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Modelling Sudden Deaths from Myocardial Infarction and Stroke

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***Abstract*—**Death within 30 days is an important factor to be looked into, as there is a significant risk of deaths immediately following or soon after, myocardial infarction (MI) or stroke. In this paper, we will model the deaths within 30 days following a myocardial infarction (MI) or stroke in the UK. We will see how the probabilities of sudden deaths from MI or stroke have changed over the period 1981-2000. We will model the sudden deaths using a generalized linear model (GLM), fitted using the R statistical package, under a Binomial distribution for the number of sudden deaths. We parameterize our model using the extensive and detailed data from the Framingham Heart Study, adjusted to match UK rates. The results show that there is a reduction for the sudden deaths following a MI over time but no significant improvement for sudden deaths following a stroke.

***Keywords*—**Sudden deaths, myocardial infarction, stroke, ischemic heart disease.

I. Introduction

SUDDEN deaths from myocardial infarction and stroke is a significant factor to be looked into as the crude risk of death was greatest in the first year after stroke (36% in 1989-90 and 37% in 1995-96) and particularly in the first 30 days from onset (22% in 1989-90 and 23% in 1995-96), according to [4].

17% of patients with myocardial infarction and 10\% of patients who suffered a stroke died within the first 30 days [2]. In this study, sudden death is defined as death from any cause within one month following myocardial infarction (MI) or stroke. We are interested to see how the probability of sudden death from MI or stroke has changed over the period 1981-2000.

II. Myocardial Infarction

Studies that we had looked into suggested that the case fatality rates for myocardial infarction in England and some other countries decreased over the period 1981-2000. The Oxford Myocardial Infarction Incidence Study Group (OXMIS), studied the case fatality rate for myocardial infarction among a population of 568, 800 in Oxfordshire, England in 1994 – 95 [11]. The OXMIS study considered the rate for overall case fatality, which is the proportion of hospitalized patients who died within 28 days of onset of symptoms and the proportion of these patients who died before reaching hospital (out of hospital case fatality rate). The overall case fatality rate declined significantly by 28% in men (from 56.7% in 1966-67 to 41.0% in 1994-95) and 32% (from 64.6% in 1966-67 to 44.1% in 1994-95) in women.

Another useful study that shows the reduction in the rates of sudden deaths from myocardial infarction is given by the National Centre for Health Outcomes Development [7]. This provides a recent set of data which includes years 1999 to 2007. The National Health Service (NHS) has calculated the indirectly standardized by age and diagnosis rates for deaths from myocardial infarction. The data consists of deaths in hospital and after discharge within 30 days of an emergency admission to hospital with myocardial infarction. All death records are taken from the Hospital Episodes Statistics and the Office for National Statistics from ages 35 to 74. 30-day death rates for women were higher than men in both conditions, but both have shown some improvements. The 30-day death rate for myocardial infarction reduced by 41% for women and 38% for men. These data include only those who had reached hospital and do not include sudden deaths at home without being referred to the hospital.

Studies from other countries also suggest that there are reductions in sudden death from myocardial infarction. Over the period from 1950 to 1999 the sudden death rate in the Framingham Heart Study decreased by 49% [3]. The risk of sudden death for those without prior history of IHD was 39% lower in 1990 to 1999 compared to 1950 to 1969, whereas for those with a prior history, the risk was 57% lower, comparing the same year. A study of trends in the incidence of coronary disease conducted in Minnesota indicated that the age and sex adjusted incidence of sudden deaths declined over time, from 23% in 1979-1983 period to 17% during the 1994-1998 period, a reduction of 26.1% by [1]. However, there are some studies that reported no changes in sudden deaths from myocardial infarction. Over 21 years of study for white males, aged 35 to 44 years old in Pennsylvania reported no reduction in sudden deaths for IHD [10]. This study defined sudden death as death within 24 hours of the symptoms with no history of heart disease.

III. Stroke

Sudden death from stroke has shown no significant improvement over time, as reported in some studies that have similar definition of sudden death following a hard stroke (SDHS) with this study. SDHS is defined as sudden deaths following a stroke from hospitalized and non-hospitalized

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cases within 30 days. Sudden death from stroke has shown no significant improvement over time as reported in some studies. In an Oxfordshire Study, the 30-day case-fatality from stroke remained the same between 1981-1984 and 2002-04, where the rates were 17.8% and 17.2% respectively, although there was a decline of 29% in incidence of stroke [8].

In a study that analyzed the case fatality from stroke in Finland, the decrease in 28-day case fatality of stroke between 1983 and 1997 in men is from 21.7% to 18.2% and from 22.2% to 19.2% in women [9]. Dividing this into different types of stroke, case fatality of ischemic stroke remained stable and similar in men and women between 1988 and 1997, while case fatality of hemorrhagic stroke decreased slightly in men and significantly in women, from 55.2% to 32.6%.

The latest data (1999 to 2007) from The National Health Service has shown some reductions in sudden deaths from stroke [6]. The NHS has calculated rates of deaths from stroke the indirectly standardized by age and diagnosis. The data are the same as the data for myocardial infarction, where it is deaths after admission to hospital or after discharge within 30 days. Fig. 1 shows the trend of SDHS from 1999 to 2007 for men and women. Between these years, the probability of deaths within 30 days for stroke seems to be declining. Deaths within 30 days declined by 27.5% and 21% for men and women, respectively. Comparing it with the study in Oxfordshire which showed no significant reduction between 1981-1984 and 2002-04 [8], the reduction shown in these data might indicate that within recent years there may has been an improvement in treatment, as people who have strokes are more likely to survive if admitted quickly to a hospital with treatment and care provided by a specialist coordinated stroke team. Also, the NHS data relates to 1999 to 2007, which does not overlap with the period that we are interested in.

IV. Methodology

We will model the probability of sudden death following a myocardial infarction (SDMI) by using the data from the Framingham Heart Study from 1971 to 1991, which is the Original Cohort (OC). In the Framingham OC data, there were 179 sudden deaths following a MI from 1049 MI cases for males and females. We will model the sudden deaths using a GLM, fitted using the R statistical package, under a binomial distribution for the number of sudden deaths. The response variable which is the SDMI (D_{MI}) will take the value 0 if the individual is alive after 30 days and 1 if the individual has died within 30 days after MI. We will model the probability of sudden deaths following a stroke by using the same dataset and methods as used for the SDMI. We will use the Framingham dataset, which includes 157 cases of sudden deaths following a stroke from 740 stroke cases for males and females.

V. Results

First we model the SDMI using age at MI, year of MI and sex as the explanatory variables. We found that age at MI and year of MI are significant explanatory variables while sex is not a significant factor for modelling the SDMI. The model is shown below and the R output is shown in Table I:

$$D_{SDMI} \sim \text{Bin}\,(1,\ \text{P}_{\text{SDMI}})$$

where

$$logit\,(P_{SDMI}) = b_0 + b_1 Age + b_2 YearMI$$

TABLE I
SUMMARY OF SMDI MODEL

Coefficients	Estimate	Standard Error	P-value
b_0	36.83813	21.27982	0.0834
b_1	0.06241	0.01109	1.81e-08
b_2	-0.02166	0.01105	0.0499

Fig. 1 shows the probability of sudden deaths from myocardial infarction from the modelling for 3 different ages, 40, 71 and 80. We can see that the probability increases as age increases and there are reductions over the years for all ages. The probability is consistent with most of the literatures which suggests that the rates decreased over time. The probability of sudden death following myocardial infarction from the R output in Table I is shown below:

$$P_{SDMI} = \frac{exp^{(36.83813+0.06241*Age-0.02166*Year)}}{1+\ exp^{(36.83813+0.06241*Age-0.02166*Year)}}$$

For stroke, we start the modelling by including age at stroke, year of stroke and sex as the explanatory variables. However, year of stroke and sex were found to be not significant for SDHS. This can also be seen in Fig. 2 where we can see that the rates for different ages are almost the same over the years. This means that there is no calendar time effect in the sudden death rates following a stroke. The model is shown below and the R output is shown in Table II:

$$D_{SDHS} \sim \text{Bin}\,(1,\ \text{P}_{\text{SDHS}})$$

where

$$logit\,(P_{SDHS}) = b_0 + b_1 Age$$

TABLE II
SUMMARY OF SMHS MODEL

Coefficients	Estimate	Standard Error	P-value
b_0	-3.625166	0.651198	2.59e-08
b_1	0.032011	0.008797	0.000274

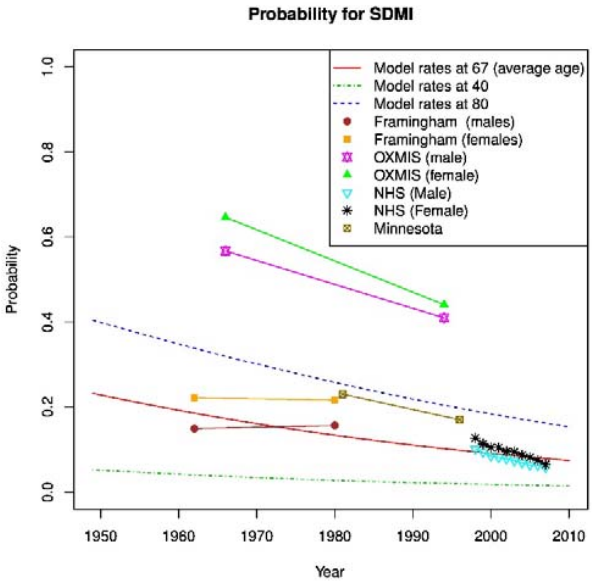

Fig. 1 SDMI model and UK age standardized rates

As year of event is not a significant factor, our model for the sudden deaths from stroke uses only age, which can be referred to Table II and is shown below:

$$P_{SDHS} = \frac{exp^{(-3.625166+0.032011*Age)}}{1 + exp^{(-3.625166+0.032011*Age)}}$$

VI. Discussions

A possible explanation for the reason why the rate of sudden death from stroke in the NHS England and NHS Scotland data decreased over time can be given by looking at the incidence rate for stroke over the populations. We will look at the incidence rate per 100,000 people which is available for the NHS and Oxfordshire studies and see what makes the trend in sudden death different between the studies. We would expect the incidence rate from the NHS data to be lower than in the Oxfordshire Study as the NHS only includes those who were hospitalized. Tables III and IV show the incidence rate of stroke per 100,000 people for males and females from the NHS and Oxfordshire studies.

From the tables, we can see that indeed the incidence rates for the NHS are generally lower than for Oxfordshire. The higher rates in the Oxfordshire study could represent the out-of-hospital cases which might explain why there were no changes over time for sudden death. The number of out of hospital cases in the Oxfordshire study would result in more sudden deaths compared to the NHS. So the reduction in the sudden death rates from hospitalized cases has been cancelled out by the out of hospital sudden death cases which probably resulted in no changes over time in sudden death rates in Oxfordshire and Finstroke.

The incidence of stroke fell by 29% between 1981-84 and 2002-04 (from 2.27 to 1.62 per 1000 population) [8]. This can be seen in Tables III and IV by comparing the incidence rates between 1983 and 2004 in the Oxfordshire rates. The decline resulted from the increased use of preventive treatment and better control of vascular risk factors [8]. The decline is consistent with the reduction in mortality due to stroke in the absence of the reduction of sudden death.

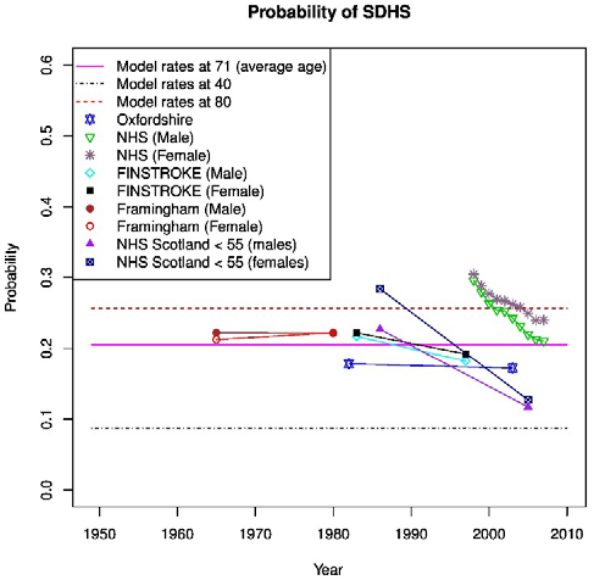

Fig. 2 SDHS model and UK age standardized rates

TABLE III
Incidence Rate of Stroke per 100,000 Populations for Males

Age	NHS Scotland		Oxfordshire	
	1985	2005	1983	2004
55-64	250	250	368	214
65-74	500	450	819	678
75-84	1250	900	1772	1085
85+	1900	1300	1994	2063

TABLE IV
Incidence Rate of Stroke per 100,000 Populations for Females

Age	NHS Scotland		Oxfordshire	
	1985	2005	1983	2004
55-64	200	200	181	140
65-74	450	300	601	464
75-84	1000	750	1529	1109
85+	1600	1250	1769	1863

A population-based study in the United States mentioned that the annual incidence of hospitalized stroke did not change significantly between 1993-94 and 1999 [5]. The incidence rate in both periods; 1993-94 and 1999 was 158 per 100,000 people. They also measures the out-of-hospital incidence rate and there was a slight increase over the study period, from 186 to 206 per 100,000 [5]. The 30-day case fatality rates from this study were consistent with the Oxfordshire study where there were no significant changes over time. The 30-day case fatality rates in 1993-94 and 1999 were 13.9% and 14.7%, respectively. These rates include the hospitalized and out of hospital cases.

Using the England NHS data and estimated population data

from the ONS, we calculated the age-standardized incidence rates per 100,000 people from 1999 to 2008 for males and females. These are shown in Table V. There is a slight decrease in the incidence of stroke over the time period. The NHS data includes all ages so we compared the rate with the Oxfordshire rate for all age groups. In 2004, the Oxfordshire incidence rate per 100,000 populations for all ages was 134 for males and 156 for females which is shown in Table I as in [8]. Comparing these rates with the NHS incidence rates in the same year, the NHS rates were lower than the Oxfordshire rates, 127 and 138 for males and females, respectively.

TABLE V
NHS INCIDENCE RATE OF STROKE PER 100,000 FOR MALES AND FEMALES

Year	Males	Females
1999	140	151
2000	134	147
2001	129	141
2002	130	139
2003	130	141
2004	127	138
2005	123	133
2006	121	130
2007	116	123
2008	115	119

There were no changes in case fatality rates over time although there were changes in the incidence of stroke, as mentioned in the Oxfordshire study. As expected, the incidence rate for studies that includes hospitalized and out of hospital cases is higher than hospitalized only cases. The risk of sudden death from stroke is higher for those who have not been admitted to hospital so this may cause the rate of sudden death to remain the same.

VII. CONCLUSION

There are more improvements in sudden deaths from myocardial infarction compared to stroke. Reductions in sudden death in myocardial infarction can be seen from studies in England and Framingham. Sudden death from stroke has not shown significant improvements, as mentioned in the Oxfordshire and Finland studies, but there are improvements since 1999 as shown in the NHS data.

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