National Audit Office

Progress in improving stroke care

Report on the findings from our modelling of stroke care provision

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Summary

1 **Background and Objectives:** Stroke is a chronic condition, and one of the main causes of death and disability in the UK. Since the National Audit Office Report in 2005, *Reducing Brain Damage: Faster access to better stroke care*, and publication of the National Stroke Strategy in 2007 there have been improvements in the level of stroke care provision in England. This study aims to measure the effects of these improvements, in terms of costs and outcomes, by modelling the stroke care pathway using a long-term perspective of ten years.

2 **Methods:** We developed an economic model that simulates the patient journey from the onset of stroke to ten years after. The model includes time to admission, inpatient stay, post-discharge rehabilitation and long-term follow-up. The model was run using the current (2009) and pre-Strategy (2006) levels of care. It also considers alternative scenarios, with comparisons based on incremental cost-effectiveness ratios.

3 **Results:** Our comparison of the current level of stroke care with previous provision levels demonstrates that the improvements have been cost-effective, with an incremental cost-effectiveness ratio of £5,500 per quality adjusted life year (QALY) gained. This is well below the standard benchmark for evaluating the cost-effectiveness of care which the National Institute for Health and Clinical Excellence (NICE) considers to be between £20,000 and £30,000. We also found that specific interventions, such as improvements in the provision of stroke unit care and early supported discharge, were also cost-effective.

4 **Conclusion:** The improvements in the provision of stroke care have been cost-effective, but there is scope for further improvements in value-for-money, especially by extending the provision of stroke units and allowing for better discharge services to be provided to patients.

Part One

Introduction

1.1 Following the publication of the National Stroke Strategy in 2007, stroke services have been going through an improvement process in England[1]. As part of the methodology for our follow-up work to assess the effectiveness of these improvements we developed an economic model to evaluate the costs and outcomes of different models of care provision. The results of this evaluation form part of the evidence for the National Audit Office report *Progress in improving stroke care* (HC 291-Session 2009-2010).

1.2 This part of the report details the pathway used to model stroke services. The data sources, use of data to structure the model, and the model outputs have been validated by medical and health services research experts across different parts of the country (mentioned in the acknowledgements section). Incremental cost-effectiveness ratios (ICER) were used to compare the cost-effectiveness of different scenarios of care provision. Part Two details the assumptions made to structure the model; Part Three, the results of the modelling; Part Four, the process of validation and sensitivity analysis; and Part Five, the discussion of the results.

Modelling Method

1.3 We used a discrete event simulation (DES) to model the provision of stroke services by replicating the current care provision pathway. DES models not only allow a real-time calendar to be used in modelling care scenarios but they also allow the integration of resource availability (i.e. beds, specialist staff, radiology services) into the modelled pathways, therefore allowing the identification of resource issues that the health and social care system may face. In the case of stroke care, the resource constraints include the availability of ambulance services, timely scanning of stroke patients, stroke unit (SU) beds and stroke specific neuro-rehabilitation teams in the community.

Stroke Pathway

1.4 Our development of the care pathway model was based on literature reviews, input from the Intercollegiate Working Group on Stroke and discussions with stroke specialists from London, Oxford, Manchester, Newcastle and Cornwall. We also visited these sites to provide further insight into the practical operation of the stroke care pathway.

Stroke event

1.5 Stroke onset is a medical emergency, and the symptoms depend on the area of the brain affected. The more extensive the area of brain affected the more functions that are likely to be lost and hence the severity of initial disability varies substantially from patient to patient. A stroke can occur at any time, anywhere, during normal day to day activities or during sleep.

Time delay in calling for help

1.6 Once patients have a stroke, an important factor in determining their care pathway is the time it takes for them to call for help from the emergency services. The Rapid Ambulance Protocol for Acute Stroke estimated that the average time it takes for patients to call the emergency services is 33 minutes, however, the time varies from under a minute to 17 hours and 48 minutes[2]. The Department of Health launched the Stroke - Act F.A.S.T. media campaign in February 2009 to highlight the importance of rapid recognition of symptoms and the need to seek immediate help[3].

Ambulance Response

1.7 In the model the ambulance service response is evaluated using three time periods:

a The time it takes for the ambulance to reach the patients location;

b The time the ambulance spends at the scene to attend to the patient;

c The travel time to the closest specialist stroke centre.

1.8 This section of the pathway is dependent on the geographical location of the patient as well as the urgent classification of the disease. In ambulance services different calls are prioritised according to their level of urgency. Another important factor in the ambulance response time is the accurate diagnosis of stroke at this stage. This will then determine the rapid response to stroke as soon as the patients are delivered to the hospital. In 2009, the software used to telephone triage 999 calls was revised to better identify stroke patients and stroke was assigned a higher priority so that more people with stroke would receive the highest priority (Category A) response. There is varying evidence on the accuracy of paramedics in diagnosing stroke, from 97 per cent to 80 per cent[4, 5].

Time to Scan

1.9 The Intercollegiate Stroke Working Party National Clinical Guidelines for Stroke stipulate that patients should be scanned immediately and no later than 24 hours following hospital admission[6]. This is mainly to determine the type of stroke the patient is suffering from and to understand the level of damage to the brain tissue.

Thrombolysis

1.10 If patients are diagnosed to be suffering from an ischaemic stroke they may be considered for thrombolytic treatment. The health technology assessment by the National Institute of Clinical Excellence (NICE) on the use of thrombolysis (using alteplase), published in May 2007, concluded that "alteplase plus best supportive care is clinically and cost-effective compared with best supportive care"[7]. Furthermore, because of the importance of both best practice in the overall management of acute stroke and the requirement for a careful assessment of risks and benefits on an individual patient basis there should be particular emphasis on considering the appropriate conditions for the use of alteplase. Alteplase should be used by a physician trained and experienced in the management of acute stroke and only in centres with facilities that enable it to be used in full accordance with its marketing authorisation.

1.11 In England, thrombolysis treatment is licenced for patients younger than 80 years of age and within a 3-hour window of opportunity from the onset of stroke[8]. Additionally, the presence of clinical co-morbidities may allow the clinical experts to exclude the patient as a potential thrombolysis case. Even though the current licence allows for thrombolysis to be provided only within a 3-hour window, there are examples of administration of thrombolysis safely up to 4.5 hours[9], although the probability of a favourable outcome decreases with time.

1.12 The National Stroke Sentinel Audit Phase (Clinical Audit) 2008 noted that "approximately 15 per cent of patients are eligible for thrombolysis, however, in 2008 only one per cent were receiving it. Although increasing numbers of centres are providing a thrombolysis service, less than 10 per cent of appropriate patients are actually receiving the drug nationally. The service developments, being driven by the need to deliver the National Stroke Strategies, are likely to result in an increase in this percentage in coming years".[10] The National Stroke Sentinel Audit Phase 1 Organisational audit further suggests that "We should be aiming for at least 10 per cent of stroke admissions being thrombolysed. It is vital, however, that this is delivered safely by experienced teams"[11].

Inpatient Stay

1.13 The Cochrane Stroke Unit Trialists group identified three types of stroke units[12]:

- **a** Stroke Ward: a multidisciplinary team including specialist nursing staff based in a ward caring exclusively for stroke patients. A stroke ward is subdivided into acute stroke units, rehabilitation stroke units, and comprehensive stroke units.
- **b** Mixed rehabilitation ward: a multidisciplinary team including specialist nursing staff in a ward providing a generic rehabilitation service but not exclusively caring for stroke patients.
- **c** Mobile stroke team: a multidisciplinary team (excluding specialist nursing staff) providing care in a variety of settings.

1.14 After consulting stroke experts in England and examining various stroke care programs, we decided to model the provision of stroke unit care in two stages, hyperacute stage (HAS) and acute stage (AS). The HAS requires an intensive model of care with continuous monitoring, high nurse staffing levels and potential for life support. After a relatively short phase (1-3 days) in HAS, patients spend the rest of their stay in the AS. We recognise that the structure of care provision is not the same in all the stoke units in England. Some of the stroke units in the country are specifically designed to have two sections – hyperacute stroke unit (HASU) and acute stroke unit (ASU) – whereas other stoke units are designed as a merger of these, providing patients more intense monitoring at the hyperacute stage, albeit not in a specifically designated hyperacute stroke unit. The stroke experts we consulted were in consensus on the higher costs of hyperacute stage stroke provision; to reflect this, our model of hospital provision has two stages (hyperacute and post-hyperacute).

1.15 In England about 68 per cent of patients currently receive the majority of their treatment in a stroke unit, with the remainder treated in non-stroke specialised care clinical departments. In order to be able to reflect this pattern of care provision, patients in our model may be admitted to a stroke unit (SU) (as explained above) or to a non-stroke specialised care unit, which we are referring to as a generic medical ward (GMW). It is assumed that a generic medical ward can be anywhere where there is no routine multidisciplinary stroke specialised care. The care provided in a generic medical ward is often not as intensive as the care provided in an SU, or of the same quality, resulting in increased long-term mortality and stroke recurrence rates[13].

1.16 On admission to a stroke unit, patients in our model are admitted initially to a hyperacute stroke unit. Discussions with experts indicated that up to 20 per cent of patients that stay in a hyperacute stroke unit may require no further inpatient rehabilitation, due to mild symptoms, and that they are fit for discharge to their location of residence. The patients that require additional rehabilitation but not hyperacute care are transferred to an ASU.

Discharge

1.17 Modelling the provision of discharge services is the most complicated aspect of modelling stroke services, mainly due to the wide variation in practice and the variability of resources from locality to locality. The model allows the patients to follow two options after being discharged from the stroke unit, the early supported discharge (ESD) route and a conventional discharge route as defined in Rudd *et al*[14]. Early supported discharge services are currently available to 37 per cent of the sites[15]; this is replicated in the model where a certain availability of early supported discharge services is allowed.

Long-term care

1.18 The evidence on the long-term (more than a year) needs of stroke patients is very limited. Therefore for the purposes of the model we relied on assumptions backed up with expert opinion. The types of long-term care elements that we included are the costs of staying in a nursing home, outpatient care, and carer support and community care services.

Part Two

Methodology

Model Description

2.1 A discrete event simulation model was developed to evaluate the cost and outcome consequences of the improvements in stroke care provision. As the analysis aims to evaluate the changes in the provision of stroke care, taking into account the variation in costs between different patient types (age, severity), an incidence-based approach is adopted. The model is segmented into three parts for this purpose (**Figures 1** overleaf and **Figure 2** on page 12):

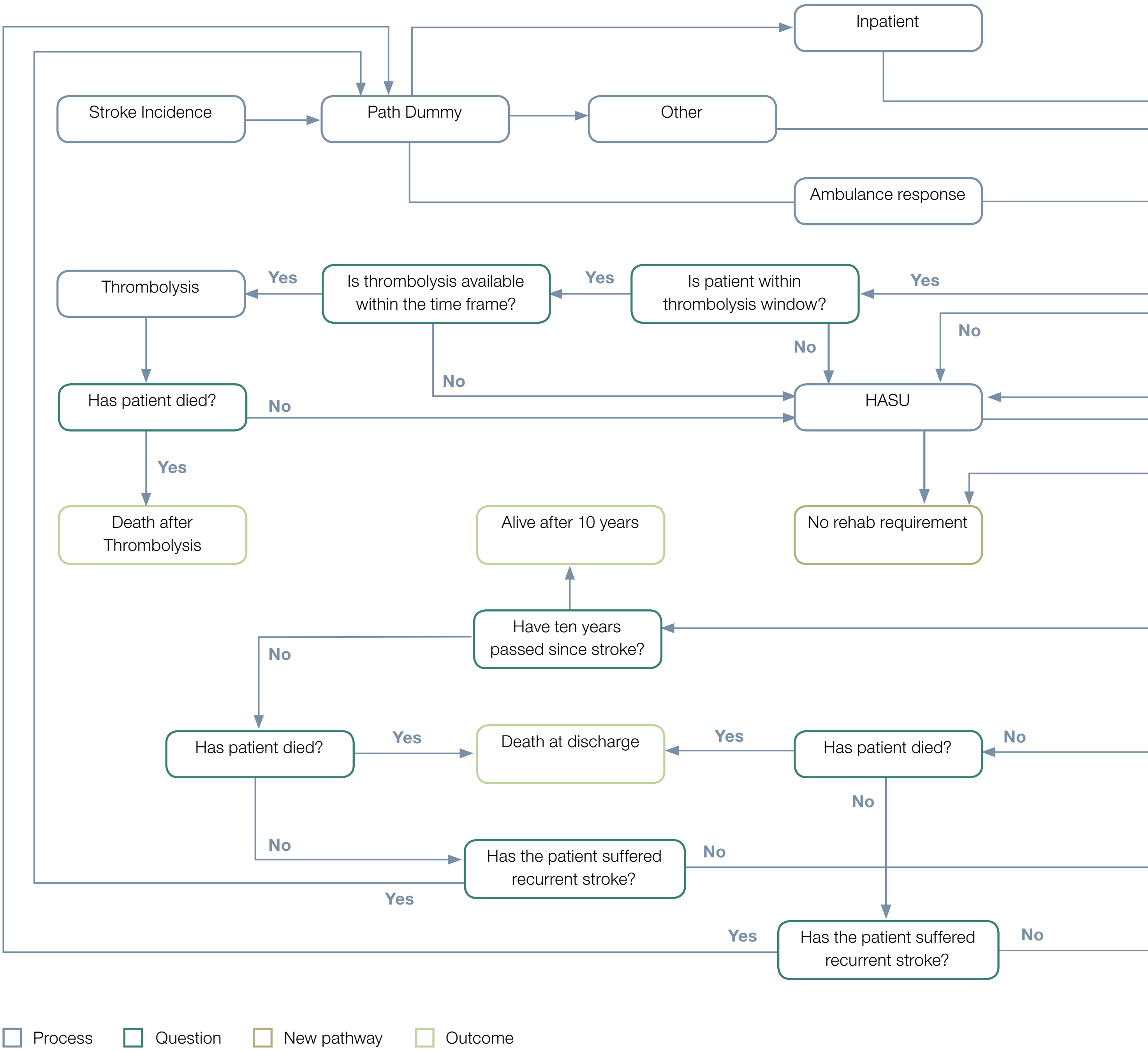
a Time from onset to hospital admission;

b Time spent in hospital; and

c Post-discharge care.

Figure 1
Logic Flow Diagram and model snapshot

This diagram highlights the logic behind the pathway of patients in the model



NOTE
The pathway after conventional discharge and after nursing home is identified to the pathway of 'Supported Discharge' and 'Home' described above, however they are separated due to differences in outcomes and costs.

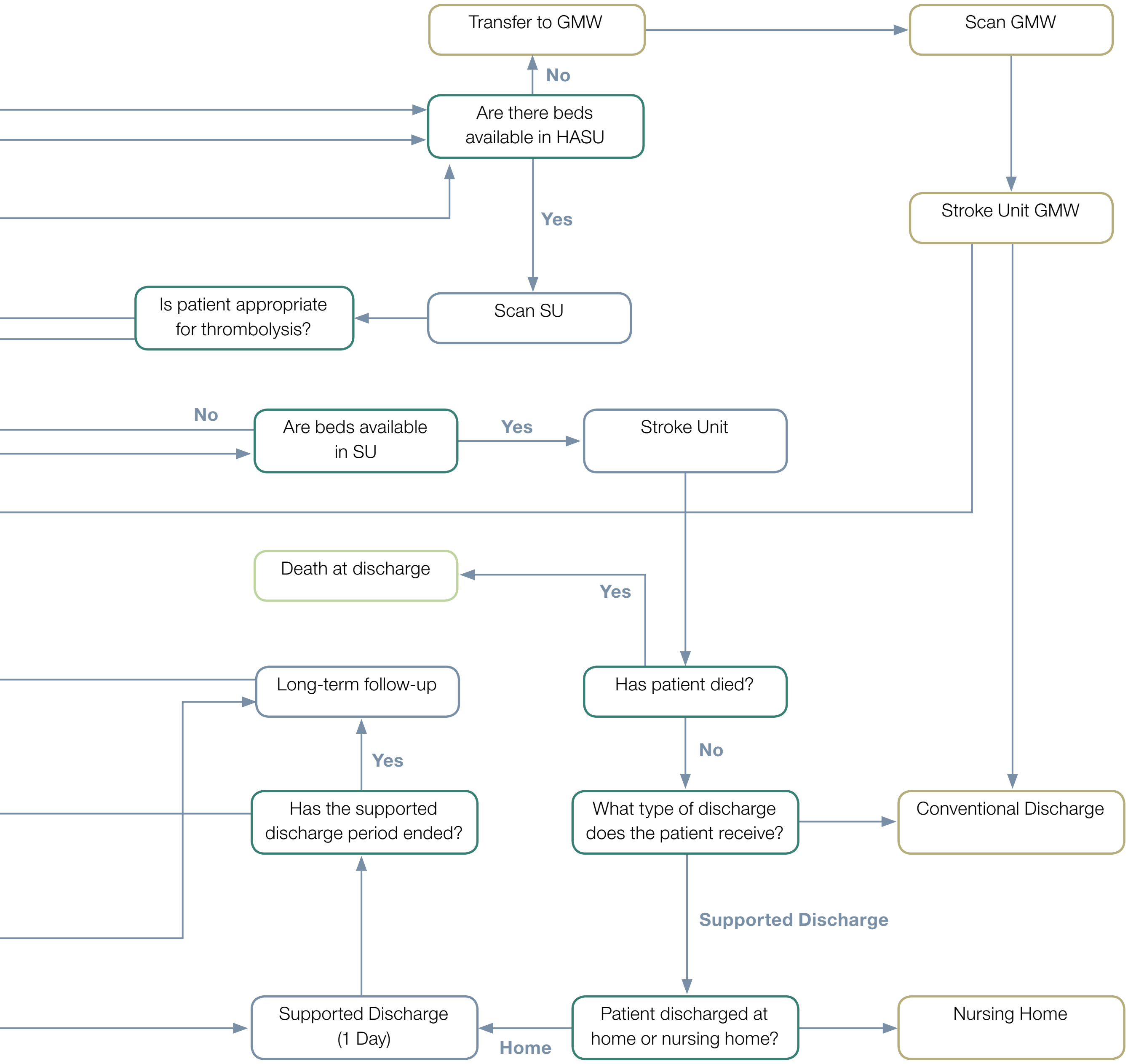
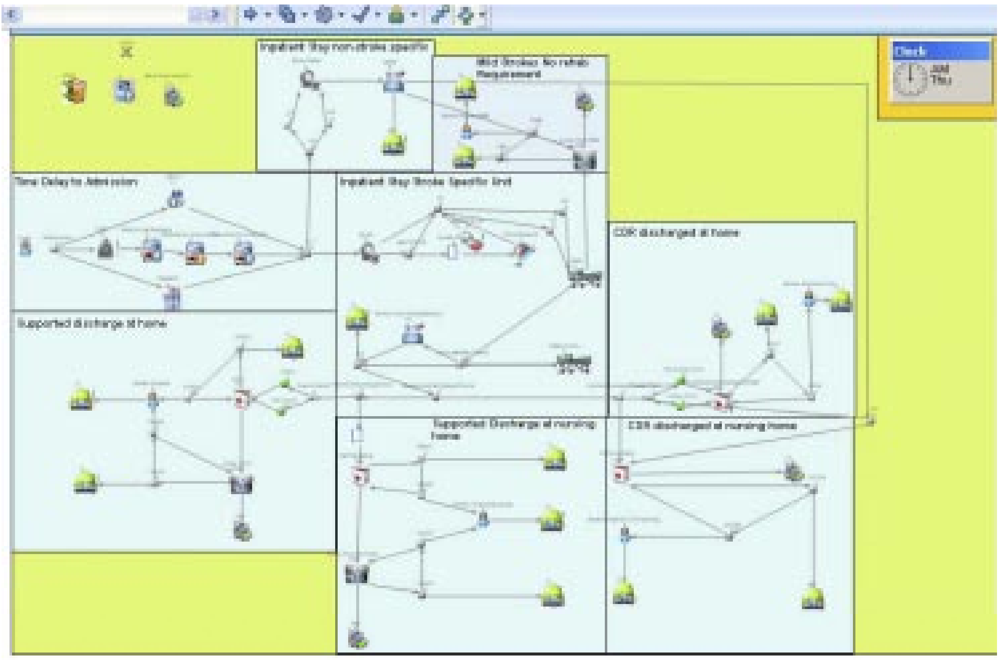

Transfer to GMW
Scan GMW
No
Are there beds available in HASU
Yes
Stroke Unit GMW
Is patient appropriate for thrombolysis?
Scan SU
No
Are beds available in SU
Yes
Stroke Unit
Death at discharge
Yes
Long-term follow-up
Has patient died?
Yes
No
Has the supported discharge period ended?
What type of discharge does the patient receive?
Conventional Discharge
Supported Discharge
Supported Discharge (1 Day)
Home
Patient discharged at home or nursing home?
Nursing Home

Figure 2
Model Screen Snapshot



Source: National Audit Office Model

Time from onset to admission

2.2 This section models the elapsed time from the onset of stroke to admission of the patient to the hospital. Patients can arrive at the hospital following three different routes: (1) they can arrive by ambulance as an emergency case, (2) they can have their stroke whilst they are already staying at the hospital, (3) other (they may have been referred by their GP or by a TIA clinic and may have arrived at the hospital using their own means).

Inpatient stay element

2.3 This section includes the care of the patient from time of admission to discharge; including the time it takes from arrival at the hospital to scanning, whether the patient is thrombolysed, and whether the patient is treated at a stroke unit (HASU only or HASU followed by ASU) or a GMW.

Follow-up care

2.4 This section is separated into early supported discharge and long-term follow-up care. Early supported discharge consists of stroke specific neuro-rehabilitation teams that provide specialised immediate post-discharge care. The availability of early supported discharge is modelled on the current availability of such services. The view of the stroke experts we consulted was that 20 per cent of patients have a very mild stroke which does not necessitate the provision of post-discharge rehabilitation; therefore 20 per cent of patients in the model are classified as not requiring further post-discharge therapy.

2.5 The modelling assumption is that when the patients are at the end of their inpatient spell they are discharged to a nursing (or residential) home or to a private residence (home). Patients are then followed up for ten years to examine the long-term outcome of each individual patient created in the model. The probability of death and stroke recurrence is modelled using survival curves according to age, severity and treatment of patient.

Assumptions and simplifications

2.6 When modelling the system, certain assumptions and simplifications were made to reduce complexity and account for lack of evidence (**Table 1**). All the assumptions and simplifications are checked with health care and modelling experts.

Table 1
Assumptions and Justifications

Assumption	Justification
A year has 365 days	
Patients that are inpatients at the time of stroke have no time lapse from onset to admission.	If patients are inpatients at the time of stroke, physicians should recognise the symptoms and act accordingly.
Patients' stay in HASU is extended if no beds are available in ASU.	This is common practice in various institutions. Assumption validated by stroke physicians.
Thrombolysis is not provided in a GMW.	This is based on the clinical stroke guidelines (reference guidelines), that thrombolysis should not be administered if the follow-up care is not of high standard. Assumption validated with clinical stroke experts.
Patients who are treated in a GMW do not receive early supported discharge.	Treatment in a non-stroke specific unit is not recommended therefore the type of discharge does not coincide with the best practice either.
Travel times within the hospital are zero.	If the stroke takes places whilst the patient is already in the hospital then he/she will have to be transported to scanning. Also once the patient is scanned and/or thrombolysed they will have to be taken to a stroke unit bed. This will require some travelling within the hospital premises. Such travel times are assumed to be insignificant and have no impact on the outcomes.
Recurrent stroke is treated in the same way as first-ever stroke.	There is limited data on the specific outcomes after recurrent strokes (as opposed to first-ever stroke); therefore they are treated as first strokes.
Patients that suffer from a third stroke die.	There is limited data on the severity and outcome of patients that have suffered subsequent recurrent strokes. This assumption has been validated with clinical stroke experts.
Patients who spent the majority of their time in a stroke unit are defined to be stroke unit patients.	There is a lack of data to evaluate the outcomes of care for patients who spend 'all' of their inpatient stay in a stroke unit in comparison to patients who spend the 'majority' of their inpatient stay in a stroke unit.

Model Scope

2.7 Given the nature of the objectives and the complexity of the system, some components of stroke care are excluded from the model. **Table 2** outlines the incorporated and excluded components.

Table 2
Model Scope

Component	Include/ Exclude	Justification
Type of stroke:		
• Haemorrhagic	Include	
• Ischaemic	Include	
• Sub-Arachnoid Haemorrhage (SAH)	Exclude	SAH makes up only a very small percentage of stroke patients and the data on the outcomes of SAH is very limited.
• Transient ischaemic attack (TIA)	Exclude	TIA's will not affect the model, as we are concerned with inpatient care and rehab, whereas TIA's are treated in clinics. If prevention strategies were tested this would be required.
Time from onset to admission	Include	Affects care pathway – decision to thrombolyse.
Mode of admission:		Admission by ambulance or if patient was an inpatient are included. If admission was by A&E or through a GP the admission is noted as 'other'. This is due to differences in time-delay and differences in costs.
• Ambulance	Include	
• A&E	Include	
• GP	Include	
• Inpatient	Include	
Ambulance response times	Include	Affects care pathway – decision to thrombolyse.
Type of unit:		The literature suggests different outcomes are associated with different units. Additionally different costs are associated with them.
• SU (HASU and ASU)	Include	
• Non stroke specific (GMW)	Include	
Time to scan	Include	Affects care pathway – decision to thrombolyse.
Scan type:		Conventional CT scanning is the most common method for identifying the type of stroke. There are studies that suggest that perfusion CT and MRI may have better outcomes but this is subject to the publication of more robust evidence in the future[16]. After consultation with clinical experts we decided to exclude other scanning methods.
• CT	Include	
• Perfusion CT	Exclude	
• MRI	Exclude	
Thrombolysis	Include	Affects severity and outcome.
Acute care:		Affects throughput and cost of treatment. Stroke unit care is assumed to have hyperacute and acute care components.
• Hyperacute stage	Include	
• Acute stage	Include	

Table 2
Model Scope continued

Component	Include/ Exclude	Justification
Discharge support:		Alternative discharge schemes have different costs and outcomes, and supported discharge decreases length of stay in an SU.
• Supported discharge (early supported discharge)	Include	
• Conventional discharge	Include	
Discharge location		
• Home	Include	Affects the costs of stroke.
• Nursing home	Include	
Long-term care	Include	Stroke is a chronic condition with lifetime costs.
Resources:		Model allows stroke specific resource constraints (stroke unit and early supported discharge). When local service and organisational needs are assessed other resource constraints can be included which are not stroke-specific (e.g. ambulance, availability of nursing home beds, availability of outpatient clinic time etc.)
• Ambulance	Exclude	
• Early supported discharge availability	Include	
• Stroke unit beds	Include	

Data analysis

2.8 Data was obtained from: the Royal College of Physicians Sentinel Stroke Audit (SSA) 2009 organisational data[15], 2008 clinical data[10], and 2006 clinical and organisational data[17], and the South London Stroke Register (South London Stroke Register (SLSR) is a population-based register of stroke patients following first-in-lifetime strokes and is described in detail elsewhere[18]). Data from SSA organisational audits in 2006 and 2009 were used to compare the care provision before and after the establishment of the National Stroke Strategy. Additional data was obtained from London Ambulance Services[19] (Note: We also received ambulance data from South West and South East Ambulance Services at a later stage. We descriptively compared the data sets and did not find significant differences[20, 21]).

Data Analysis for Label Values

2.9 Once patients are created, they are given certain characteristic attributes which then determine their care pathway. These characteristics include age, severity, type of stroke, whether the time of stroke is known and whether the patient comes from a location that provides early supported discharge services.

2.10 The age of patients was attributed according to the observations in the South London Stroke Register, with mean age 69.89. According to the frequency of each observation the age was added as a probability distribution, with ages varying from 18 to 105. Patients were then grouped into different age groups (**Table 3**).

Table 3
Age groups

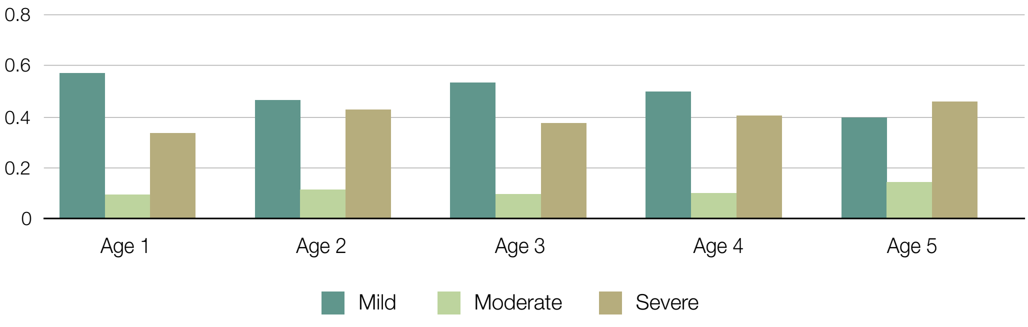
	Age group 1 ≤45	Age group 2 45<Age≤65	Age group 3 65<Age≤75	Age group 4 75<Age≤85	Age group 5 Age>85
Probability (%)	7.2	25.1	24.6	28.2	14.9

Disability and care outcome

2.11 The key output from the model includes the average disability levels of patients under different scenarios. The disability levels used in the model are Barthel Index (BI) scores. BI scores consist of “a disability profile scale developed to evaluate a patient’s self-care abilities in 10 areas”[22]. These areas include bowels, bladder, grooming, toilet use, feeding, mobility, transfer, dressing, stairs, and bathing. Each patient receives a score from 0-2 in each of these areas and a total is calculated, 0 signifying dependence and 20 signifying independence. Patients with BI score ranging from 0-9, 10-14 and 15-20 are classified as severe, moderate and mild, respectively.

2.12 The chart below (**Figure 3**) highlights the variability of severity in each age group. The table shows the probability of a patient being of a certain severity by age group. The older the patient the more likely they are to have a severe stroke.

Figure 3
Severity according to Age



Use of Quality Adjusted Life Years (QALYs)

2.13 The BI scores are then converted to quality adjusted life years (QALY) by using the conversion method developed by Van Exel *et al*[23]. QALY takes into account both the quantity and quality of life generated by healthcare interventions. It is the arithmetic product of life expectancy and a measure of the quality of the remaining life-years, and it is used in health economics to estimate the overall outcomes of care provision[24].

Severity Changes

2.14 The care pathway of each patient has an impact on the outcome. It is therefore necessary to demonstrate the effect alternative treatment types would have on the mortality and morbidity levels.

2.15 The effect of a stroke unit on outcomes is modelled by using reduced mortality and recurrence for patients treated in a stroke unit[12]. The improvements in outcome after thrombolysis treatment are obtained from Sandercock's estimations[25]. The Sandercock study also estimated an increase in early mortality in relation to thrombolysis (odds ratio 1.16 in thrombolysed patients). However, after discussions with experts, we decided to use death rate applied to thrombolysed patients in the base case as derived from the ATLANTIS, ECASS and NINDS rt-PA Study Group investigators ("The adjusted hazard ratio for death was not significantly different from 1:0 (HR [95% CI]) for patients treated within 0–270 min and exceeded 1:0 (1:45 [1:02–2:07]) in the interval 271–360")[26]. We also tested the model using the Sandercock odds ratio of death (1.16) reported by Sandercock and report this additional sensitivity run in the Appendix (Appendix, Section B, Tables i to m).

2.16 The severity changes after discharge (early supported discharge vs conventional discharge support) are obtained from Rudd *et al*[14]. The baseline proportion of BI scores were compared with the 1-year outcome BI scores to obtain the probability of being mild, moderate and severe for patients (**Table 4**).

Table 4
Severity Changes After Discharge

	Early Supported Discharge			Conventional Discharge Rehabilitation		
Initial Severity	Mild	Moderate	Severe	Mild	Moderate	Severe
Mild	1	0	0	1	0	0
Moderate	0.94	0.06	0	0.91	0.09	0
Severe	0.39	0.08	0.53	0.25	0.05	0.7

Additional Labels

2.17 The SSA data highlighted that 32 per cent of patients do not know their time of stroke, however, further investigation of the data set suggested that only 9 per cent of patients did not know the time of stroke due to stroke taking place during their sleep[15]. Therefore, when testing the effects of decreasing the time to call emergency time (for example, through increased public awareness) we only applied the potential reduction in time-to-call to the (23 per cent) patients who are awake at the time of onset of stroke.

2.18 We accepted the proportion of ischaemic and haemorrhagic strokes to be 85 per cent and 15 per cent respectively after discussions with experts.

Number of patients created in the model

2.19 The model is designed to replicate a stroke unit setting with a certain number of beds, based on the stroke unit from an existing hospital which has four hyperacute and 19 acute unit beds and treating around 300 patients a year. An alternative to using a known setting might have been to create exactly the incidence number of stroke patients in the UK in each year of model run. This would have meant that the model created around 110,000 stroke patients each year[27]. This would have increased the time to run the model extensively and would, therefore, not have been practical. Inter-arrival times of patients are assumed to be Poisson-distributed.

Activity times

2.20 To determine activity durations, the data was analysed and then fitted to probability distribution functions. Rather than using an empirical modelling approach, by using fitted probability distribution functions the activity durations are not restricted, allowing for the inclusion of extreme values. When choosing between distributions, statistical significance was taken into consideration, however the nature of the distributions was further accounted for. In order to enhance validity, q-q and p-p plots were examined (and if their shapes were almost linear, the fits were considered to be good).

Time from Onset to Admission (for non-ambulance admissions)

2.21 Our estimation is based on SSA data. Average time from onset to admission is 9.7 hours with lower and upper bounds of 0 and 24. A beta distribution was chosen as it provided the best fit, statistically and visually.

Time to Call

2.22 The time it takes for the patients to make the call from the onset of the symptoms is not recorded. However, data from onset to admission is recorded by the SSA[15]. In order to retrieve an estimate of the time from stroke to call for ambulance, data from onset to admission was fitted, and the fitted ambulance response times were subtracted from the distribution (negative numbers were counted as 0). This was simulated 1000 times over 100 repetitions to retrieve a distribution of time delays.

Travel Time to Patient

2.23 We used a Lognormal distribution to define the time taken by ambulance staff to reach a patient. Although a few other distributions had a better chi-squared statistic, the lognormal distribution was chosen as it allows for the majority of the results to be concentrated around the mean, with less frequent observations for larger durations. As paramedics are stationed around a geographical area for optimum travel time, the observations that have a larger travel time will be less frequent; therefore a lognormal distribution was used.

Time Spent at Scene

2.24 We estimated this time component using data from London Ambulance Services, which suggested an average of 21.66 minutes. Although the triangular distribution and uniform distribution had a better chi-squared statistic, the lognormal distribution was chosen as it allows for the majority of the results to be concentrated around the mean, with less frequent observations for larger durations (as the data suggests).

Time to Hospital

2.25 Data from London Ambulance Services is used with average time to hospital being 13.72 minutes[19]. A Pearson5 distribution was chosen as it has been proven useful in modelling time delays. Travel times to a hospital are more frequent around the mean, a patient's location or traffic times may increase the travel time substantially, but this effect would be present in fewer observations. Therefore the Pearson5 distribution would provide a good fit in capturing this effect.

Time to Scan

2.26 SSA data suggests that the average time to scan is 9.69 hours with a wide variation (0 to 24 hours). After consulting the experts, we used a beta-general distribution based on a mean of one hour.

Time to Thrombolysis

2.27 Thrombolysis services are assumed to be available from 8am to 8pm on weekdays and 9am to 4pm on weekends, to reflect SSA findings that, currently, service times of thrombolysis on average are around 12 hours on weekdays and seven hours on weekends[15].

Length of Stay

2.28 SSA data is used to fit length of stay[15]. As the length of stay is highly dependent on patient characteristics, a different approach to distribution fitting was adopted. A Poisson regression model with a dependent variable of length of stay was estimated. A Poisson model was chosen over a linear model, due to its nature in estimating 'count data' and it also provided a better fit. Missing data was not included in the estimates.

Equation 1

Length of Stay Regression

LOS = 2.118 – 0.038 Thrombolysis -0.053 Stroke Unit + 0.579 Severity Class
(0.0163) (0.0165) (0.0058) (0.0028)

+0.059 Age 2 + 0.155 Age 3 + 0.149 Age 4 + 0.046 Age 5 + 0.236 Haemorrhagic
(0.0168) (0.0164) (0.0162) 0.0167) (0.0071)

2.29 The above regression was calculated using data from the patients that were alive after discharge. For the patients that died as inpatients an average length of stay and data on their level of disability were unavailable. Therefore, the calculation of LOS for patients that die as inpatients was fitted to a distribution (**Table 5**). An exponential distribution was the best fit for the LOS data.

2.30 An obstacle in randomizing the model was the different practice across different institutions. As some institutions do not operate with a HASU and a stroke unit, rather a combined ward, the length of stay data was not segmented to reflect the length of stays for patients at hyperacute and acute stages of care. Therefore, expert opinion was used to estimate the length of stay at hyperacute stage and outlined in the table below (Table 5).

Table 5

Length of Stay in HASU

Severity	Distribution	Mean LOS in HASU
Mild (Severity Class 1)	Average	1
Moderate (Severity Class 2)	Average	2
High (Severity Class 3)	Average	3

2.31 The model records the exact length of stay at hyperacute stage and subtracts it from the total length of stay to determine the length of stay in the acute stage. This subtraction is only used for patients that go to a stroke unit. The model accounts for a reduction in the length of stay for patients that receive early supported discharge using an estimated decrease based on the Cochrane review[28].

Activity Times after Discharge

2.32 The activity times for early supported discharge services and long-term follow-up are recorded daily. Patients are routed back according to daily probability of death and recurrence and continue in the same loop until the total period of early supported discharge and long-term follow-up ends. The early supported discharge (or conventional discharge follow-up) period lasts for three months, whereas the model continues following patients up for ten years in the system from the onset of first stroke. All the activity times' variables are presented in **Table 6**.

Table 6
Activity time parameters

Activity	Source	Distribution	Parameter 1	Parameter 2
Onset to admission	RCP – National Sentinel Audit	Beta	1: 0.84997	2: 1.2463
Time to call	Simulated using data from RCP	Exponential	: 0.37014	–
Travel time to patient	London Ambulance Service	Lognormal	: 0.013634	: 0.010106
Time spent at scene	London Ambulance Service	Lognormal	: 0.0150	: 0.00640
Travel time to hospital	London Ambulance Service	Pearson5	: 7.3915	: 0.098496
Time to scan	RCP – National Sentinel Audit	Beta General	1: 0.60817 min: 0.041	2: 0.87186 max: 1.041
Length of stay (dead in the hospital)	RCP – National Sentinel Audit	Exponential	: 16.70853	–

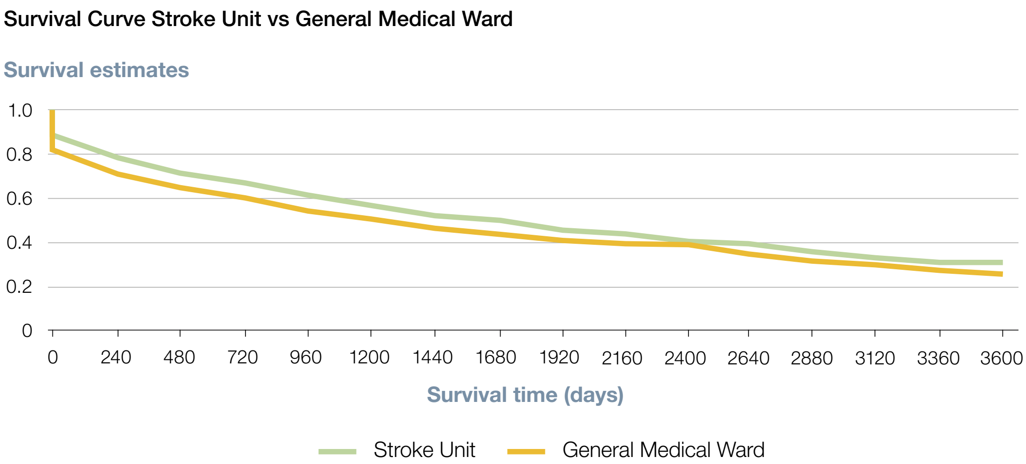
Probabilities of death, discharge location and recurrence

Probability of death and discharge location

2.33 The probability of dying in the hospital after being admitted is taken from SLSR and is different for stroke unit and GMW. It is calculated by using a probit model using age, disability levels and location as the determinants of the probability. The probabilities generated are assumed to have a beta distribution.

2.34 The probability of death after being discharged from the hospital was calculated by using two survival curves, one for stroke unit patients and another for general medical ward patients. The model estimates the likelihood of dying at a given time point determined by the age, disability status, discharge location and the location of care of the patient (SU vs GMW) (**Figure 4**).

Figure 4
Survival curves for SU and GMW



2.35 A probit model was used to estimate the likelihood of being discharged to an institutional setting or to home using South London Stroke Register data. Age, disability levels and location of care were used to estimate the probabilities, which are assumed to have a beta distribution.

Probability of recurrence

2.36 The possibility of recurrence is considered after discharge. During the 10-year follow-up, patients can suffer from a recurrent stroke at any time-point. Cumulative risk of recurrence is calculated to be 7.1 per cent, 16.2 per cent and 24.5 per cent at one year, five years and ten years respectively[29].

Cost Analysis

2.37 We have adopted a healthcare perspective and included costs that are related to the treatment of the patient. This included inpatient care costs (including ambulance cost, hospital stay and diagnostic costs), post-discharge rehabilitation care costs, and long-term care costs (including outpatient GP visits and outpatient drug costs, nursing home costs and the cost of a carer if the patient is living at home). We obtained costs for the model from a number of national and local data sources (**Table 7**, overleaf). Stroke unit costs are obtained from two resources; King's College Hospital in London[30] and Northumbria Health Care Trust in Northumberland[31]. The 'per day' hospital costs of acute stage in all these centres were very similar (£226 in Northumbria and £231 at King's College Hospital). We received costs for the hyperacute stage separated from the acute stage only from King's College Hospital. Therefore we used King's College Hospital costs for the hyperacute stage and also the acute stage. For outpatient hospital visit costs we have used expert opinion and accounted for one outpatient visit to an outpatient stroke clinic in the first year for stroke unit patients. We also included one GP visit for all the patients each year. The cost of early supported discharge and conventional discharge programmes are taken from Beech *et al* after discussing the appropriateness with early supported discharge experts[32]. We used the cost of a nursing home for patients discharged to a nursing home. We have calculated costs for those home care patients who may be requiring care from a professional carer or from a family member. After discussing with experts, two hours of carer time per day is included for each patient.

Table 7
Unit costs used

Cost item	Reference	Unit	Average cost (£)	Frequency of use
Ambulance cost	Ambulance trust SLA comparator[33]	Per service use	222	Estimated by the model
Diagnosis GP visit	PSSRU UC 2008[34], P. 109	Per service use	54	Estimated by the model
Hospital initial diagnosis	PSSRU UC 2008, P. 91	Per service use	87	Estimated by the model
CT	NHS reference costs[35]	Per scan	121	Estimated by the model
HASU cost	King's College Hospital	Per day	583	Estimated by the model
ASU cost	King's College Hospital	Per day	231	Estimated by the model
GMW cost	St Thomas' hospital	Per day	181	Estimated by the model
Thrombolysis cost	King's College Hospital	Unit	691	Estimated by the model
Outpatient visit Stroke unit	2007-08 Outpatient Mandatory Tariff payment by results the cost of seeing a general medicine specialist there is no cost in the tariff for a stroke specialist	Unit	98	One visit in the first year for stroke unit patients
Early supported discharge				
Mild	Beech *et al.*[32] (including post discharge physiotherapy, speech and language therapy, occupational therapy)	Per month	213	
Moderate		Per month	460	
Severe		Per month	535	
Conventional Discharge				
Mild	Beech *et al.*[32] (including post discharge physiotherapy, speech and language therapy, occupational therapy)	Per month	240	
Moderate		Per month	266	
Severe		Per month	350	

Table 7
Unit costs used continued

Cost item	Cost (£)	Unit Cost: Unit	Unit Cost: Reference	Frequency of use[36]: Resource use (percentage of all the patients) (%)	Frequency of use[36]: Mean (mean for users only)
SU – GP home visit	53.00	Per home visit lasting 23.4 minutes (includes travel time)	PSSRU UC 2008 P. 109	34.5	1.9
SU – GP surgery visit	32.74	Per surgery consultation lasting 11.7 minutes	PSSRU UC 2008 P. 109	59.5	2.7
GMW – GP home visit	53.00	Per home visit lasting 23.4 minutes (includes travel time)	PSSRU UC 2008 P. 109	44.2	1.9
GMW - GP surgery visit	32.74	Per surgery consultation lasting 11.7 minutes	PSSRU UC 2008 P. 109	55.8	2.2
SU – Home help – Mild	80.02	Per week	PSSRU UC 2008 P. 39	22.8	280.7
SU – Home help – Moderate	200.58	Per week	PSSRU UC 2008 P. 39	22.8	280.7
SU - Home help – Severe	200.58	Per week	PSSRU UC 2008 P. 39	22.8	280.7
SU – Meals on wheels	38.45	Per week	PSSRU UC 2008 P. 38	5.4	93
SU – Social services day centre visits	30.66	Per attendance	PSSRU UC 2006 P. 55	5.4	16.3
GMW – Social worker visit	30.14	Per hour	PSSRU UC 2008 P. 114	2.7	2.8
GMW – Home help - Mild	80.02	Per week	PSSRU UC 2008 P. 39	12.2	353
GMW – Home help – Moderate	200.58	Per week	PSSRU UC 2008 P. 39	12.2	353
GMW – Home help – Severe	200.58	Per week	PSSRU UC 2008 Pg39	12.2	353
GMW – Meals on wheels	38.45	Per week	PSSRU UC 2008 P. 38	3.4	207.2
GMW – Social services day centre visits	30.66	Per attendance	PSSRU UC 2006[37] P. 55	3.4	39.6

2.38 All costs are adjusted to 2008-09 prices with an annual discount rate of 3.5 per cent in accordance with NICE guidance. Outcomes are discounted by 1.5 per cent in accordance with Department of Health guidance. We also tested the response of the model when 0 per cent and 6 per cent discounting are used for both costs and outcomes.

Establishing the scenarios for comparison

2.39 We compared a number of scenarios to test the cost-effectiveness of care provision if one or more aspects of service provision are changed. The baseline scenario we used here is the current level of care provision. The current level of care provision consists of the proportion of patients going to a stroke unit, the proportion receiving early supported discharge and the proportion thrombolysis. We used the estimations in the most recent Sentinel Stroke Audit for that purpose[15]. Similarly, for the previous scenario, the estimates of the pre-Stroke Strategy Sentinel Stroke Audit are used. The current provision of care is also compared with a best-care scenario where 100 per cent of patients are treated in an SU, where there is 24/7 scanning and thrombolysis coverage, and all of the patients treated in a stroke unit access early supported discharge.

2.40 In addition to these, a number of other scenarios were tested by changing a single variable or a number of variables, such as:

- improving only the stroke unit care provision from its current level to 100 per cent;
- providing early supported discharge to all stroke unit patients;
- decreasing the ambulance response time; and
- potential effect of F.A.S.T. (or other public awareness) campaign.

2.41 Additionally, we tested the effect of increasing the early supported discharge services (from a hypothetical level of 10 per cent of the patients who qualify for early supported discharge to 100 per cent of the patients) on the bed utilisation rates and length of stay.

Part Three

Results

3.1 The current scenario results provide an insight into strategies that may provide a better outcome; however, the effect can be captured only by testing these strategies and comparing the key outcomes with the current scenario to see if they provide an improvement in costs and outcomes. When testing alternative scenarios it should be noted that the same random number streams are used for all replications in order to enable comparison.

The current and previous care provision scenarios

3.2 The current stroke care provision plan is estimated to cost an average of £23,315 per patient. We estimate the average QALYs obtained in the current scenarios to be 2.54. These results will be set as the baseline of comparison with experimental scenarios. The previous care provision scenario is then compared with this level of care and the findings suggest that the changes have been cost-effective with an incremental cost-effectiveness ratio (ICER) of £5,500 (**Table 8**, Appendix Table a).

> "Improved patient outcomes from reductions in death and disability can be quantified in terms of 'quality-adjusted life years' (QALYs). We estimate that the average number of QALYs per patient has increased to 2.5 from 2.3, for an increase in average per-patient cost of seven per cent in real terms (to £24,900 from £23,300). This represents an incremental cost-effectiveness ratio of £5,500 per QALY, well below the standard benchmark for assessing cost-effectiveness in healthcare of £20,000 to £30,000 per QALY gained."

Table 8
Comparing the current scenario with the previous standards

	Previous care provision	Current care provision	Change in costs	Change in QALYs	ICER
Average cost	£23,315	£24,855	£1,540		£5,500
Average QALY	2.26	2.54		0.28	
Percentage of mortality in 10 years	70.81	66.75			

Improvement of services

3.3 We evaluated the effects of further improving the provision of stroke unit and early supported discharge services to all patients, with 24/7 coverage of scanning and thrombolysis (**Table 9**, Appendix Table b).

Table 9
Comparing the current scenario with further improvements

	Current care provision	Further improvements	Change in costs	Change in QALYs	ICER
Average cost	£24,855	£25,950	£1,095		£2,858
Average QALY	2.54	2.92		0.38	
Percentage of mortality in 10 years	66.75	62.49			

3.4 We compared the cost-effectiveness of the improvement of some of the services individually. **Table 10** evaluates the cost-effectiveness of increasing the provision of stroke unit services to 100 per cent of patients. This would be a cost-effective service improvement costing around £7,000 per QALY gained (Table 10, Appendix Table c).

Table 10
Only increasing the coverage of stroke unit services to 100 per cent

	Current care provision	100 per cent stroke unit provision	Change in costs	Change in QALYs	ICER
Average cost	£24,855	£26,701	£1,846		£7,249
Average QALY	2.54	2.79		0.25	
Percentage of mortality in 10 years	66.75	63.16			

3.5 Our modelling suggests 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 (**Table 11**, Appendix Table d). This would increase the overall provision of early supported discharge from 20 per cent of patients to 43 per cent of patients.

> "Our modelling suggests that increasing the availability of Early Supported Discharge from its current level – equating to around 20 per cent of patients – to a more optimal level of 43 per cent of patients, with all stroke units providing Early Supported Discharge, would be cost-effective over a ten-year timeframe, costing about £5,800 per QALY gained." *Progress in improving stroke care*, National Audit Office (HC 291 Session 2009-10)

Table 11

Only increasing the coverage of early supported discharge to all stroke unit patients

	Current care provision	100 per cent early supported discharge provision	Change in costs	Change in QALYs	ICER
Average cost	£24,855	£25,659			£2,881
Average QALY	2.54	2.67		0.38	
Percentage of mortality in 10 years	66.75	65.49			

The effect of reduced time-to-call on the number of patients being thrombolysed

3.6 Here we evaluated the effect of two issues on service provision. First we estimated the effect of a reduction in ambulance response times, and later the effect of a reduction in the time it takes for the patients to call for an ambulance, on the number of patients getting to the hospital on time to be able to receive thrombolysis.

3.7 If all the strokes were treated as category A then the target response time for all stroke cases would be 8 minutes. We evaluated the effect of decreasing the target time from its current level to 8 minutes. This made no significant difference to the number of patients being thrombolysed (**Table 12**, Appendix Table o).

> "Our modelling suggests that reductions in ambulance response times would not significantly impact the overall outcomes of care." *Progress in improving stroke care*, National Audit Office (HC 291 Session 2009-10)

Table 12

Percentage of patients thrombolysed if ambulance response times are reduced

	Current response times	Reduced ambulance response time
Percentage of thrombolysed	1.9	1.9

3.8 However, reducing the time that patients take to call for help –through, for example, a public awareness campaign such as the Stroke – Act F.A.S.T. initiative – can potentially lead to a more substantial increase in the number of patients being able to make it to hospital within the three hour window to be scanned. We have calculated what this improvement would mean in terms of numbers of patients being thrombolysed each year, basing our calculations on an estimated 2,000 patients currently being thrombolysed per annum (**Table 13** overleaf, Appendix Table p).

"Our modelling confirms the importance of people recognising stroke as a medical emergency and acting accordingly, estimating a 10 per cent reduction in the average time between onset of symptoms and calling an ambulance alone could allow an additional 200 patients to be thrombolysed each year." *Progress in improving stroke care*, National Audit Office (HC 291 Session 2009-10)

Table 13
Reduction in the time to call emergency services

	Current care provision	10 per cent reduction in 'time to call emergency services'	20 per cent reduction in 'time to call emergency services'	30 per cent reduction in 'time to call emergency services'
Percentage of patients thrombolysed	1.91	2.11	2.29	2.55
Percentage of increase from actual		10.5 increase from actual	19.9 increase from actual	33.5 from actual
Potential number of patients thrombolysed (per annum)	2,000	2,209	2,398	2,670
Potential increase in the number of patients from actual (per annum)		209	398	670

The impact of early supported discharge on bed utilisation

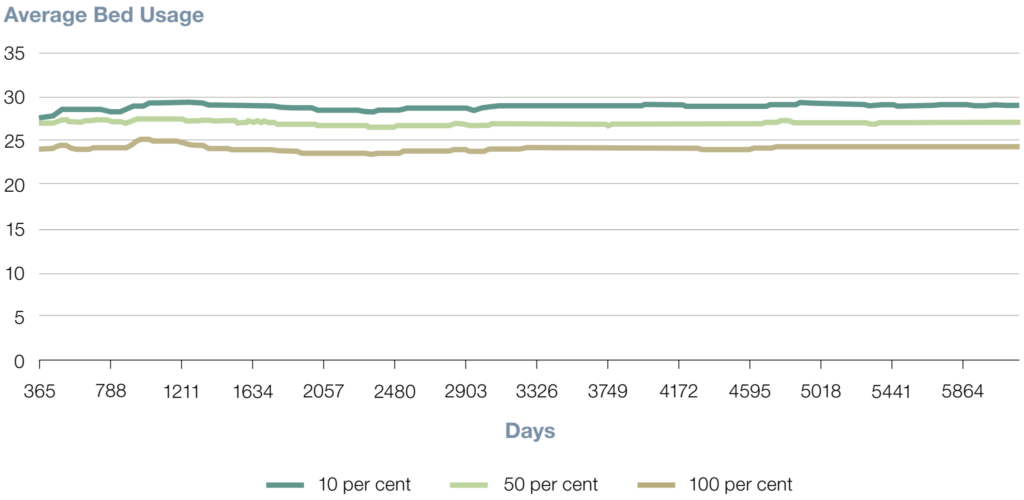
3.9 We evaluated the potential impact of early supported discharge on the overall bed utilisation rates. Currently around 37 per cent of stroke units provide early supported discharge services[15], however, for the purpose of the model, we compared the potential impact of increasing the provision of early supported discharge services from 10 per cent of units, 50 per cent and 100 per cent (**Table 14**).

Table 14
Increasing early supported discharge provision

Percentage of units providing early supported discharge	10	50	100
Average LOS	27.60	25.53	22.45
Average HASU bed usage	2.40	2.39	2.41
Average ASU bed usage	28.84	27.08	24.29

3.10 These findings demonstrate that the stroke unit bed utilisation is dependent on the appropriate post-discharge support (early supported discharge) which not only reduces LOS but improves outcomes. **Figure 5** demonstrates that about 4-5 stroke unit beds can be saved per annum by increasing the provision of early supported discharge from 10 per cent to 100 per cent in a unit which is serving 300-350 patients a year.

Figure 5
ASU bed average Usage under alternative ESD provision schemes



Source: National Audit Office modelling

Part Four

Model verification and sensitivity analysis

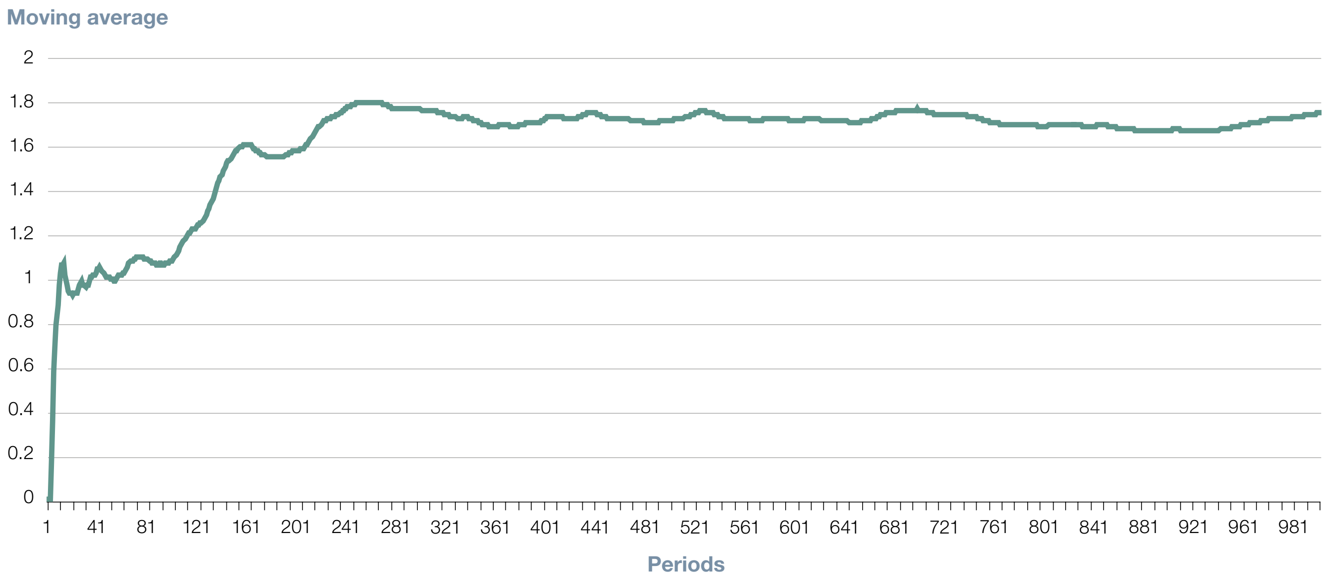
Verification

Variance Reduction

4.1 When testing alternative scenarios it is important to collect results using a consistent methodology. As the model is a non-terminating system, a warm-up period should be set to ensure patients are routed to the pathways as they would be in real life (with finite resource capacities). In determining the warm-up period, the average use of HASU and ASU beds is observed on a daily basis. The average bed use was plotted on a graph to observe the resource utilisation behaviour (**Figure 6**). The transient phase of resource utilisation occurs on days 1-350. After day 350, resource utilisation seems to reach a steady state. Therefore for simplicity a warm-up period of one year (365 days) is used.

Figure 6
Resource utilisation graphs to determine warm-up period

ASU bed utilisation



4.2 It is of additional significance to certify that the results do not vary significantly with different random number streams. This can be ensured by either increasing the run length or performing multiple replications. In order to determine the run length Robinson's[39] convergence method was used. However, the key outcome measure – of average QALY – converges to the 5 per cent level after approximately 1600 observations. This would require the collection of patients for six years, therefore including the warm-up and follow-up period the model will be run for 17 years (six years collection) and six replications will be made for each scenario to account for the variation in results.

Conceptual Model Verification

4.3 A verification process undertaken throughout the model-building period. All the label values were evaluated to certify that the model adhered to the coding of the variables. Step verification of the model allows the modeller to find errors and correct them as the model progressively runs. A second analyst also went through the model repeating the same process once more.

White-box validation

4.4 In order to test the model at a 'micro' level and observe whether it is reacting to the inputs in the way it is expected to, some extreme case scenarios were tested and the model output was compared to the expected result. The model performed well in obtaining the expected results (**Table 15**).

Table 15
Extreme Value Testing

Test Description	Expected Result	Model Response
Resources set to 100	All patients go to stroke unit	As expected
Resources set to 0	All patients go to GMW	As expected
Early supported discharge provision set to 100	More patients are treated in a stroke unit and length of stay is lower	As expected
Early supported discharge provision set to 0	Resource utilisation and length of stay are higher	As expected
Time to scan fixed to 1 day	No patients are thrombolysed	As expected
Time to scan fixed to 0	Increase in the number of patients thrombolysed	As expected

Face Validation

4.5 During the development phase, the model was presented to a number of specialists including stroke physicians, stroke nurses and specialists, health economists, modellers, ambulance commissioners (for a detailed list see the acknowledgements), and they were asked to reflect on it. This process enhanced the model structure throughout. This process was repeated at each stage of the model development.

Replication of the scenarios and sensitivity analysis

4.6 We have tested the sensitivity of our results by repeating the model runs for each scenario six times using the same random sampling numbers to make sure that each run would reflect the same randomness. Each run of each scenario generated around 2500 hypothetical patients (entities) and took approximately 45 minutes to run. With six runs, over 15,000 samples are created for each scenario and average cost-effectiveness ratios are generated. In addition, incremental cost-effectiveness ratios are compared between each of the six runs. These are presented in the appendix.

4.7 We tested the potential effect of using different discount rates on the incremental cost-effectiveness ratios as well. The results of that comparison are presented in **Tables 16 and 17** (Appendix Tables e to h).

Table 16
Previous care provision vs current care provision scenario comparison

	Previous care provision 0 per cent discount	Current care provision 0 per cent discount	Change in costs	Change in QALYs	ICER
Average Cost	£25,387	£27,240	£1,853		5,931
Average QALY	2.53	2.84		0.31	
	Previous care provision 6 per cent discount	**Current care provision 6 per cent discount**	**Change in costs**	**Change in QALYs**	**ICER**
Average Cost	£22,091	£23,448	£1,353		6,822
Average QALY	1.65	1.84		0.20	

Table 17
Current care provision vs further improvements scenario comparison

	Current care provision 0 per cent discount	Further improvement 0 per cent discount	Change in costs	Change in QALYs	ICER
Average Cost	£27,240	£28,498	£1,258		2,910
Average QALY	2.84	3.27		0.43	
	Current care provision 6 per cent discount	**Further improvement 6 per cent discount**	**Change in costs**	**Change in QALYs**	**ICER**
Average Cost	£23,448	£24,447	£999		3,697
Average QALY	1.84	2.11		0.27	

Part Five

Discussion and overall conclusion

5.1 The modelling exercise supporting the National Audit Office 2010 report, *Progress in improving stroke care*, took place between March and November 2009.

5.2 Overall, stroke services have improved with relatively minor increases in costs since the establishment of the National Stroke Strategy in 2007 (Table 8). This improvement is a result of the progress in many components of the service provision; better recognition of stroke, increase in the treatment of patients in a stroke unit, increase in the provision of early supported discharge services, increase in the availability of scanning and more thrombolysis services in hospitals. However, there is still scope for further improvement. The hypothetical scenarios we used suggest that increasing the provision of gold standard treatment services would improve outcomes, within a reasonable increase in costs, leading to an overall cost-effective improvement in stroke services.

5.3 Stroke unit treatment is cost-effective as it improves overall outcomes and reduces mortality over ten years. The stroke unit scenario only tests for an increase in the availability of stroke unit services. A separate scenario tests improvement in the early supported discharge provision without changing the current level of stroke unit provision. This also provides a very favourable cost per QALY ratio. A combination of both of these scenarios does then give an idea on the overall bed requirements. When the availability of stroke unit services is coupled with the availability of early supported discharge services, the requirement for additional stroke unit beds is reduced.

5.4 Our findings suggest that a potential increase in the availability of early supported discharge services from 50 per cent of the population to a 100 per cent of the patients would lead to 10 to 15 per cent savings in the stroke unit bed requirements. This could lead to a reduction in overall bed numbers or an increase in the number of patients that could be admitted to a stroke unit, thereby increasing stroke unit coverage in the country. The model does not estimate the additional staffing requirements which will accompany such service improvements, although it could be assumed that staff requirements might follow bed requirements up to a certain point. Of course, creating an additional stroke unit bed or increasing the capacity of early supported discharge services could also mean an increase in the whole time equivalent of stroke specialists, (physicians and nurses), rehabilitation specialists, etc. As the training of health care specialists can take time, there would inevitably be some delay in achieving optimal levels of service provision.

5.5 We evaluated the potential increases in the number of patients being thrombolysed using two different hypothetical scenarios. The first tested a potential decrease in the ambulance response time to an emergency call. We found that this would not have an impact on the number of patients being thrombolysed. We did not calculate the resource consequences of reducing response times for stroke patients on the ambulance services as a whole or the potential effect of a change in stroke response times on other conditions which require an emergency response.

5.6 The second scenario considered the impact of an increase in public awareness and consequent reduction in the time taken for patients to call for help in the case of a stroke, thereby improving the speed with which patients are taken to the hospital and increasing the chance of being scanned quickly and, if indicated, thrombolysed. We estimated that increasing the awareness of patients would lead to a reduction in the time taken to call for ambulance services and that this would have a higher impact on the number of patients being thrombolysed. We used a discount rate of 3 per cent for costs and 1.5 per cent for outcomes, as recommended by NICE and by the Department of Health, in the main calculations. However, we also tested the potential effect of using different discounting rates on the results. We repeated the current care provision, previous care provision and further improvements models with no discounting (0 per cent discounting) and 6 per cent discounting of both costs and outcomes. The results indicate that using different discount rates did not change the cost-effectiveness estimates.

5.7 The model has a number of limitations. For example, limited evidence on early supported discharge. The assumptions on LOS reduction are based on the Cochrane review meta-analysis carried out on the effect of early supported discharge on care provision[28]. However, the costs and service models are taken from a randomised control trial carried out in London over ten years ago[14]. Currently there are no agreed standards for the provision of early supported discharge services. The composition of the early supported discharge team, frequency of visits and the extent of post-discharge follow-up all vary from region to region and from practice to practice. Different studies suggest that there would be an increased need for therapy as the severity/disability of patients increases.[40] However, there seems to be no standard on the therapy needs of patients based on their severity/disability levels. As such, the model results may be susceptible to changes in current practice. However, the Cochrane review and other international studies suggest that within the boundaries of the current evidence early supported discharge provides a very effective pathway in the treatment of patients.

5.8 Whilst the results of our modelling suggest an overall cost-effective improvement in services, this is at a national level, as the organisation of local services vary this will not be the case for all locations. The modelling also does not take into account the impact of stroke care, such as the benefit of post-discharge care, on the welfare of patient carers.

Conclusion

5.9 The improvements in the provision of stroke services have been cost-effective, but there is scope for further improvements in value-for-money, especially by extending the provision of stroke units and allowing for better discharge services to be provided to patients.

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Appendix

Colour coding

Improvement cost saving (Decreased cost with increased outcome)	● (dark green)
Improvement cost-effective (Increased cost with increased outcome, ICER less than £30,000)	● (light green)
Improvement not cost-effective (Increased cost with increased outcome, ICER higher than £30,000)	● (amber)
Improvement dominated (Costs more for decreased outcome)	● (red)

A Multiple runs of comparisons between scenarios

Table a
Comparing the current scenario with the previous standards

Run	Current care provision		Previous care provision		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.57	25,262	2.34	24,347	● (light green) 3,943
2	2.59	25,276	2.26	22,711	● (light green) 7,908
3	2.54	25,211	2.19	24,592	● (light green) 1,770
4	2.44	24,828	2.26	22,060	● (light green) 14,845
5	2.49	24,059	2.18	21,544	● (light green) 8,174
6	2.60	24,495	2.33	24,634	● (dark green) -519

Table b
Comparing the current scenario with further improvements

Run	Current care provision		Further improvements		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.57	25,262	2.94	24,562	● (dark green) -1,887
2	2.59	25,276	2.92	25,909	● (light green) 1,915
3	2.54	25,211	2.97	26,896	● (light green) 3,888
4	2.44	24,828	2.91	26,451	● (light green) 3,457
5	2.49	24,059	2.80	25,730	● (light green) 5,350
6	2.60	24,495	2.98	26,154	● (light green) 4,340

Table c

Comparing the current provision of services with increasing the coverage of stroke unit services to 100 per cent

Run	Current care provision		100 per cent stroke unit provision		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.57	25,262	2.86	27,915	9,180
2	2.59	25,276	2.78	26,486	6,080
3	2.54	25,211	2.79	26,474	5,121
4	2.44	24,828	2.78	27,144	6,767
5	2.49	24,059	2.73	24,708	2,644
6	2.60	24,495	2.80	27,476	14,537

Table d

Comparing the current provision of services with extending the coverage of early supported discharge to all stroke unit patients

Run	Current care provision		100 per cent early supported discharge provision		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.57	25,262	2.72	25,869	3,953
2	2.59	25,276	2.67	23,888	-15,769
3	2.54	25,211	2.70	27,087	11,845
4	2.44	24,828	2.60	26,816	12,401
5	2.49	24,059	2.64	25,093	6,535
6	2.60	24,495	2.71	25,199	6,406

Table e

Comparing the current scenario with the previous standards

Run	Current care provision, 0 per cent discount		Previous care provision, 0 per cent discount		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.87	27,673	2.61	26,522	4,401
2	2.90	27,778	2.53	24,738	8,343
3	2.84	27,597	2.45	26,878	1,831
4	2.73	27,210	2.52	23,968	15,460
5	2.78	26,321	2.44	23,425	8,399
6	2.91	26,859	2.61	26,793	221

Table f

Comparing the current scenario with further improvements

Run	Current care provision, 0 per cent discount		Further improvements, 0 per cent discount		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.87	27,673	3.29	26,926	-1,790
2	2.90	27,778	3.27	28,449	1,804
3	2.84	27,597	3.33	29,563	4,015
4	2.73	27,210	3.26	29,065	3,498
5	2.78	26,321	3.13	28,254	5,478
6	2.91	26,859	3.34	28,731	4,329

Table g

Comparing the current scenario with the previous standards

Run	Current care provision, 6 per cent discount		Previous care provision, 6 per cent discount		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	1.87	23,838	1.70	23,062	4,710
2	1.87	23,805	1.64	21,515	9,840
3	1.85	23,799	1.60	23,245	2,223
4	1.78	23,422	1.64	20,932	18,673
5	1.81	22,721	1.59	20,435	10,286
6	1.88	23,102	1.69	23,355	-1,328

Table h

Comparing the current scenario with further improvements

Run	Current care provision, 6 per cent discount		Further improvements, 6 per cent discount		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	1.87	23,838	2.13	23,166	-2,546
2	1.87	23,805	2.11	24,410	2,583
3	1.85	23,799	2.16	25,323	4,986
4	1.78	23,422	2.11	24,907	4,494
5	1.81	22,721	2.03	24,242	6,930
6	1.88	23,102	2.15	24,634	5,725

B Thrombolysis re-runs with elevated risk of death (OR = 1.16)

Elevated risk of death (OR = 1.16) as a result of thrombolysis

Table i
Comparing the current scenario with the previous standards

Current care provision, OR of mortality 1.16		Previous care provision, OR of mortality 1.16		
QALY	Cost £	QALY	Cost £	ICER (Cost per QALY gained) £
2.55	24,780	2.26	23,487	4,458

Table j
Comparing the current scenario with further improvements

Current care provision, OR of mortality 1.16		Further improvements, OR of mortality 1.16		
QALY	Cost £	QALY	Cost £	ICER (Cost per QALY gained) £
2.55	24,780	2.98	26,331	3,606

Elevated risk of death (OR = 1.16) as a result of thrombolysis, multiple runs

Table k
Comparing the current scenario with the previous standards

Run	Current care provision		Previous care provision		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.57	25,262	2.34	24,347	3,943
2	2.59	25,276	2.26	22,711	7,908
3	2.54	25,211	2.19	24,592	1,770
4	2.44	24,828	2.26	22,060	14,845
5	2.49	24,059	2.18	21,544	8,174
6	2.60	24,495	2.33	24,634	-519

Table l

Comparing the current scenario with further improvements

Run	Current care provision		Further improvements		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.57	25,262	2.94	24,562	-1,887
2	2.59	25,276	2.92	25,909	1,915
3	2.54	25,211	2.97	26,896	3,888
4	2.44	24,828	2.91	26,451	3,457
5	2.49	24,059	2.80	25,730	5,350
6	2.60	24,495	2.98	26,154	4,340

Table m

Comparing the current scenario with the previous standards

Run	Current care provision, 0 per cent discount		Previous care provision, 0 per cent discount		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.55	24,691	2.34	24,347	1,576
2	2.57	23,860	2.25	22,805	3,308
3	2.60	26,001	2.19	24,592	3,454
4	2.44	23,809	2.26	22,410	7,657
5	2.55	24,162	2.21	21,872	6,730
6	2.62	26,155	2.32	24,893	4,288

Table n

Comparing the current scenario with further improvements

Run	Current care provision, 0 per cent discount		Further improvements, 0 per cent discount		ICER (Cost per QALY gained) £
	QALY	Cost £	QALY	Cost £	
1	2.55	24,691	2.94	24,901	547
2	2.57	23,860	2.98	26,791	7,074
3	2.60	26,001	3.05	26,398	880
4	2.44	23,809	2.96	26,814	5,825
5	2.55	24,162	2.89	26,403	6,452
6	2.62	26,155	3.04	26,677	1,240

C Time reductions

Percentage of patients thrombolysed if ambulance response times are reduced, multiple runs

Table o
Percentage of patients thrombolysed with reduced ambulance response time

Run	Current percentage of patients thrombolysed	Reduced ambulance response time, percentage of patients thrombolysed	Difference
1	2.06	2.06	0.00
2	1.82	2.06	0.24
3	1.77	1.69	-0.08
4	2.17	1.91	-0.26
5	1.23	1.57	0.34
6	2.30	1.91	-0.39

Percentage of patients thrombolysed if there is a reduction in patient time to call emergency services

Table p
Reduction in the time to call emergency services

Run	Current care provision, percentage of patients thrombolysed	10 per cent reduction in 'time to call emergency services' as a result of FAST campaign	20 per cent reduction in 'time to call emergency services' as a result of FAST campaign	30 per cent reduction in 'time to call emergency services' as a result of FAST campaign
1	2.06	1.98	2.53	2.95
2	1.82	1.84	2.18	2.18
3	1.77	1.57	1.88	1.84
4	2.17	2.47	2.40	2.59
5	1.23	2.52	1.82	2.59
6	2.30	2.30	2.92	3.12