Modelling the short term consequences of smoking cessation in England on the hospitalisation rates for acute myocardial infarction and stroke

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Abstract

***Objectives*—To estimate the short term event and cost consequences of achieving two smoking cessation targets for England among a cohort of 35–64 year olds, in terms of the number of hospitalised acute myocardial infarctions (AMIs) and strokes avoided.**

***Design*—A spreadsheet model based on previous work and using data for England was constructed to simulate the effects of achieving the target set out in the government's tobacco white paper (target 1). We also examined the consequence of achieving the intensive smoking reduction witnessed in California (target 2).**

***Results*—Target 1 would result in 347 AMI and 214 stroke hospitalisations avoided in the year 2000, and by 2010 this would be 6386 AMI and 4964 strokes avoided. Achieving target 2 would result in 739 AMI and 455 stroke hospitalisations avoided in 2000, and 14 554 AMI and 11 304 strokes avoided by 2010. Achieving target 1 would save £524 million (£423 million discounted at a rate of 2.67% for stroke and 2.31% for AMI) and target 2 would save £1.14 billion (£921 million discounted) in terms of National Health Service costs.**

***Conclusion*—In the short term (11 years), reductions in the prevalence of smoking will produce sizeable reductions in both events and hospital costs.**

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Keywords: smoking cessation modelling cost; acute myocardial infarction; stroke

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Tobacco smoking is the most dangerous single threat to the health of populations in most countries of the world.[1] When smoked as intended, cigarettes are highly addictive.[2] Recent evidence from documents uncovered in the USA suggests that tobacco companies have long targeted children and young people "to replace adult smokers lost through natural attrition".[3] Long after identifying the addictiveness of tobacco smoke, over the past 20 or so years tobacco companies appear to have introduced additives that increase the nicotine delivery of cigarettes.[4]

After the perinatal and neonatal periods, the serious health consequences of smoking are minimal until middle age is reached. Peto reports from the 40 year follow up study of British doctors that those who stopped smoking before age 35 survived about as well as life long non-smokers and those who stopped between the ages of 35 and 44 years did nearly as well non-smokers.[5] However, stopping at any age gives rise to the immediate benefit of losing an addiction[2] with palpable long term consequences.

In order to prevent the large scale death and disease consequences of smoking, cessation programmes have been recommended since the Royal College of Physicians published its seminal report in 1962.[6] The tobacco white paper[7] aims to provide a whole body of circumstances whereby tobacco consumption patterns can be importantly reduced.

The cost effectiveness of smoking cessation has been recently reviewed[8] but these benefits seem far away, and usually not within the lifetime of a government. Of the 25 diseases known to increase in incidence because of smoking, the risk of two of the most common, coronary thrombosis and stroke, can be directly and quickly affected by stopping smoking. This study seeks to estimate the numbers of beneficiaries and the associated health service costs in England of two smoking cessation scenarios just for these diseases.

Specifically, the study aimed to estimate the health and National Health Service (NHS) cost consequences of avoided hospitalised acute myocardial infarctions (AMIs) and strokes for England in a cohort of 35–64 year olds due to achieving two smoking cessation targets.

The smoking prevalence changes modelled were:

- *Target 1*—meeting the targets as specified in the white paper that adult smoking rates be decreased from 28% in 1996 to 26% by 2005 and 24% by 2010;
- *Target 2*—meeting the more ambitious targets that adult smoking rates be decreased from 28% in 1996 to 22% in 2005 and 17% in 2010, as a result of an absolute 1% reduction year on year. This is the pattern observed in California currently.[9]

The model aimed to simulate the effects of achieving the two smoking targets outlined in terms of the number of AMIs and strokes that reach hospital avoided in the initial cohort until 2010, in comparison to the same cohort which had continued to smoke.

Table 1 Data sources used in the simulations

Parameter	Data source
Proportion of smokers	Health survey for England
Proportion of ex-smokers	Health survey for England
Observed incidence in the population	Hospital episode statistics
35–64 year old cohort size	National population projections
Number of smokers equivalent to a % drop in prevalence	Health survey for England and national population projections
Annual survival probability	Mortality statistics

Methods

The method outlined in the paper by Lightwood[10] in the USA was translated to a spreadsheet model with data for the English population. The parameters, as used by Lightwood, and data sources are shown in table 1. We chose 1995 as the base year, since this was the last year for which detailed information on hospital admissions for AMI and stroke existed. Unlike in the Lightwood paper (which grouped the sexes together for stroke) we were able to apply different event rates to each sex.

The size of the 35–64 year old cohort in 1995 was derived, and then their yearly survival projected until 2010 to estimate the numbers in the cohort alive for each year of the simulation. This was calculated using the mortality statistics and population projections for 1995. The initial cohort of 35–64 years olds constituted 17 670 400 individuals (8 825 000 males and 8 845 400 females). With the cohort aging the annual survival for 40–69 year olds for 2005 and for 45–74 year olds for 2010 was used, and interpolated between 1995, 2005, and 2010 to calculate the cohort's changing survival probability over time. The same interpolation method was used to calculate the cohort's changing AMI and stroke hospital admission rates as it aged using hospital episode statistics (HES) data.

To estimate the fall in relative risk (RR) of an MI or stroke for ex-smokers over time since quitting we used the equations and parameters from Lightwood. To estimate the decline in RR of all cause mortality after cessation of smoking, data for 30–64 year olds were taken from the British doctors cohort,[11] assuming that the decline in RR over time would be the same for males and females. These data are shown in table 2.

The yearly increase in the proportion of new ex-smokers for each sex that would result from achieving each of the two targets, assuming that an equal number of males and females at each age would be affected, was estimated. The average hospitalisation (AMIs or strokes) rates for never-smokers in each simulation year were calculated using the equation from Lightwood, but using the changing hospitalisation rates for the aging cohort estimated from the HES, and the proportion of smokers derived from the Health Survey for England.

From this the sex specific incidence rates of event hospitalisations for ex-smokers who stopped smoking "t" months ago was calculated using Lightwood's method. This method was adapted to also calculate the sex specific all cause mortality rates for ex-smokers who stopped smoking "t" months ago. These event hospitalisation and all cause mortality rates were applied to each new subcohort of ex-smokers that stopped smoking in each year of the simulation, for each year to calculate the number of yearly events and those surviving to the next year of simulation for each subcohort.

Finally the absolute number of event hospitalisations avoided in year "s" for a subcohort of individuals who stopped smoking "t" months ago was calculated at 12 monthly intervals by subtraction from those expected with no reduction in smoking prevalence.

The cost consequences of the two smoking cessation targets are restricted to those costs related to hospitalisation for the number of events of myocardial infarction and stroke. Costs are estimated for the both admission and immediate hospital treatment, and for the following cost of managing the disease post-event, for a period of 4.6 years for MI[12] and 3.8 years for stroke.[13] Costs for myocardial infarction were taken from the comprehensive "cost of CHD" study.[14] The costs for both admission and management of stroke were estimated from data on 97 hospitals across six studies throughout the 1990s.[15–20] Where the studies are based outside the UK, the resource use data from the study has been combined with UK specific unit cost data. A mean was then taken across all studies for the cost of an admission because of stroke and the management of stroke thereafter. All costs were converted in 1999/2000 prices for use in the model.

Two aspects of discounting were considered. First the rate of change of the value of benefits, in this case health and the rate of change of unit cost. Normal discount rates to discount against the future value of money were included as zero assuming that the question is being taken from a societal perspective, that the value of money to society now is the same as its value in 10 years' time.[21] The second aspect is that used against the relative value of health benefits between now and 10 years' time. Here we have taken life expectancy at 45 to be the relative measure of our value of life, using a discount rate of 0.7% based on the real trend of change in life expectancy over the last 10 years.[22]

To account for real change in relative cost of treatment over time, we have taken a sample trend from finished consultant episode unit costs for both cardiology and neurology specialists from 152 hospitals over a three year period from 1991 to 1993.[22] This shows a reduction in real unit cost of 1.97% per annum for neurology and 1.61% per annum for cardiology. This is most likely caused by a combination of changes to length of stay and improvements in technology.

Table 2 Estimated decline in RR for all cause mortality after smoking cessation

Years since smoking cessation	0	< 5	5–9	10–14	15
All cause RR	2.0	1.7	1.6	1.4	1.1

Results

The results for England in each calendar year for the original cohort of 35–64 year olds from the two smoking interventions are shown by

Table 3 Yearly event hospitalisations expected and avoided because of achieving the targets by sex

	Expected events				*Target 1*				*Target 2*			
	Males		*Females*		*Males*		*Females*		*Males*		*Females*	
Year	*AMIs*	*Strokes*	*AMIs*	*Strokes*	*AMIs*	*Strokes*	*AMIs*	*Strokes*	*AMIs*	*Strokes*	*AMIs*	*Strokes*
2000	20085	10148	7466	6749	245	123	102	91	521	262	217	194
2001	21222	11167	8291	7500	533	277	233	207	1134	590	496	440
2002	22310	12152	9100	8237	857	501	390	374	1824	978	831	734
2003	23347	13100	9891	8957	1212	705	572	530	2581	1501	1218	1129
2004	24329	14008	10661	9658	1596	936	778	709	3397	1992	1655	1509
2005	25252	14875	11409	10340	2004	1190	1004	907	4266	2534	2138	1931
2006	26166	15978	12270	11361	2391	1462	1241	1138	5192	3175	2694	2470
2007	27002	17017	13098	12347	2790	1753	1495	1389	6157	3868	3296	3062
2008	27756	17986	13890	13295	3201	2061	1764	1659	7155	4606	3941	3704
2009	28425	18882	14644	14201	3619	2382	2048	1946	8177	5381	4623	4391
2010	29007	19701	15358	15064	4042	2715	2344	2248	9216	6187	5338	5117
Total	274903	165013	126078	117707	22490	14106	11971	11196	49619	31073	26447	24681

sex in table 3, as well as the expected number of AMIs and strokes in the reference (no intervention) cohort. Target 1 (meeting the smoking targets as specified in the White Paper) would result in 347 AMI and 214 stroke hospitalisations avoided after only a year, which by the year 2010 would increase to 6386 AMI and 4964 stroke hospitalisations avoided. Overall during the period 1999 to 2010, achieving target 1 would reduce the number of AMI and stroke hospitalisations by 34 460 and 25 301, respectively.

The more ambitious target 2 (an absolute 1% reduction in the prevalence of smoking year on year) would result in 739 AMI and 455 stroke hospitalisations avoided by the year 2000, over twice the effect of target 1. By 2010 this would increase to 14 554 AMI and 11 304 stroke hospitalisations avoided. In total, achieving target 2 would reduce the number of hospitalisations by 76 066 for AMI and by 55 755 for stroke during the period 1999 to 2010.

The estimated overall cost saving over 10 years as a result of achieving target 1 is just over half a billion pounds at 1999/2000 prices (£524 million), non-discounted or £423 million discounted. Similarly for target 2 it is just under £1.14 billion non-discounted or £921 million discounted. Table 4 shows the growth in cost savings over the 10 years modelled by target and by event type, for both discounted and non-discounted.

Another area of sensitivity and unpredictability is the discount rate used for calculating the total costs over the 10 year period in question. We used two alternative discount rates for the cost of AMI and stroke; a zero discount rate, and the UK Treasury suggested rate of 6%.[23] The results, in table 5, show that the effect on the results is substantial, with a zero discount rate lifting total potential cost savings to £525 million in target 1 and £1.14 billion in target 2. The effect of the 6% rate, shown in table 6, is obviously to reduce the potential savings, but still keeps it in excess of £320 million for target 1 and £680 million for target 2. Figure 1 shows the estimated cost savings as a proportion of the total expenditure of the NHS.

Although the consequence of achieving these targets were predicted until 2010, the benefits of achieving each target would clearly persist. In the longer term there would be reductions in other smoking related illnesses such as lung cancer and chronic obstructive lung diseases. In addition, this work does not take into account the reduction in the number of AMIs and strokes for those people that die before they reach hospital, so the number of events avoided owing to these interventions

Table 4 Yearly cost savings (£) for the 10 years 2000 to 2010 (1999-00 prices)

	Target 1		*Target 2*	
Year	*AMIs*	*Strokes*	*AMIs*	*Strokes*
2000	894951	1127711	1904991	2400444
2001	2310274	3078752	4917646	6553425
2002	4264087	6263700	9076528	12584659
2003	6767145	10049474	14404533	21002606
2004	9681208	14322538	20607403	30110274
2005	12915811	19413690	27492574	41033315
2006	16524125	25332747	35519843	54356053
2007	20562408	32321066	44644280	69780167
2008	25021144	40212192	54843802	87756019
2009	29884601	48986995	66081015	107906221
2010	35150535	58597765	78290231	129977615
Total	163976288	259706629	357782846	563460798

Table 5 Yearly cost savings (£) with 0% discount rate

	Target 1		*Target 2*	
Year	*AMIs*	*Strokes*	*AMIs*	*Strokes*
2000	916113	1156683	1950037	2462114
2001	2420825	3241086	5152964	6898970
2002	4573784	6769280	9735750	13601680
2003	7430277	11152794	15816076	23306670
2004	10881255	16321765	23161822	34311219
2005	14860076	22719798	31631133	48019416
2006	19461114	30447510	41833121	65326416
2007	24789804	39900151	53822634	86132243
2008	30878498	50990411	67682527	111261398
2009	37752556	63807563	83478687	140529992
2010	45454903	78405788	101240987	173883984
Total	199419207	324912829	435505737	705734101

Table 6 Yearly cost savings (£) with 6% discount rate

	Target 1		*Target 2*	
Year	*AMIs*	*Strokes*	*AMIs*	*Strokes*
2000	861146	1087282	1833035	2314387
2001	2139041	2863824	4553159	6095930
2002	3798912	5622456	8086358	11297338
2003	5801181	8707533	12348385	18196658
2004	7985797	11978609	16998554	25181142
2005	10251517	15673702	21821363	33127144
2006	12620096	19744528	27127842	42362717
2007	15111095	24321892	32808606	52503540
2008	17693219	29217240	38781736	63752203
2009	20334097	34367718	44962882	75691578
2010	23013736	39696710	51258130	88037149
Total	119609838	193281494	260580050	418559785

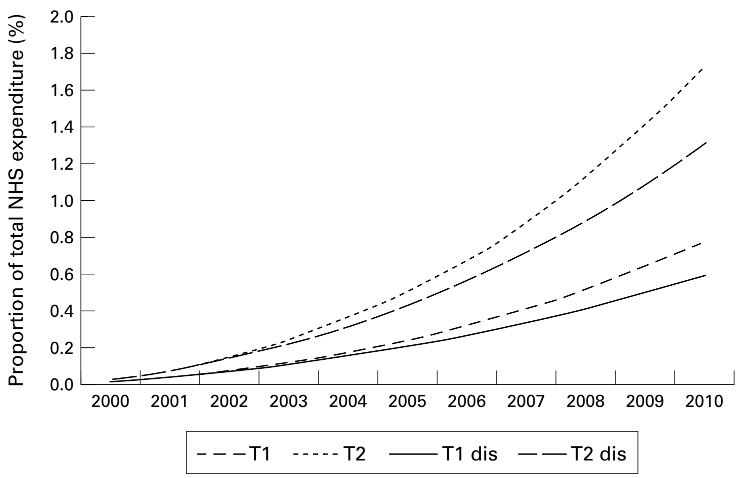

Figure 1 Estimated cost savings as a proportion of total NHS expenditure.

would be greater than those calculated here. The UK Audit Commission reported that 25% of heart attacks resulted in death before reaching hospital,[24] and obviously these events, along with before hospital stroke deaths, are not counted here although presumably they would be prevented at the same rate.

Discussion

The cost saving to the NHS, or more widely, the economic consequences of reducing smoking are higher than those reported here. This study has limited its savings to health service resources, for only two of many smoking related diseases. There have been a number of attempts to assess the true cost of smoking to the NHS, with varying degrees of lucidity and precision. This method gives an example of what can be achieved with an effective model, appropriate data, and limited outcomes. It could be adapted for use with other cohorts, such as health regions in England, or the Health Education Authority Quitline cohort. In the long run it would be advisable to incorporate a series of other disease end points and to include primary care based management of disease, which, for a number of diseases, can outweigh the hospital based costs associated with them.

In addition the effect of a cumulative reduction in demand for specific procedures, such as coronary artery bypass grafting (CABG) and percutaneous transluminal coronary angioplasty (PTCA), could have a significant effect on waiting lists. For example, the total reduction in demand for CABGs by the year 2005 would be equivalent to 2% of the current waiting list for this procedure,[25] and by 2010 it would be as high as 4%. Similarly the figures for PTCAs would be 5% by 2005 and 10% by 2010.

Coronary heart disease alone currently costs the NHS approximately £1000 million,[23] with smoking contributing significantly to these costs. This work shows that the savings made through moderate success in cessation programmes are in themselves significant, cumulative and immediate, not just in terms of mortality and morbidity, but on the utilisation of scarce health care resources.

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