methods; reported currency and cost year.

Although the research aim of WP1 was to estimate the societal cost of stroke in the UK, this focused review did not exclude studies conducted in other countries with highly developed economies and healthcare systems. This was done for two reasons: firstly, it was deemed that cost estimates from resource-rich countries were generalizable to the UK; secondly, the inclusion of data from a larger pool of studies was more likely to produce an accurate estimate of the mean and confidence interval.

Relevant studies were grouped into two categories: estimates of informal care and estimates of lost productivity/earnings. In the case of studies which reported standard errors, or a combination of standard deviation and sample size which allowed the calculation of a standard error, 95% confidence intervals were estimated using the mean and standard error. Given that cost data are often right-skewed, these confidence intervals should not be taken strictly at face value, but rather as an indication of the uncertainty around reported estimates to be used for estimation of societal cost in WP1 and future trends in the cost of stroke in WP2. Cost estimates from non-UK studies were converted to Great British Pounds using historical exchange rates for the 1st January of the year of publication of the original study. The converted cost estimates were inflated to the 2015 cost year using the Hospital and community health services (HCHS) pay & prices index.

Details of included studies

Key information from included studies is listed in Table A2.4 and Table A2.5.

Table A2.4: Findings from literature review of informal care costs

Author	Category	Cost year	Currency	Original cost	Min	Max	2015 cost (£)	Min	Max
Saka et al (2009)(1)	Cost of purchased care based on hourly wage of professional, informal family care based on average	2006	GBP	1891.56	1472.83	2158.06	2301.44	1791.97	2625.69
Fattore et al (2012)(2)	Cost of purchased professional care, informal care using substitution cost method	2007	EUR	Mean cost of informal care 6656 (sd 11051), mean cost of paid	Min informal care 5588, min paid care 542	Max informal care 7724, max paid care 974	Mean cost of informal care 5261, mean cost	Min informal care 4416 min paid care 429	Max informal care 6105, max paid care 770
Lopez-Bastida et al (2012)(3)	Cost of purchased professional care; Cost of informal care estimated using the opportunity cost method using mean wage in alternative	2004	EUR	Mean cost in 1st year: 10684 (sd 10575); 2nd year: 11285 (sd 10572);	Min 1st year: 8546; min 2nd year: 9838 ; min	Max 1st year: 12822; max 2nd year: 12732 ; max	Mean cost in 1st year: 9774; 2nd year: 10324; 3rd	Min 1st year: 7818; min 2nd year: 9000 ;	Max 1st year: 11730; max 2nd year: 11647 ; max
Persson et al (2012)(4)	Cost of informal care attributed to stroke estimated using the opportunity cost approach by applying	2008	SEK	12687	Not reported	Not reported	1126	Not reported	Not reported
Forster et al (2013) (TRACS Trial)(5)	Informal care (at 12 months in patients with follow-up)	2010	GBP	First 6 months: 10841; 6-12 months: 9323	First 6 months: 9896; 6-12 months: 8349	First 6 months: 11786; 6-12 months: 10297	First 6 months: 11829; 6-12 months:10173	First 6 months: 10798; 6-12	First 6 months: 12861; 6-12 months:11237
Forster et al (2014) (LoTS study)(6)	Informal care (at 12 months in patients with follow-up)	2011	GBP	First 6 months: 6176; 6-12 months: 5686	First 6 months: 5462; 6-12	First 6 months: 6890; 6-12	First 6 months: 6542; 6-12	First 6 months:	First 6 months: 7298; 6-12
Joo et al (2014)(7)	Substitution approach was used to value the excess no. of hours of informal care in a matched cohort	2008	USD	Mean cost $8211; $4356 attributable to	min cost $5857; min attributable	max cost $10565; max	Mean cost £4715; £2501	min cost £3363; min	max cost £6066; max attributable
Health Information and Quality Authority (Ireland) (2015)(8)	Informal care, moderate and severe stroke	2007	EUR	10938	6789	15087	8645	5366	11925
Skolarus et al (2016)(9)	Annual cost of both formal and informal care attributable to stroke using substitution method	2011	USD	5000	Not reported	Not reported	3393	Not reported	Not reported
Alvarez-Sabin et al (2016)(10)	Observed no. of hours of informal care valued using the substitution method	2008	EUR	Informal care: 16515 and 18398 for ischaemic and haemorrhagic, respectively	Not reported	Not reported	Informal care: 13836 and 15414 for ischaemic and haemorrhagic, respectively	Not reported	Not reported

Table A2.5: Findings from literature review of lost productivity due to stroke

Author	Category	Cost year	Currency	Original cost	Min	Max	2015 cost (£)	Min	Max
Saka et al (2009)(1)	Lost earnings estimated using human capital approach based on average	2006	GBP	2083	Not reported	Not reported	2534.22	Not reported	Not reported
Fattore et al (2012)(2)	Lost productivity estimated using human capital approach	2007	EUR	792 (sd 28)	781	803	626	617	635
Lopez-Bastida et al (2012)(3)	Lost productivity estimated using human capital approach	2004	EUR	1st year: 1926 (sd 4616); 2nd year: 995 (sd 3396); 3rd year:	Min 1st year: 993; 2nd year: 530 ; 3rd year: 407	Max 1st year: 2859; 2nd year: 1460 ; 3rd year:	1st year: 1762; 2nd year: 910; 3rd year: 890	Min 1st year: 908; 2nd year: 485 ;	Max 1st year: 2615; 2nd year: 1336 ;
Persson et al (2012)(4)	Lost productivity estimated using human capital approach	2008	SEK	18868	Not reported	Not reported	1675	Not reported	Not reported
Alvarez-Sabin et al (2016)(10)	Lost productivity estimated using human capital approach	2008	EUR	lost earnings: 595 and 380 for ischaemic and haemorrhagic, respectively	Not reported	Not reported	lost earnings: 498 and 318 for ischaemic and	Not reported	Not reported

Summary of findings from the review

There were differences in the type of data collected and methods used to value informal care input across studies:

- Studies which collected data on type of care: purchased or unpaid: Saka et al. (2009), Fattore et al. (2012), Lopez-Bastilda et al. (2012)
- Studies which collected data on the number of weekly hours of care: Lopez-Bastilda et al. (2012), Forster et al. (2013), Forster et al. (2014)
- Number of hours of informal care based on assumptions: Saka et al. (2009), Persson et al. (2012), Health Information and Quality Authority (2015)
- Substitution cost approach for unpaid care (assuming purchased care): Joo et al. (2014), Skolarus et al. (2016), Alvarez-Sabin et al. (2017)
- Opportunity cost approach for unpaid care (average foregone earnings): Saka et al. (2009), Fattore et al. (2012), Lopez-Bastilda et al. (2012), Persson et al. (2012), Forster et al. (2013), Forster et al., (2014), Health Information and Quality Authority (2015)

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Appendix 3.1: Delphi questionnaires

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Participant number: 00

Economic impact of stroke study
Research priorities Delphi questionnaire

Round 1

Thank you for agreeing to participate in this Delphi study on the priorities for stroke research. This is the first of two rounds of questionnaires. Once we close this round, we will collate and summarise the findings from all respondents and formulate the second questionnaire. Alongside the second questionnaire, you will receive a summary of all participant responses from this round to inform your answers to the second questionnaire.

We assure you that your participation in this study and your individual responses will be strictly confidential to the research team and will not be divulged to other Delphi group participants or any outside parties.

Q1 What is your main area of expertise? *Select all that apply*

- ☐ Clinical science
- ☐ Clinical and related practice – acute stroke
- ☐ Clinical and related practice – stroke rehabilitation
- ☐ Clinical and related practice – stroke prevention
- ☐ Epidemiology
- ☐ Health services research/evaluation
- ☐ Health policy
- ☐ Other, please state... Click here to enter text.

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Q2 Please **list up to 3** priorities/priority areas for future stroke research. **For each priority**, please **select the likelihood and timing** of each of the following potential benefits if that research was funded immediately.

The order of your list does not matter and you can list less than three if you wish.

Research priority 1: Click here to enter text.

		Likelihood and timing of benefits for research priority 1 *For each row, select all that apply*			
		unlikely	likely within 10 years	likely within 11-20 years	likely after 21 years
1	Fewer first strokes:	☐	☐	☐	☐
2	Fewer subsequent strokes:	☐	☐	☐	☐
3	Greater patient survival:	☐	☐	☐	☐
4	Improved patient quality of life:	☐	☐	☐	☐
5	Improved physical functioning:	☐	☐	☐	☐
6	Improved psychological functioning:	☐	☐	☐	☐
7	Improved social functioning:	☐	☐	☐	☐
8	Improved employment prospects	☐	☐	☐	☐
	Reduced carer burden	☐	☐	☐	☐
9	Reduced health care spending:	☐	☐	☐	☐
10	Reduced social care spending:	☐	☐	☐	☐
11	Improvements to processes and organisation in hospital care:	☐	☐	☐	☐
12	Improvements to processes and organisation in primary/community care:	☐	☐	☐	☐
13	Improvements to processes and organisation in social care:	☐	☐	☐	☐
15	Greater facilitation of future stroke research/understanding	☐	☐	☐	☐
16	Other, please state: Click here to enter text.	☐	☐	☐	☐

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Research priority 2: Click here to enter text.

		Likelihood and timing of benefits for research priority 2 *For each row, select all that apply*			
		unlikely	likely within 10 years	likely within 11-20 years	likely after 21 years
1	Fewer first strokes:	☐	☐	☐	☐
2	Fewer subsequent strokes:	☐	☐	☐	☐
3	Greater patient survival:	☐	☐	☐	☐
4	Improved patient quality of life:	☐	☐	☐	☐
5	Improved physical functioning:	☐	☐	☐	☐
6	Improved psychological functioning:	☐	☐	☐	☐
7	Improved social functioning:	☐	☐	☐	☐
8	Improved employment prospects	☐	☐	☐	☐
	Reduced carer burden	☐	☐	☐	☐
9	Reduced health care spending:	☐	☐	☐	☐
10	Reduced social care spending:	☐	☐	☐	☐
11	Improvements to processes and organisation in hospital care:	☐	☐	☐	☐
12	Improvements to processes and organisation in primary/community care:	☐	☐	☐	☐
13	Improvements to processes and organisation in social care:	☐	☐	☐	☐
15	Greater facilitation of future stroke research/understanding	☐	☐	☐	☐
16	Other, please state: Click here to enter text.	☐	☐	☐	☐

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Research priority 3: Click here to enter text.

		Likelihood and timing of benefits for research priority 3 *For each row, select all that apply*			
		unlikely	likely within 10 years	likely within 11-20 years	likely after 21 years
1	Fewer first strokes:	☐	☐	☐	☐
2	Fewer subsequent strokes:	☐	☐	☐	☐
3	Greater patient survival:	☐	☐	☐	☐
4	Improved patient quality of life:	☐	☐	☐	☐
5	Improved physical functioning:	☐	☐	☐	☐
6	Improved psychological functioning:	☐	☐	☐	☐
7	Improved social functioning:	☐	☐	☐	☐
8	Improved employment prospects	☐	☐	☐	☐
	Reduced carer burden	☐	☐	☐	☐
9	Reduced health care spending:	☐	☐	☐	☐
10	Reduced social care spending:	☐	☐	☐	☐
11	Improvements to processes and organisation in hospital care:	☐	☐	☐	☐
12	Improvements to processes and organisation in primary/community care:	☐	☐	☐	☐
13	Improvements to processes and organisation in social care:	☐	☐	☐	☐
15	Greater facilitation of future stroke research/understanding	☐	☐	☐	☐
16	Other, please state: Click here to enter text.	☐	☐	☐	☐

Thank you

Please feel free to leave any other comments you have in relation to these questions or research priorities more generally.

Click here to enter text.

Queen Mary
University of London

Participant number: 00

Economic impact of stroke study
Research priorities Delphi questionnaire

Round 2

Thank you for your participation in this Delphi study on the priorities for stroke research. This is the second and final round of questionnaires.

In this second round, you have the opportunity to (a) review your previous responses in the context of others' responses (b) select to keep or change your previous responses (c) rank broad areas of research and (d) select priorities within each broad area.

After this round, we will share a short summary of the results with you and use the results as inputs to our projections.

We assure you that your participation in this study and your individual responses will be strictly confidential to the research team and will not be divulged to other Delphi group participants or any outside parties.

Round 2 context

In Round 1, 28 respondents (including you) specified up to three specific research priorities each. These are listed in the long table overleaf. Using your ID number (see the top of this page for a reminder of it), you should find your own responses among the list.

We have placed similar suggestions together and have categorised all suggestions into 5 broad areas related to different parts of the stroke care pathway.

Round 2 tasks

In this second round, we would like you to **first review the long-list** of research priorities and **then complete the following 3 tasks** to help us develop a short-list.

ENTER YOUR RESPONSES FOR ALL TASKS IN THE TABLE OVERLEAF

1. In the column headed 1, **rank the 5 broad areas** from 1 (lowest priority) to 5 (highest priority).
2. In the column headed 2, **select one specific priority in each of the 5 areas (i.e. 5 in total).** You may include the same ones you suggested in Round 1.
3. In the column headed 3, **if you wish to change any/all of the 3 priorities you suggested in Round 1, please tick a set of three** (you can include the same ones you suggested previously). **If you are happy to stick with all your Round 1 suggestions, leave this column blank.**

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ROUND 2 TASKS

Please refer to details on the front page, review the table below and follow instructions in its last three columns.

	Specific priorities suggested in Round 1 These are listed verbatim, and similar suggestions are placed together. Figures in parentheses are respondent ID numbers; see front page for a reminder of your own. [1]Response fall into more than one area so is repeated accordingly.	**YOUR TASKS FOR ROUND 2**		
		1	**2**	**3**
		Rank the 5 broad areas from 1 (lowest priority) to 5 (highest priority). Enter your rankings in the grey text areas below.	**Select one** specific priority **within each of the 5 areas** (i.e. 5 in total).	**If you wish to change your suggestions from Round 1, tick three priorities** (you can include the same ones you suggested previously). **If you are happy to stick** with all your Round 1 suggestions, leave this column blank.
Area 1: Risk factors, primary prevention		Click here to enter text.		
1	The applicability of existing stroke prevention interventions to the oldest old (01)		☐	☐
2	Stratified (individualized) medicine approach to pharmacological prevention and treatment of stroke (06)[1]		☐	☐
3	Find treatment for cerebral small vessel disease (09) / Cerebral small vessel disease (21)		☐	☐
4	Research into prevention (10)		☐	☐
5	Socio-economic health inequalities (13)		☐	☐
6	Reduce the incidence of 1st time strokes (18)		☐	☐
7	Identify optimal strategies to improve cardiovascular physical fitness of those at risk of stroke, or subsequent stroke (26)[1]		☐	☐
8	Optimizing primary prevention - implementing what we already know (30)		☐	☐
9	Implementation of preventative measures eg obesity, air pollution (36)		☐	☐
Area 2: Acute care		Click here to enter text.		
10	Treatment for stroke due to brain haemorrhage (01) / Treatment of haemorrhagic stroke (14) / Treatment for haemorrhagic stroke (39)		☐	☐
11	Development of intervention with longer treatment windows (02)		☐	☐
12	Stratified (individualized) medicine approach to pharmacological prevention and treatment of stroke (06)[1]		☐	☐
13	To develop and test systems to better inform patients/families of the risks and benefits of treatments to allow more informed shared decision making (08)		☐	☐
14	Intracerebral Haemorrhage- better acute treatments (21) / Intracerebral haemorrhage (36)		☐	☐
15	Improve assessment and management of swallowing problems after stroke including NG and PEG feeding strategies (22)		☐	☐

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16	Assessment of the options for delivery of thrombectomy in acute stroke to increase the population able to benefit (22) / Effective implementation of thrombectomy (30) / Research into widening thrombectomy indications using advanced brain imaging techniques combined with RCTs to determine optimum thrombectomy techniques (41)		☐	☐
17	Embedding visions services within stroke units (32)		☐	☐
18	Determine clinical efficiency of treatment options for PSVI (32)		☐	☐
19	Optimal management of severe stroke (39)		☐	☐
20	Service organisation research for acute stroke to identify optimum for best patient outcomes e.g. bypass model versus drip and ship (secondary transfer) (41)		☐	☐
21	Better drug treatments for acute disabling stroke (41)		☐	☐
Area 3: Long-term care, rehabilitation		Click here to enter text.		
22	Reduction of vascular dementia (01) / Vascular cognitive impairment /dementia (21)		☐	☐
23	Effective management and support for life after stroke (02) / Longer term care of stroke survivors (28) / Management of stroke as long term condition (42)		☐	☐
24	Development of effective rehabilitation strategies that commence early index stroke (02)		☐	☐
25	Rehabilitation for cognitive difficulties (04) / Improvements to cognitive and communicative aspects of recovery (05)[1] / Assessment, rehabilitation and pharmacological treatment of cognitive impairment after stroke (06) / Novel treatment for cognitive decline (07) / Cognitive function in stroke including brain structure / location - deficit associations (15) / Long term cognitive impairment (36)		☐	☐
26	Rehabilitation for communication difficulties (04) / Improvements to cognitive and communicative aspects of recovery (05) [1] / Language and aphasia following stroke (15)		☐	☐
27	Support for carers (04)		☐	☐
28	Improvement to process and organisation in primary/community care (05) / Organisation and delivery of community stroke services (06) / How can rehabilitation be optimally delivered to stroke survivors/ carers in the community? (35)		☐	☐
29	Improved rehabilitation strategies (07) / Stronger evidence for rehabilitation therapies (14) / Effects of longer term access to therapy on physical, social and psychological function (18) / Creating an evidence base for stroke rehabilitation (28) / Developing and evaluating services to meet the long term needs of stroke patients and their family (30)		☐	☐
30	Improve assessments and treatment and fatigue (09)		☐	☐
31	Intervention to improve quality of life (10)		☐	☐
32	To improve upper limb function (10)		☐	☐
33	Examination of prevalence of stroke induced disabilities (eg. hemiplegia, dysphasia, hemianopia etc.----these will have changed over last decade with newer interventions such as thrombolysis etc. and most studies are old (11)		☐	☐
34	Walking rehabilitation, Upper limb rehabilitation, Falls rehabilitation (12)		☐	☐
35	Vision impairment: quality of life (13)		☐	☐
36	Service planning/delivery of visual care after stroke (13)		☐	☐
37	Specific rehabilitation for returning to work (14)		☐	☐
38	Sensory and motor rehabilitation following stroke (15)		☐	☐
39	How to increase adoption of physical activity post stroke? (17)		☐	☐

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40	Evaluation of different models of self-management support (group based and ono-to-one); how to increase access, impact and equity (17) / How can we support stroke survivors to meet their personal goals after stroke? (35)		☐	☐
41	Exploring models of social participation post stroke; greater use of social and community networks; impact on psychological and social health (17)		☐	☐
42	What intensity/dose of therapy is required to promote neuroplasticity (18) / Improve assessment and treatment of spasticity and longer term after stroke (22)		☐	☐
43	Identify effective strategies for increasing the amount of rehabilitation activities/practice stroke survivors do outwith their therapist-led sessions (26)		☐	☐
44	Identify optimal strategies for provision of effective long-term emotional/psychological support (26) / Post stroke psychological problems (28) / Impact on outcomes of delivering psychology services to stroke survivors (33) / How to optimally support psychosocial adjustment post stroke (35)		☐	☐
45	Determine cost implication of untreated PSVI (32)		☐	☐
46	Delivery of ESD and longer term rehab through telemedicine as a substitute for face to face interaction (33)		☐	☐
47	Replacement of bed based complex neurorehab (level 1, 2a, 2b) with intensive domiciliary services (33)		☐	☐
Area 4: Secondary prevention		Click here to enter text.		
48	Improved secondary prevention (07)		☐	☐
49	Identify optimal strategies to improve cardiovascular physical fitness of those at risk of stroke, or subsequent stroke (26)[1]		☐	☐
50	Models of behaviour change to improve secondary prevention (42)		☐	☐
Area 5: Cross-cutting issues across the care pathway		Click here to enter text.		
51	Develop and test IT system to optimise the delivery of current evidence based treatment in the NHS (08)		☐	☐
52	Develop and test systems better predict future strokes, and recovery to allow us to target our treatments on those who have most benefit (08)		☐	☐
53	Better access to existing stroke services and treatment for all (09)		☐	☐
54	Identify the process and outcomes of large number of consecutive stroke patients from across the UK and other European countries for 2 year follow up - aiming at Big Data (11)		☐	☐
55	Implementation of interventions and practices for stroke care and rehabilitation that we know are effective and cessation of practices that we know are not effective (05) / Implementation of evidence based practice (39)		☐	☐
56	Management of multi-morbidity in population (not only stroke) (42)		☐	☐

Thank you

Please feel free to leave any other comments you have in relation to these questions or research priorities more generally.

Click here to enter text.

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Participant number: 00

Economic impact of stroke study
Incidence/prevalence Delphi questionnaire

Round 1

Thank you for agreeing to participate in this Delphi study on the incidence and prevalence of stroke. This is the first of two rounds of questionnaires. Once we close this round, we will collate and summarise the findings from all respondents and formulate the second questionnaire. Alongside the second questionnaire, you will receive a summary of all participant responses from this round to inform your answers to the second questionnaire.

We assure you that your participation in this study and your individual responses will be strictly confidential to the research team and will not be divulged to other Delphi group participants or any outside parties.

Q1 What is your main area of expertise? Select all that apply

- ☐ Clinical science
- ☐ Clinical and related practice – acute stroke
- ☐ Clinical and related practice – stroke rehabilitation
- ☐ Clinical and related practice – stroke prevention
- ☐ Epidemiology
- ☐ Health services research/evaluation
- ☐ Health policy
- ☐ Other, please state... Click here to enter text.

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Future trends in stroke incidence

Q2 Below are current best estimates of stroke **incidence** for 4 age groups. **For each age group**, please indicate the level of **annual change** you would expect in each incidence rate over the next (a) **10 years** and (b) **11-20** years (i.e. the period 2026 to 2036). Note that stated percentage changes relate to the amount of change to rates, NOT to point changes in the incident rate.

	Expected annual change in next **10 years**	Expected annual change in next **11-20 years**
Aged 40-64 years: current annual estimates range 114 to 147 per 100,000		
Increase of 2% to 3% per year	☐	☐
Increase of 1% to <2% per year	☐	☐
Increase of <1% per year/no change	☐	☐
Decrease	☐	☐
Aged 65-74 years: current annual estimates range 496 to 522 per 100,000		
Increase of 2% to 3% per year	☐	☐
Increase of 1% to <2% per year	☐	☐
Increase of <1% per year/no change	☐	☐
Decrease	☐	☐
Aged 75-84 years: current annual estimates range 890 to 1003 per 100,000		
Increase of 2% to 3% per year	☐	☐
Increase of 1% to <2% per year	☐	☐
Increase of <1% per year/no change	☐	☐
Decrease	☐	☐
Aged 85-100 years: current annual estimates range 1674 to 1972 per 100,000		
Increase of 2% to 3% per year	☐	☐
Increase of 1% to <2% per year	☐	☐
Increase of <1% per year/no change	☐	☐
Decrease	☐	☐

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Future trends in stroke prevalence

Q3 Below are current best estimates of stroke **prevalence** for 4 age groups. **For each age group**, please indicate the level of **annual change** you would expect in each prevalence rate over the next (a) **10 years** and (b) **11-20** years (i.e. the period 2026 to 2036). Note that stated percentage changes relate to the amount of change to rates, NOT to point changes in the prevalence rate.

	Expected annual change in next **10 years**	Expected annual change in next **11-20 years**
Aged 40-64 years: current annual estimates range 1640 to 2182 per 100,000		
Increase of 2% to 3% per year	☐	☐
Increase of 1% to <2% per year	☐	☐
Increase of <1% per year/no change	☐	☐
Decrease	☐	☐
Aged 65-74 years: current annual estimates range 3980 to 6040 per 100,000		
Increase of 2% to 3% per year	☐	☐
Increase of 1% to <2% per year	☐	☐
Increase of <1% per year/no change	☐	☐
Decrease	☐	☐
Aged 75-84 years: current annual estimates range 9110 to 10990 per 100,000		
Increase of 2% to 3% per year	☐	☐
Increase of 1% to <2% per year	☐	☐
Increase of <1% per year/no change	☐	☐
Decrease	☐	☐
Aged 85-100 years: current annual estimates range 9300 to 9840 per 100,000		
Increase of 2% to 3% per year	☐	☐
Increase of 1% to <2% per year	☐	☐
Increase of <1% per year/no change	☐	☐
Decrease	☐	☐

Thank you

Please feel free to leave any other comments you have in relation to these questions or stroke incidence/prevalence more generally.

Click here to enter text.

Queen Mary
University of London

Participant number: 00

Economic impact of stroke study
Incidence/prevalence Delphi questionnaire

Round 2

Thank you for your participation in this Delphi study on the incidence and prevalence of stroke. This is the second and final round of questionnaires.

In this second round, you have the opportunity to (1) review your previous responses in the context of others' responses (2) select to keep or change your previous responses and (3) offer your views on the best sources for current incidence/prevalence estimates.

After this round, we will share a short summary of the results with you and use the results as inputs to our cost projections.

We assure you that your participation in this study and your individual responses will be strictly confidential to the research team and will not be divulged to other Delphi group participants or any outside parties.

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Q1 Future trends in stroke incidence

Below are current best estimates of stroke incidence for 4 age groups. We previously asked you to indicate the level of **annual change** you would expect in each incidence rate over the next (a) **10 years** and (b) **11-20** years (i.e. the period 2026 to 2036). Now please:

1. **Review** your own Round 1 responses for each age group below (indicated by green shaded cells) and the distribution of responses from all participants (indicated as percentages* of n=11 including you).

2. **Then choose** to:
   EITHER **stick with all** your Round 1 responses, by doing nothing and moving to Q2
   OR **change any/all responses** by simply ticking alternative boxes in relevant sub-sections.

   Note that **we are not seeking consensus** on responses, this is merely an opportunity to change your views in light of others' views, and that the stated percentage change options below relate to the amount of change to rates, NOT to point changes in the incident rate.

	Expected annual change in next **10 years**		Expected annual change in next **11-20 years**	
	Your previous response is highlighted green	Panel's previous response	Your previous response is highlighted green	Panel's previous response
Aged 40-64 years: current annual estimates range 114 to 147 per 100,000				
Increase of 2% to 3% per year	☐	18%	☐	18%
Increase of 1% to <2% per year	☐	27%	☐	27%
Increase of <1% per year/no change	☐	27%	☐	9%
Decrease	☐	27%	☐	36%
Aged 65-74 years: current annual estimates range 496 to 522 per 100,000				
Increase of 2% to 3% per year	☐	9%	☐	9%
Increase of 1% to <2% per year	☐	27%	☐	27%
Increase of <1% per year/no change	☐	18%	☐	18%
Decrease	☐	45%	☐	36%
Aged 75-84 years: current annual estimates range 890 to 1003 per 100,000				
Increase of 2% to 3% per year	☐	18%	☐	18%
Increase of 1% to <2% per year	☐	9%	☐	18%
Increase of <1% per year/no change	☐	36%	☐	27%
Decrease	☐	36%	☐	27%
Aged 85-100 years: current annual estimates range 1674 to 1972 per 100,000				
Increase of 2% to 3% per year	☐	18%	☐	27%
Increase of 1% to <2% per year	☐	18%	☐	9%
Increase of <1% per year/no change	☐	45%	☐	36%
Decrease	☐	18%	☐	18%

*Percentages within each section don't always add to 100% due to rounding

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Q2 Future trends in stroke prevalence

TASKS FOR THIS QUESTION ARE THE SAME AS FOR Q1

Below are current best estimates of stroke prevalence for 4 age groups. We previously asked you to indicate the level of **annual change** you would expect in each prevalence rate over the next (a) **10 years** and (b) **11-20** years (i.e. the period 2026 to 2036). Now please:

1. **Review** your own Round 1 responses for each age group below (indicated by green shaded cells) and the distribution of responses from all participants (indicated as percentages* of n=11 including you).

2. **Then choose** to:
   EITHER **stick with all** your Round 1 responses, by doing nothing and moving to Q3
   OR **change any/all responses** by simply ticking alternative boxes in relevant sub-sections.

   Note that **we are not seeking consensus** on responses, this is merely an opportunity to change your views in light of others' views, and that the stated percentage change options below relate to the amount of change to rates, NOT to point changes in the prevalence rate.

	Expected annual change in next **10 years**		Expected annual change in next **11-20 years**	
	Your previous response is highlighted green	Panel's previous response	Your previous response is highlighted green	Panel's previous response
Aged 40-64 years: current annual estimates range 1640 to 2182 per 100,000				
Increase of 2% to 3% per year	☐	9%	☐	9%
Increase of 1% to <2% per year	☐	36%	☐	36%
Increase of <1% per year/no change	☐	45%	☐	45%
Decrease	☐	9%	☐	9%
Aged 65-74 years: current annual estimates range 3980 to 6040 per 100,000				
Increase of 2% to 3% per year	☐	9%	☐	9%
Increase of 1% to <2% per year	☐	64%	☐	82%
Increase of <1% per year/no change	☐	27%	☐	9%
Decrease	☐	0%	☐	0%
Aged 75-84 years: current annual estimates range 9110 to 10990 per 100,000				
Increase of 2% to 3% per year	☐	36%	☐	55%
Increase of 1% to <2% per year	☐	55%	☐	36%
Increase of <1% per year/no change	☐	9%	☐	9
Decrease	☐	0%	☐	0%
Aged 85-100 years: current annual estimates range 9300 to 9840 per 100,000				
Increase of 2% to 3% per year	☐	74%	☐	82%
Increase of 1% to <2% per year	☐	18%	☐	9%
Increase of <1% per year/no change	☐	9%	☐	9%
Decrease	☐	0%	☐	0%

*Percentages within each section don't always add to 100% due to rounding

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Q3 Sources of current incidence/prevalence rates

As indicated in the questions above, there is a wide range of uncertainty about the current UK incidence and prevalence rates of stroke by age band. This reflects differing findings from different studies. We have listed below the studies we used to generate the age-band specific rates for this questionnaire. We would appreciate your advice about:

EITHER

(a) Which of these studies you consider currently provide the most robust incidence and prevalence rates by age band for the UK. Select all that apply.

- ☐ Wolfe CD, Rudd AG, Howard R, Coshall C, Stewart J, Lawrence E, Hillen T. Incidence and case fatality rates of stroke subtypes in a multiethnic population: the South London Stroke Register. Journal of Neurology, Neurosurgery, and Psychiatry 2002; 72(2): 211–216
- ☐ Stewart J A, Dundas R, Howard RS, Rudd AG, Wolfe CD. Ethnic differences in incidence of stroke: prospective study with stroke register. BMJ 1999; 318(7189): 967–971
- ☐ Rothwell PM, Coull AJ, Giles MF, Howard SC, Silver LE, Bull LM, Gutnikov SA, Edwards P, Mant D, Sackley CM, Farmer A, Sandercock PAG, Dennis MS, Warlow CP, Bamford JM, Anslow P. Change in stroke incidence, mortality, case-fatality, severity, and risk factors in Oxfordshire, UK from 1981 to 2004 (Oxford Vascular Study). Lancet 2004; 363 (9425): 1925-33
- ☐ Saka Ö, McGuire A, Wolfe C. Cost of stroke in the United Kingdom. Age and Ageing 2009; 38(1): 27-32
- ☐ Geddes JM, Fear J, Tennant A, Pickering A, Hillman M, Chamberlain MA. Prevalence of self reported stroke in a population in northern England. Journal of Epidemiology and Community Health 1996; 50 (2): 140-3

OR

(b) What current UK incidence and prevalence rates by age band (or overall) you use in your work or would recommend.

Click here to enter text.

Thank you

Please feel free to leave any other comments you have in relation to these questions or stroke incidence/prevalence more generally.

Click here to enter text.

Appendix 3.2: Delphi study details

Table A3.1: Self-reported area of expertise of participants in incidence/prevalence Delphi group (n=11)

	N*	%
Clinical science	6	55
Clinical and related practice – acute stroke	9	82
Clinical and related practice – stroke rehabilitation	8	73
Clinical and related practice – stroke prevention	7	64
Epidemiology	2	18
Health services research/evaluation	7	64
Health policy	3	27

Table A3.2: Self-reported area of expertise of participants in research priorities Delphi group (n=28)

	N*	%
Clinical science	8	29
Clinical and related practice – acute stroke	15	54
Clinical and related practice – stroke rehabilitation	21	75
Clinical and related practice – stroke prevention	9	32
Epidemiology	4	14
Health services research/evaluation	15	54
Health policy	4	14
Other	3	11

*Total numbers in each group exceed the sample size of each group because participants were able to select more than one area from the list of areas provided (which was as stated above)

Table A3.3: Research priorities Delphi group Round 2: rankings assigned to 5 broad areas (available n=25)

	Rank 5 (Highest)	Rank 4	Rank 3	Rank 2	Rank 1 (Lowest)
	Number (%) selecting rank for each area				
	n (%)	n (%)	n (%)	n (%)	n (%)
Area 1: Risk factors, primary prevention	4(16)	0(0)	9(36)	11(44)	1(4)
Area 2: Acute care	5(20)	6(24)	5(20)	2(8)	7(28)
Area 3: Long-term care, rehabilitation	8(32)	6(24)	2(8)	2(8)	7(28)
Area 4: Secondary prevention	2(8)	4(16)	6(24)	9(36)	4(16)
Area 5: Cross-cutting issues across the care pathway	6(24)	9(36)	3(12)	1(4)	6(24)

Table A3.4: Research priorities Delphi group Round 2: number of participants selecting each research priority, unweighted and weighted for number of options in each category and the rank assigned to each category (available n= 27)

Code	Research priority	Number of participants selecting this priority	Number of participants selecting this priority, weighted by the number of options available in the category	Number of participants selecting this priority, further weighted by the ranking applied to the category
	Area 1: Risk factors, primary prevention			
1	The applicability of existing stroke prevention interventions to the oldest old	0	0.00	0.00

Code	Research priority	Number of participants selecting this priority	Number of participants selecting this priority, weighted by the number of options available in the category	Number of participants selecting this priority, further weighted by the ranking applied to the category
2	Stratified (individualized) medicine approach to pharmacological prevention and treatment of stroke	0	0.00	0.00
3	Find treatment for cerebral small vessel disease / Cerebral small vessel disease	7	2.33	6.53
4	Research into prevention	2	0.67	1.87
5	Socio-economic health inequalities	4	1.33	3.73
6	Reduce the incidence of 1st time strokes	4	1.33	3.73
7	Identify optimal strategies to improve cardiovascular physical fitness of those at risk of stroke, or subsequent stroke	1	0.33	0.93
8	Optimizing primary prevention - implementing what we already know	7	2.33	6.53
9	Implementation of preventative measures e.g. obesity, air pollution	2	0.67	1.87
		27		
	Area 2: Acute care			
10	Treatment for stroke due to brain haemorrhage / Treatment of haemorrhagic stroke / Treatment for haemorrhagic stroke	3	1.33	4.00
11	Development of intervention with longer treatment windows	1	0.44	1.33
12	Stratified (individualized) medicine approach to pharmacological prevention and treatment of stroke	1	0.44	1.33
13	To develop and test systems to better inform patients/families of the risks and benefits of treatments to allow more informed shared decision making	1	0.44	1.33
14	Intracerebral Haemorrhage- better acute treatments / Intracerebral haemorrhage	2	0.89	2.67
15	Improve assessment and management of swallowing problems after stroke including NG and PEG feeding strategies	2	0.89	2.67
16	Assessment of the options for delivery of thrombectomy in acute stroke to increase the population able to benefit / Effective implementation of thrombectomy / Research into widening thrombectomy indications using advanced brain imaging techniques combined with RCTs to determine optimum thrombectomy techniques	8	3.56	10.67
17	Embedding visions services within stroke units	2	0.89	2.67
18	Determine clinical efficiency of treatment options for PSVI	0	0.00	0.00
19	Optimal management of severe stroke	4	1.78	5.33

Code	Research priority	Number of participants selecting this priority	Number of participants selecting this priority, weighted by the number of options available in the category	Number of participants selecting this priority, further weighted by the ranking applied to the category
20	Service organisation research for acute stroke to identify optimum for best patient outcomes e.g. bypass model versus drip and ship (secondary transfer)	3	1.33	4.00
21	Better drug treatments for acute disabling stroke	0	0.00	0.00
		27		
	Area 3: Long-term care, rehabilitation			
22	Reduction of vascular dementia / Vascular cognitive impairment /dementia	4	3.85	12.48
23	Effective management and support for life after stroke / Longer term care of stroke survivors / Management of stroke as long term condition	1	0.96	3.12
24	Development of effective rehabilitation strategies that commence early index stroke	0	0.00	0.00
25	Rehabilitation for cognitive difficulties / Improvements to cognitive and communicative aspects of recovery / Assessment, rehabilitation and pharmacological treatment of cognitive impairment after stroke / Novel treatment for cognitive decline / Cognitive function in stroke including brain structure / location - deficit associations / Long term cognitive impairment	5	4.81	15.60
26	Rehabilitation for communication difficulties / Improvements to cognitive and communicative aspects of recovery / Language and aphasia following stroke	1	0.96	3.12
27	Support for carers	0	0.00	0.00
28	Improvement to process and organisation in primary/community care / Organisation and delivery of community stroke services / How can rehabilitation be optimally delivered to stroke survivors/ carers in the community	1	0.96	3.12
29	Improved rehabilitation strategies / Stronger evidence for rehabilitation therapies / Effects of longer term access to therapy on physical, social and psychological function / Creating an evidence base for stroke rehabilitation / Developing and evaluating services to meet the long term needs of stroke patients and their family	6	5.78	18.72
30	Improve assessments and treatment and fatigue	0	0.00	0.00
31	Intervention to improve quality of life	1	0.96	3.12
32	To improve upper limb function	0	0.00	0.00

Code	Research priority	Number of participants selecting this priority	Number of participants selecting this priority, weighted by the number of options available in the category	Number of participants selecting this priority, further weighted by the ranking applied to the category
33	Examination of prevalence of stroke induced disabilities (e.g. hemiplegia, dysphasia, hemianopia etc.----these will have changed over last decade with newer interventions such as thrombolysis etc. and most studies are old	0	0.00	0.00
34	Walking rehabilitation, Upper limb rehabilitation, Falls rehabilitation	1	0.96	3.12
35	Vision impairment: quality of life	1	0.96	3.12
36	Service planning/delivery of visual care after stroke	1	0.96	3.12
37	Specific rehabilitation for returning to work	0	0.00	0.00
38	Sensory and motor rehabilitation following stroke	0	0.00	0.00
39	How to increase adoption of physical activity post stroke?	0	0.00	0.00
40	Evaluation of different models of self-management support (group based and one-to-one); how to increase access, impact and equity / How can we support stroke survivors to meet their personal goals after stroke?	2	1.93	6.24
41	Exploring models of social participation post stroke; greater use of social and community networks; impact on psychological and social health	1	0.96	3.12
42	What intensity/dose of therapy is required to promote neuroplasticity / Improve assessment and treatment of spasticity and longer term after stroke	0	0.00	0.00
43	Identify effective strategies for increasing the amount of rehabilitation activities/practice stroke survivors do outwith their therapist-led sessions	1	0.96	3.12
44	Identify optimal strategies for provision of effective long-term emotional/psychological support / Post stroke psychological problems / Impact on outcomes of delivering psychology services to stroke survivors / How to optimally support psychosocial adjustment post stroke	1	0.96	3.12
45	Determine cost implication of untreated PSVI	0	0.00	0.00
46	Delivery of ESD and longer term rehab through telemedicine as a substitute for face to face interaction	0	0.00	0.00
47	Replacement of bed based complex neurorehab (level 1, 2a, 2b) with intensive domiciliary services	0	0.00	0.00
		27		
	Area 4: Secondary prevention			
48	Improved secondary prevention	10	0.74	1.96

Code	Research priority	Number of participants selecting this priority	Number of participants selecting this priority, weighted by the number of options available in the category	Number of participants selecting this priority, further weighted by the ranking applied to the category
49	Identify optimal strategies to improve cardiovascular physical fitness of those at risk of stroke, or subsequent stroke	6	0.44	1.17
50	Models of behaviour change to improve secondary prevention	10	0.74	1.96
	(No answer)	1		
		27		
	Area 5: Cross-cutting issues across the care pathway			
51	Develop and test IT system to optimise the delivery of current evidence based treatment in the NHS	4	0.89	2.95
52	Develop and test systems better predict future strokes, and recovery to allow us to target our treatments on those who have most benefit	2	0.44	1.48
53	Better access to existing stroke services and treatment for all	7	1.56	5.16
54	Identify the process and outcomes of large number of consecutive stroke patients from across the UK and other European countries for 2 year follow up - aiming at Big Data	1	0.22	0.74
55	Implementation of interventions and practices for stroke care and rehabilitation that we know are effective and cessation of practices that we know are not effective/ Implementation of evidence based practice	12	2.67	8.85
56	Management of multi-morbidity in population (not only stroke)	1	0.22	0.74
		27	6.00	19.92

Those highlighted in red achieved the highest weighted number of selections

Appendix 3.3: Expert views on sources of incidence and prevalence rates for stroke

Responses (direct quotations, ID numbers in brackets) to the question: "What current UK incidence and prevalence rates by age band (or overall) you use in your work or would recommend."

All the papers above are out of date ones. S lomdon ones better to have wang et al papers and wolfe et al for aetiology-best for ethnicity and inner city saka is not an epi study Rothwell rates updated too-good for Caucasian urban/rural (42)
SSNAP data as this will be more comprehensive and accurate than any other (41)
1. GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980-2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet. 2016 Oct 8;388 2. Hajat C, Heuschmann PU, Coshall C, Padayachee S, Chambers J, Rudd AG, Wolfe CD. Incidence of aetiological subtypes of stroke in a multi-ethnic population based study: the South London Stroke Register. J Neurol Neurosurg Psychiatry. 2011 May; 82(5):527-33. (33)
O'Mahony P, Rodgers H, Dobson R, James OFW, Thomson R. Prevalence of stroke and related disability in Newcastle upon Tyne. Journal of Public Health 1999;21:166-71 (30)
Several of the texts included above are based on the same dataset eg South London Stroke Register. I have chosen the most contemporary analysis but I have reservations about the generalisability of the South London data to the UK as a whole. For stroke incidence we are lucky in the UK to have good data from the national stroke registries – SSNAP and SSCA. Although these resources only include hospitalised stroke, The Borders Stroke Study would suggest that most stroke (as opposed to TIA) will present to hospital [https://www.ncbi.nlm.nih.gov/pubmed/16081859]. Prevalence data are more difficult. For local work I had used primary care data as Glasgow GP surgeries were paid to keep a register

of all with stroke and offer annual review (the Local Enhanced Service). Even with this dataset there was substantial missing data particularly those who are housebound, have cognitive impairment are resident in carehomes. (see http://heart.bmj.com/content/100/7/557 for an example of a paper using the LES data) (28)

Appendix 5.1: Approaches for estimating return on research investment

Table A5.1: Examples of approaches for estimating returns on research investment

Publication Source and Year	Country, context and type of study	Health area	Summary of methods	Comments
Glover et al. 2014	UK, assessing the returns publicly funded research. A review	Cancer related research	Reviewed five studies and examined the following five issues: **1.How health gains were assessed** Four studies for assessing health gains used a top-down approach: overall gain in mortality and morbidity (mostly not linked to specific intervention) and attributed certain proportion to R&D investment. One study (HERG/OHE/RAND Europe, 2008) identified research-based interventions, then quantified health impact using a bottom up approach **2.How health gains were valued** Four studies used a willingness to pay approach for valuing health gains – value derived from labour economics; among these one did a meta-analysis of international studies and the HERG/OHE/RAND Europe (2008) study used current level of	Validation of the bottom-up approach developed by HERG/OHE/RAND Europe (2008) to estimate economic returns from research from public and charitable expenditure on cancer research in the UK. The focus of was health gains (measured by QALYs)

Publication Source and Year	Country, context and type of study	Health area	Summary of methods	Comments
			NHS spending i.e. the opportunity cost of a QALY within the current NHS budget. **3.Proportion of national health gains allocated to national research** Three studies discussed the issue of proportion of national health gain allocated to national research; they used bibliometric analysis-based estimates e.g. share of global research, citations of research in clinical guidelines. **4. Cost of health care considered?** The HERG/OHE/RAND Europe (2008) study did net-off the health costs required to achieve the health gains, and one other study, though did not net-off health care delivery costs but did consider avoided health systems expenditure due to gains in well-being. **5. Considered elapsed time between research and health gains?**	directly attributed to research derived interventions. They measured net monetary benefits of QALYs, estimated the proportion of net monetary benefit attributable to UK research, estimated the elapsed time between funding and health gain, and calculated an internal rate of return.

Publication Source and Year	Country, context and type of study	Health area	Summary of methods	Comments
			Four studies considered elapsed time between research and health gains, ranging from 10-40 years; one included a sensitivity analysis. **6. How the overall rate of return is calculated** Two used internal rate of return (IRR), two used overall benefit costs ratios to estimate rate of return.	
Banzi et al. 2011	A review based on 4 systematic reviews	Reviewed conceptual frameworks to assess the impact of health research	The most widespread frameworks (models) identified were: -Payback -Research impact -Research utilization ladder -Lavis decision making impact model -Weiss Logic model -Health Technology Assessment organisation assessment framework -Societal impact framework -Balanced scorecard -Research assessment exercise -Cost benefit analysis	

Publication Source and Year	Country, context and type of study	Health area	Summary of methods	Comments
			The payback model and its adaptation in Canada was the most frequently quoted. All these frameworks (models) have defined dimensions of impact evaluation and indicators to measure it. For cost benefit analysis, proposed indicators to measure health benefits include QALYs, patient-reported outcome measures (PROMs), health determinants (risk factors, educational and social level cohesion) and health systems (patient satisfaction). Proposed indicators for economic and social benefits include economic rent, licensing returns, product sales, spin-off companies, health benefits (QALYs, PROMs per health care $/£,), well-being and social benefits.	
Frank & Nason, 2009	Analysis, review of different approaches and		Two main approaches used over past 20 years to measure return to investment on health research are:	Gross econometric methods are useful for advocacy and

Publication Source and Year	Country, context and type of study	Health area	Summary of methods	Comments
	discussion on need for new methods addressing the issues/limitations		- "top-down econometric" calculations: monetised improvement in life expectancy and quality of life; attributed roughly one-third of those gains to health research; used in USA and Australia. - "bottom up" "payback" model: evolving for more than two decades; recently adapted and modified by the Canadian Institute of Health Research in Canada. These two approaches were found to be used in the US (econometric), Ireland (programme level payback model), Australia (econometric modelling) and the UK (pay back). A hybrid version was used in UK to estimate economic benefits and health gains from investment in cardiovascular disease. Both suffer from common issues: - how to attribute costs and benefits to research	decisions at policy levels. They are less helpful for improving individual programme planning or delivery. Bottom up "payback" methods are less prone to assumptions about linkage to outputs and confounding effects, but can be slow and costly due to the detail required.

Publication Source and Year	Country, context and type of study	Health area	Summary of methods	Comments
			- the "counterfactual: what would have happened if the research had not been taken conducted and how this can be determined - time lag for knowledge translation - need for clear definition of what to measure and how to capture impacts in meaningful terms	
Kwan et al. 2007	Hong Kong, survey of principal investigators	Publicly funded health and health services	Evaluated the use of public funds in health and health services. Used "payback" evaluation framework. Research "payback" in six outcome areas: - knowledge production - use of research in the research systems - use of research project findings in health system policy/decision making - application of research findings through changed behaviour - factors influencing the utilization of research - health/health services economic benefits	

Publication Source and Year	Country, context and type of study	Health area	Summary of methods	Comments
Donovan et al. 2014	Australia, impact evaluation of research	Evaluating the impact of National Breast Cancer-funded research	Considered research funded for the period 1995-2012. Conducted surveys based on Payback Framework, surveyed chief investigators of research projects. The main outcome measures were: - knowledge production - Impact on health research systems - informing policy, decision making - product development - broader economic benefits	Targeting further research and attracting further income was considered as a benefit to the health research system. Change in behaviour and practice in health care was considered as a health gain and broader economic benefit.

Appendix 5.2: Expert views from Delphi-style consultation: expected benefits from further research into the top-5 rated research priorities

Table A5.2: Potential benefits from research into improved rehabilitation strategies

Benefits	Median (1-0)	Number of Yes	N
Fewer first strokes:			
Unlikely	1	4	4
Likely within 10 years	0	0	4
Likely within 11-20 years	0	0	4
Likely after 21 years	0	0	4
Fewer subsequent strokes:			
Unlikely	1	4	4
Likely within 10 years	0	0	4
Likely within 11-20 years	0	0	4
Likely after 21 years	0	0	4
Greater patient survival:			
Unlikely	0.5	2	4
Likely within 10 years	0	1	4
Likely within 11-20 years	0	0	4
Likely after 21 years	0	1	4
Improved patient quality of life:			
Unlikely	0	0	5
Likely within 10 years	1	3	5
Likely within 11-20 years	0	2	5
Likely after 21 years	0	0	5
Improved physical functioning:			
Unlikely	0	0	5
Likely within 10 years	1	3	5

Table A5.2: Potential benefits from research into improved rehabilitation strategies			
Benefits	Median (1-0)	Number of Yes	N
Likely within 11-20 years	0	2	5
Likely after 21 years	0	0	5
Improved psycho functioning:			
Unlikely	0	0	5
Likely within 10 years	0	2	5
Likely within 11-20 years	1	3	5
Likely after 21 years	0	0	5
Improved social functioning:			
Unlikely	0	0	5
Likely within 10 years	0	2	5
Likely within 11-20 years	1	3	5
Likely after 21 years	0	0	5
Improved emp. Prospects:			
Unlikely	0	0	5
Likely within 10 years	0	2	5
Likely within 11-20 years	0	2	5
Likely after 21 years	0	1	5
Reduced carer burden			
Unlikely	0	0	5
Likely within 10 years	0	2	5
Likely within 11-20 years	0	2	5
Likely after 21 years	0	1	5
Reduced health care spending:			
Unlikely	0	1	5
Likely within 10 years	0	1	5
Likely within 11-20 years	1	3	5

Table A5.2: Potential benefits from research into improved rehabilitation strategies			
Benefits	Median (1-0)	Number of Yes	N
Likely after 21 years	0	0	5
Reduced social care spending:			
Unlikely	0	0	5
Likely within 10 years	0	1	5
Likely within 11-20 years	1	3	5
Likely after 21 years	0	1	5

Table A5.3: Potential benefits from research into rehabilitation for cognitive difficulties			
Benefits	Median (1-0)	Number of Yes	N
Fewer first strokes:			
Unlikely	1	4	4
Likely within 10 years	0	0	4
Likely within 11-20 years	0	0	4
Likely after 21 years	0	0	4
Fewer subsequent strokes:			
Unlikely	0.5	2	4
Likely within 10 years	0	1	4
Likely within 11-20 years	0	1	4
Likely after 21 years	0	0	4
Greater patient survival:			
Unlikely	0	1	4
Likely within 10 years	0	1	4
Likely within 11-20 years	0.5	2	4
Likely after 21 years	0	0	4
Improved patient quality of life:			
Unlikely	0	0	5
Likely within 10 years	1	4	5
Likely within 11-20 years	0	1	5
Likely after 21 years	0	0	5
Improved physical functioning:			
Unlikely	0	0	4
Likely within 10 years	1	3	4
Likely within 11-20 years	0	1	4
Likely after 21 years	0	0	4
Improved psycho functioning:			

Table A5.3: Potential benefits from research into rehabilitation for cognitive difficulties			
Benefits	Median (1-0)	Number of Yes	N
Unlikely	0	0	5
Likely within 10 years	1	4	5
Likely within 11-20 years	0	1	5
Likely after 21 years	0	0	5
Improved social functioning:			
Unlikely	0	0	5
Likely within 10 years	1	4	5
Likely within 11-20 years	0	1	5
Likely after 21 years	0	0	5
Improved emp. Prospects:			
Unlikely	0	1	5
Likely within 10 years	1	4	5
Likely within 11-20 years	0	0	5
Likely after 21 years	0	0	5
Reduced carer burden			
Unlikely	0	0	5
Likely within 10 years	1	4	5
Likely within 11-20 years	0	1	5
Likely after 21 years	0	0	5
Reduced health care spending:			
Unlikely	0	0	5
Likely within 10 years	1	3	5
Likely within 11-20 years	0	2	5
Likely after 21 years	0	0	5
Reduced social care spending:			
Unlikely	0	0	4
Likely within 10 years	0.5	2	4
Likely within 11-20 years	0.5	2	4

Table A5.3: Potential benefits from research into rehabilitation for cognitive difficulties			
Benefits	Median (1-0)	Number of Yes	N
Likely after 21 years	0	0	4

Table A5.4: Potential benefits from research into vascular dementia			
Benefits	Median (1-0)	Number of Yes	N
Fewer first strokes:			
Unlikely	1	1	1
Likely within 10 years	0	0	1
Likely within 11-20 years	0	0	1
Likely after 21 years	0	0	1
Fewer subsequent strokes:			
Unlikely	1	1	1
Likely within 10 years	0	0	1
Likely within 11-20 years	0	0	1
Likely after 21 years	0	0	1
Greater patient survival:			
Unlikely	1	1	1
Likely within 10 years	0	0	1
Likely within 11-20 years	0	0	1
Likely after 21 years	0	0	1
Improved patient quality of life:			
Unlikely	0	0	2
Likely within 10 years	0.5	1	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0.5	1	2
Improved physical functioning:			
Unlikely	1	1	1
Likely within 10 years	0	0	1
Likely within 11-20 years	0	0	1
Likely after 21 years	0	0	1
Improved psycho functioning:			
Unlikely	0	0	2

Table A5.4: Potential benefits from research into vascular dementia			
Benefits	Median (1-0)	Number of Yes	N
Likely within 10 years	0.5	1	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0.5	1	2
Improved social functioning:			
Unlikely	0	0	2
Likely within 10 years	0.5	1	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0.5	1	2
Improved emp. Prospects:			
Unlikely	0.5	1	2
Likely within 10 years	0.5	1	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Reduced carer burden			
Unlikely	0	0	2
Likely within 10 years	0.5	1	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0.5	1	2
Reduced health care spending:			
Unlikely	0.5	1	2
Likely within 10 years	0.5	1	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Reduced social care spending:			
Unlikely	0	0	2
Likely within 10 years	0.5	1	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0.5	1	2

Table A5.5: Potential benefits from research into thrombectomy			
Benefits	Median (1-0)	Number of Yes	N
Fewer first strokes:			
Unlikely	1	3	3
Likely within 10 years	0	0	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Fewer subsequent strokes:			
Unlikely	1	2	3
Likely within 10 years	0	1	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Greater patient survival:			
Unlikely	0	0	3
Likely within 10 years	1	3	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Improved patient quality of life:			
Unlikely	0	0	3
Likely within 10 years	1	3	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Improved physical functioning:			
Unlikely	0	0	3
Likely within 10 years	1	3	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Improved psycho functioning:			
Unlikely	0	0	3

Table A5.5: Potential benefits from research into thrombectomy			
Benefits	Median (1-0)	Number of Yes	N
Likely within 10 years	1	3	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Improved social functioning:			
Unlikely	0	0	3
Likely within 10 years	1	3	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Improved emp. Prospects:			
Unlikely	0	0	3
Likely within 10 years	1	3	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Reduced carer burden			
Unlikely	0	0	3
Likely within 10 years	1	3	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Reduced health care spending:			
Unlikely	0	0	3
Likely within 10 years	1	3	3
Likely within 11-20 years	0	0	3
Likely after 21 years	0	0	3
Reduced social care spending:			
Unlikely	0	0	3
Likely within 10 years	1	2	3
Likely within 11-20 years	0	1	3
Likely after 21 years	0	0	3

Table A5.6: Potential benefits from research into evidence based practice			
Benefits	Median (1-0)	Number of Yes	N
Fewer first strokes:			
Unlikely	0	0	1
Likely within 10 years	1	1	1
Likely within 11-20 years	0	0	1
Likely after 21 years	0	0	1
Fewer subsequent strokes:			
Unlikely	0	0	1
Likely within 10 years	1	1	1
Likely within 11-20 years	0	0	1
Likely after 21 years	0	0	1
Greater patient survival:			
Unlikely	0	0	2
Likely within 10 years	1	2	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Improved patient quality of life:			
Unlikely	0	0	2
Likely within 10 years	1	2	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Improved physical functioning:			
Unlikely	0	0	2
Likely within 10 years	1	2	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Improved psycho functioning:			
Unlikely	0	0	2
Likely within 10 years	1	2	2

Table A5.6: Potential benefits from research into evidence based practice			
Benefits	Median (1-0)	Number of Yes	N
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Improved social functioning:			
Unlikely	0	0	2
Likely within 10 years	1	2	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Improved emp. Prospects:			
Unlikely	0	0	2
Likely within 10 years	1	2	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Reduced carer burden			
Unlikely	0	0	2
Likely within 10 years	1	2	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Reduced health care spending:			
Unlikely	0	0	2
Likely within 10 years	1	2	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2
Reduced social care spending:			
Unlikely	0	0	2
Likely within 10 years	1	2	2
Likely within 11-20 years	0	0	2
Likely after 21 years	0	0	2

Appendix 5.3: Methodology for estimating impact of research priorities

This annex sets out the methodology for the estimation of the overall projected savings and the net gains from the development of rehabilitation of physical function following a research programme on this topic. The methodology for estimating the impacts of the other research priorities is similar.

The basis for the projections of the number of new strokes is set out in Chapter 4. Chapter 5 sets out the basis for estimating savings to health care, social care and unpaid care and for assuming an annual mortality rate of 6.7% for those receiving rehabilitation. It also sets the assumptions for the proportion of people receiving rehabilitation, the assumed cost of rehabilitation and its assumed impact on quality of life and on care needs and costs. Here, we explain how the findings are derived from the assumptions. The calculations were conducted in Excel.

We project that the number of new strokes in the UK will rise from 117,600 in 2015 to 133,200 in 2020, 148,700 in 2025, 168,100 in 2030 and 186,900 in 2035. This is on the basis set out in chapter 4.

We assume that 10% of those experiencing a first stroke in the years 2025 to 2029 and 20% of those experiencing a new stroke from 2030 onward will receive rehabilitation. This means, for example, that 14,870 people will receive rehabilitation in 2025 of whom 11,660 will survive to 2030 and that 33,620 will receive rehabilitation in 2030 of whom 26,270 will survive to 2035. This is on the basis of an annual mortality rate of 6.7% for those receiving rehabilitation as discussed in chapter 5.

We produce similar estimates for each year from 2025 onward and sum across cohorts the estimated number of survivors to 2030 and to 2035. On this basis we estimate that 98,100 stroke survivors in 2030 and 220,500 stroke survivors in 2035 will have received rehabilitation.

Of these, 87,400 in 2030 and 158,000 in 2035 will be within five years of their receipt of rehabilitation. The importance of identifying those stroke survivors who are within five years of receiving rehabilitation is that we assume that the benefits of rehabilitation will endure for five years.

In 2035 the estimated cost of the rehabilitation is £228 million (at 2015 prices). The estimated savings to health care, social care and unpaid care are £1,083 million on the basis of the assumptions set out in chapter 5. This produces an estimated net saving in 2035 of £855 million (at 2015 prices).

At the individual level for a person receiving rehabilitation in 2025 –

- the assumed cost of the intervention is £5,000 and of the research £100 (on the basis that so many people will benefit from it that only a small proportion of the overall cost of the research programme should be assigned to each person);
- the annual saving in health care costs is zero in the first year and then £413 per year, totalling over four years £1,593 after discounting (at 3.5%);
- the annual saving in social care costs is £1,155 in the first year and £1,415 in subsequent years, totalling over five years £6,613 after discounting, of which half is assumed to be savings to local authorities and half savings to self-funding service users;
- the annual saving in unpaid care costs is £4,998 in the first year and £3,422 in subsequent years, totalling over five years £18,197;
- the annual reduction in lost productivity is £149 in the first year and £161 in subsequent years, totalling over five years £770 after discounting;
- the value of the QALYs gained is £1,330 per year, totalling over five years £6,215 after discounting.

On this basis –

- the net gain for the public sector is -£201 (£3,306+£1,593-£5,100);
- net gain for formal services is £3,106 (£6,613+£1,593-£5,100);
- net gain to society excluding the value of QALYs is £22,073 (£3,106+£18,197+£770);
- net gain to society including the value of QALY gains is £28,288 (£22,073+£6,215).

When stroke strikes, part of your brain shuts down. And so does a part of you. Life changes instantly and recovery is tough. But the brain can adapt. Our specialist support, research and campaigning are only possible with the courage and determination of the stroke community. With more donations and support from you, we can rebuild even more lives.

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