

CHAPTER 5

LATE TRANSITIONAL MORTALITY CHANGE: STROKE

5.1. SUMMARY

Introduction This chapter describes an example of a disease-specific multi-state model to estimate mortality decline. Trends in stroke incidence and survival determine changes in stroke both morbidity and mortality. It examines the extent of the incidence decline and survival improvement in the Netherlands from 1979-1989 and it projects future changes in stroke morbidity over the period 1985-2005 when the country's population will be aging. Next, it evaluates the health effects and costs of a number of stroke interventions

Methods A multi-state model is used, which combines existing data and describes stroke epidemiology in the Netherlands. Based on the clinical course of stroke, the model describes historical national age- and gender-specific hospital admission and mortality rates for stroke.

Results: There is evidence of a continuing incidence decline. The most plausible rate of change is an annual decline of -1.9% (range: -1.7; -2.1) for men and -2.4% (range: -2.3; -2.8) for women. Projecting a constant mortality decline, the model shows a 35% decrease of the stroke incidence rate over a period of twenty years. Prevalence rates for major stroke will decline among the younger age groups. They will increase among the oldest due to increased survival in the latter. In absolute numbers, this results in an 18% decrease of acute stroke episodes and an 11% increase of major stroke cases.

Conclusion The increase in survival cannot fully explain the observed mortality decline and, therefore, a concomitant incidence decline has to be assumed. Aging of the population partially outweighs the effect of an incidence decline on the total burden of stroke. Increase in cardiovascular survival leads to a further increase in major stroke prevalence among the oldest.

5.2. INTRODUCTION

The dynamics of stroke morbidity and mortality are of major interest for clinicians as well as for epidemiologists and health policy makers. A changing stroke epidemiology results from changes in incidence and survival. The balance between these trends determines the numbers of short and long-term stroke survivors within a population. Recently, the debate on the relative contribution of trends in incidence and survival to stroke mortality decline has intensified, complicated by different study methods and inconsistent results (Casper et al., 1992; Harmsen et al., 1992; McGovern et al., 1992; Modan and Wagner, 1992).

In the Netherlands as well as in the USA, stroke mortality has been declining for all age groups since the early sixties (Casper et al., 1992; McGovern et al., 1992; Modan and Wagner, 1992; Bonita et al., 1990; Central Bureau of Statistics, 1985). In the Netherlands, the age-adjusted decline from 1979-1989 has been a constant 3.1 % per year for men and 4.0% for women, while in the USA mortality decline has been 5.7% and 5.2%, respectively (McGovern et al., 1992; Central Bureau of Statistics, 1985). An incidence decline is also observed (Broderick et al., 1989; Kotila, 1988; Terent, 1989), ascribed to better hypertension control and a decline in smoking prevalence (Broderick et al., 1989; Kotila, 1988; Tuomilehto et al., 1991). Observed incidence trends are confounded by the introduction of computerised tomography, improving the specificity of the diagnosis but also increasing case finding. Declines in short and long term case fatality have been documented for the last decades (Broderick et al., 1989; Terent, 1989; Sacco et al., 1982; Howard et al., 1989; Klag et al., 1989). It is explained mainly by a better prognosis after intra-cerebral haemorrhage, by increased hypertension control (Broderick et al., 1989; Tuomilehto et al., 1991), and by a better prevention and treatment of complications, especially of cardiac disease. However, the observed mortality decline has started long ago and cannot be fully accounted for by observed changes in risk factors. Most likely, both incidence and case-fatality decline will remain largely unexplained (McGovern et al., 1992; Klag et al., 1989).

This chapter determines the most plausible range of incidence and fatality decline that explains the impressive observed reduction in stroke mortality in the Netherlands by means of a multi-state model (Central Bureau of Statistics, 1985). Next, it shows the projected future changes in stroke incidence and prevalence using the calculated trend values.

5.3. MODEL DESCRIPTION AND VALIDATION

Changes in stroke occurrence and stroke mortality are determined by changes in stroke incidence, survival, recovery, recurrence, and mortality from other diseases. Given this complexity, a mathematical model is indispensable (Weinstein, 1989). We developed a multi-state model that is based on the clinical course of stroke (*Figure 5.1*). Combining data from various sources, the model describes the epidemiology of stroke in the Netherlands. The basic principle of the multi-state model for stroke is that patients move from one particular state to another after experiencing a particular

event (Weinstein, 1989; Tsevat et al., 1991). The likelihood to move from one state to another, a transition probability, is assumed to be independent from the preceding states or events and depends only on the current state defined by disease stage, age and gender during the event (Markov assumption). All probabilities are age and gender specific. There are five-year age groups ranging from 25 years to 90 and over. Risk of death from other causes is accounted for in all states. The model is combined with national population projections to calculate national estimates (Central Bureau of Statistics, 1985). During computation, the model annually generates first incident cases. These enter the respective states within the stroke specific component and follow the various flows with the model. Simultaneously, the model also annually updates all existing prevalent states for recurrences and their consequences.

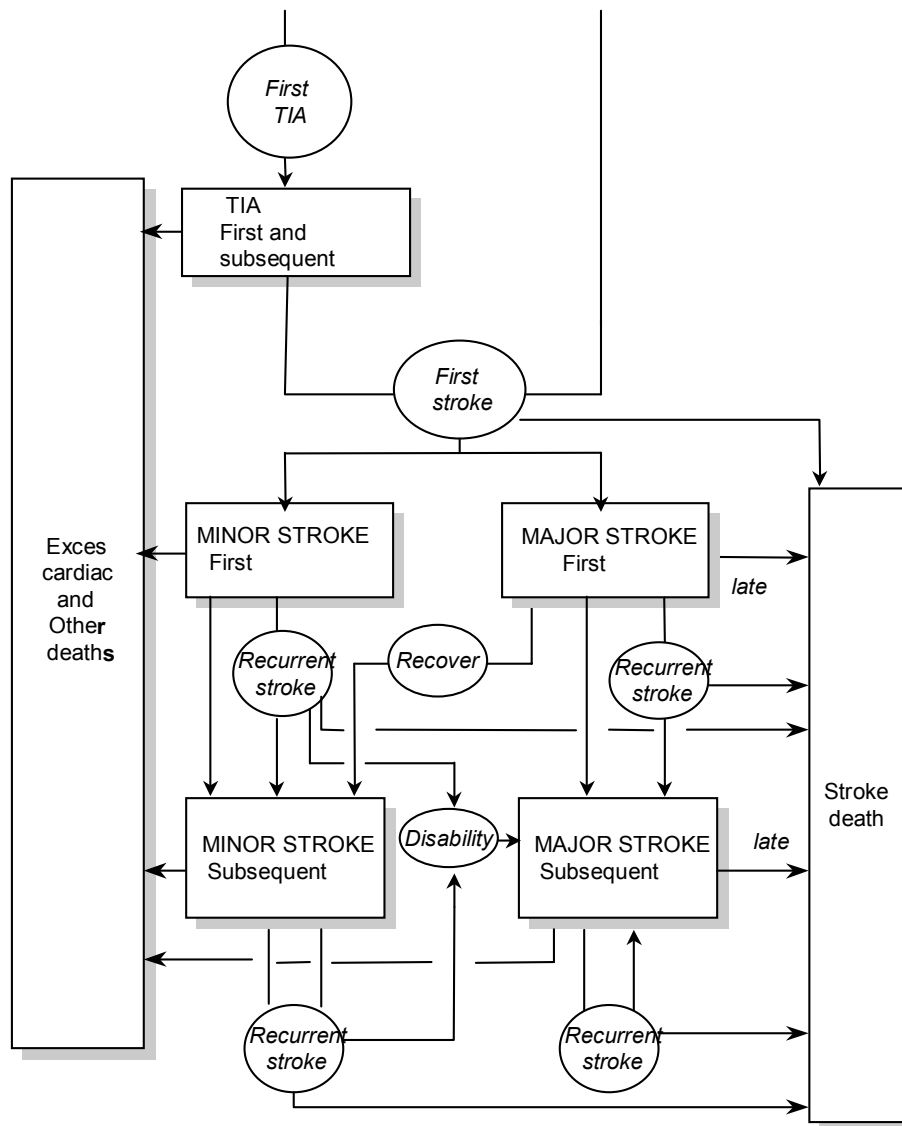


Figure 5.1. Diagram presenting the multi-state model for stroke. Major stroke results in severe disability. The boxes indicate health states; the circles indicate events and the arrows the transitions. Recurrent stroke indicates second or more stroke events.

Within the stroke disease component of the model two events can occur: a transient ischemic attack (TIA) or a stroke, both defined as in the Oxford Community Stroke Project (OCSP; Bamford et al., 1988; Dennis et al., 1989). We distinguished different states for the first year and for all subsequent years together. The flows in the model during the first year and the subsequent years are almost identical, except for recovery. In a TIA state the patient has an increased risk of stroke. After the first year, patients with a history of a TIA enter the "subsequent years" state and run a lower stroke risk. This latter risk is the same for the rest of their lives. A separate first month state after a first stroke allows for the acute phase with a high risk of disability and death. After a first stroke patients enter this state. Patients surviving the first month are left either with a minor or major stroke as defined by a Rankin grade 0-2 and 3-5 (van Swieten et al., 1988), respectively, and are divided up between the two separate states. Patients with a history of stroke run a risk of recurrence. If this occurs, there is an excess risk of dying or having a major stroke. In the first year state for major stroke, some patients recover, defined by Rankin grade 0-2. The recovered patients enter the minor stroke state. The remaining fraction moves to the major stroke state for all subsequent years. Also in both late stroke states the risk are lower and the same for the rest of the years alive. In both major stroke states a patient suffers a delayed death due to a first and disabling stroke.

One model assumption is that in the acute phase almost all deaths can be contributed to the first stroke and only a few to the other causes of death. In this phase, the risk of recurrence and the excess risk of death from heart disease are not accounted for due to an absence of recorded data. Also, a single state for all subsequent years together implies that the recurrence risk in subsequent years state is the same for all following years. This is supported by recent Dutch data (Dutch TIA Trial Study Group, 1991). Next, we do not distinguish strokes caused by intra-cerebral haemorrhage and by cerebral infarction. From a patient-based view, these are different. At the aggregated population level a distinction is less useful as thrombotic infarctions make up more the 80% of all the stroke case (Bamford et al., 1988; Herman et al., 1982). Moreover, the survival after a haemorrhagic stroke is reaching the level of survival after an infarction due to improved prognosis and due to increased detection of smaller and less harmful bleedings (Giroud et al., 1991).

Input data: epidemiology

The origin of the crude epidemiological data used to calculate the base-line input is summarised in *Table 5.1*. We have calculated the age-specific transition probabilities using the results of Dutch population-based studies, if available. If incomplete, they have been used to check selected comparable figures of other Caucasian populations as listed in the table. Relative risks are used when comparing risks for one patient category with another. Ratios are used as transition probabilities without further calculations. The choice of measure depends on the way the data have been made available.

The risk of a first TIA is calculated using the incidence figures from the OCSP (Dennis et al., 1989). Age-specific probabilities are calculated by exponential interpolation and are comparable to data from Dutch primary care practices (NUHI;

vanden Hoogen et al, 1985) and also the Rochester study (Dennis et al., 1990). The relative risks of stroke after a first TIA reported by the OCSP have been interpolated. They are multiplied by the population risks from the Tilburg Epidemiological Study of Stroke (TESS) and the Oxford Project to calculate age-specific absolute stroke risks after a TIA. (Bamford et al., 1988; Herman et al., 1982).

<i>Event</i>	<i>Crude data</i>		<i>Probability 70-74 years</i>	<i>Source</i>
	<i>Measure</i>	<i>Figure</i>		
First TIA	Rate	0.42/10 ³	0.0037/0.0026	Hoogen, 1985; Bamford, 1988
First stroke	Rate	1.62/10 ³	0.012/0.010	Herman, 1982; Bamford, 1988
Death from first stroke	Ratio	0.20	0.21/0.21	Ibid
Major disability after stroke	Ratio	0.39	0.39	Bamford, 1988
Recovery from major stroke	Ratio	0.76	0.22	Meer & Smith, 1990; Bonita, 1988
Recurrent after minor stroke	RR			Hoogen 1985; Dennis, 1989;
first year <75 years		13.2	0.09/0.07	Dutch TIA Trial, 1991
>75 years		4.5		
subsequent years		5.0	0.05/0.04	
Late death from major stroke	Ratio	0.17/0.42	0.15/0.11	CBS, 1985; Howard, 1986 & 1991
	MHR*	1.261		
Death of cardiac disease after TIA / or stroke	RR	3.2	0.038/0.025	Dutch TIA Trial, 1991; Howard, 1986 & 1991
	MHR‡	0.665		
Death of cardiac disease after major stroke	RR §	1.57	0.06/0.04	Howard, 1986 & 1991

Table 5.1. Crude literature data used to calculate base-line transition probabilities by age and sex for the stroke model and the resulting transition probabilities for one patients group (male, 70-74 years). TIA =transient ischemic attack; RR = relative risk; MHR = multivariate hazard ratio; *Risk comparison: age (X+10)/X;‡ risk comparison: women/men; § risk comparison: major/minor stroke.

Probabilities of a first stroke are calculated by averaging the results of the incidence studies by the OCSP and the TESS that have produced similar figures (Bamford et al., 1988; Herman et al., 1982). As the TESS included fewer age groups, the results of both studies are combined to have reliable incidence figures for as many age groups as possible. Results are consistent with the NUHI data (vanden Hoogen 1985). Age-adjusted all stroke case-fatality rates from the TESS study have been corrected for recurrences by assuming a twice as high risk of a stroke death. The resulting case-fatality ratios of the OCSP and TESS are nearly identical (19% and 20%). The probability of residual major disability after one month is assumed to be constant for age and gender (Bonita and Beaglehole, 1988). The recurrence risk for minor stroke patients is assumed the same as the first stroke risk for TIA patients. The ratio of the risk of dying after a recurrence versus the risk after a first ever stroke is 1.5 (Howard, et al, 1986). For the risk of a major stroke after a recurrence, the same ratio is used. Recurrence risk in the subsequent years state after a minor stroke is estimated half the first year risk (Dutch TIA Trial Group, 1991) with the same risk of dying and of major stroke, given the recurrence, as during the first year (Howard et al., 1991).

The probability of recovery from major stroke has been calculated by age group and is the same for both sexes (Herman et al., 1982). In agreement with various studies

(Terent, 1989; Herman et al., 1982; Howard et al., 1986) recurrence risk and subsequent death after major stroke has been estimated by doubling the hazard ratio of the same parameter as found by Howard (1986) for the minor stroke group. Late stroke mortality during subsequent years is half the risk in the first-year state. The recurrence risk in the subsequent years state after a disabling stroke is half the first year risk (Kotila, 1988; Tuomilehto et al., 1991) as assumed for minor stroke.

The excess age-specific risk of death from ischemic heart disease (ICD 410-414) in the prevalent states has been calculated by multiplying the hazard ratios for cardiac death (Bonita and Beaglehole, 1988; Howard et al., 1986) with the age-specific risk of death from ischemic heart disease for the general Dutch population (CBS, 1986).

Risk of death from other causes is calculated using the all causes death rates from the national death registry corrected for the stroke related figures (International Classification of Diseases (ICD) codes 430-438).

The stroke disease model in combination with the demographic data and projections describes the stroke epidemiology for the Dutch population in steady state. It has been presented with fixed transition probabilities. The model estimates stroke prevalence for the baseline year (*Figure 5.4*) after assuming the same probabilities during the preceding years.

The stroke model produces national estimates regarding the stroke epidemiology including first stroke incidence, stroke recurrences as well as stroke mortality and prevalence. *Figure 5.2* shows the model outcome regarding national stroke hospital rates, including both fatal and non-fatal cases, and national stroke mortality rates for the 1985 baseline year. There is a good fit for the age groups up to 80 years between model outcomes and the national data of the same year (CBS, 1986; van der Meer and Smith, 1990): the X^2 for men is 8.10 and 6.37, respectively and for women the X^2 is 6.21 and 8.15 (all P values are larger than 0.5, d.f.= 11). These chi-square values support the validity of the model. The national admission rate (Meer and Smith, 1990) for the 85 year old and over from the hospital registry is lower than the model admission rate, as the latter refers to the age group 85-89 only. The lower model stroke deaths rates of the same age group is most probably due to an over-registration of stroke deaths for this age group in general practice and/or a possible under-registration of incidence in the OCSP and TESS.

The external validation of the stroke model for the Dutch population consists of comparing calculated age- and sex-specific figures on stroke events and mortality to the national empirical figures on acute hospital admissions and stroke mortality. As this study is on long-term survival and costs, we validated calculated major stroke prevalence against nursing home data.

Input data: epidemiologic time trends

The model allows for age-specific time trends for all the transition probabilities depicted in *Figure 5.1*. This allows for plausible projections over longer periods. The value of these trends is calculated by time series analysis of available figures from comparable populations. A trend is defined as the annual percent change, which

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means an exponential change. To calculate this kind of trend, first, a log-transformation is applied. The regression line, through the log-transformed figures

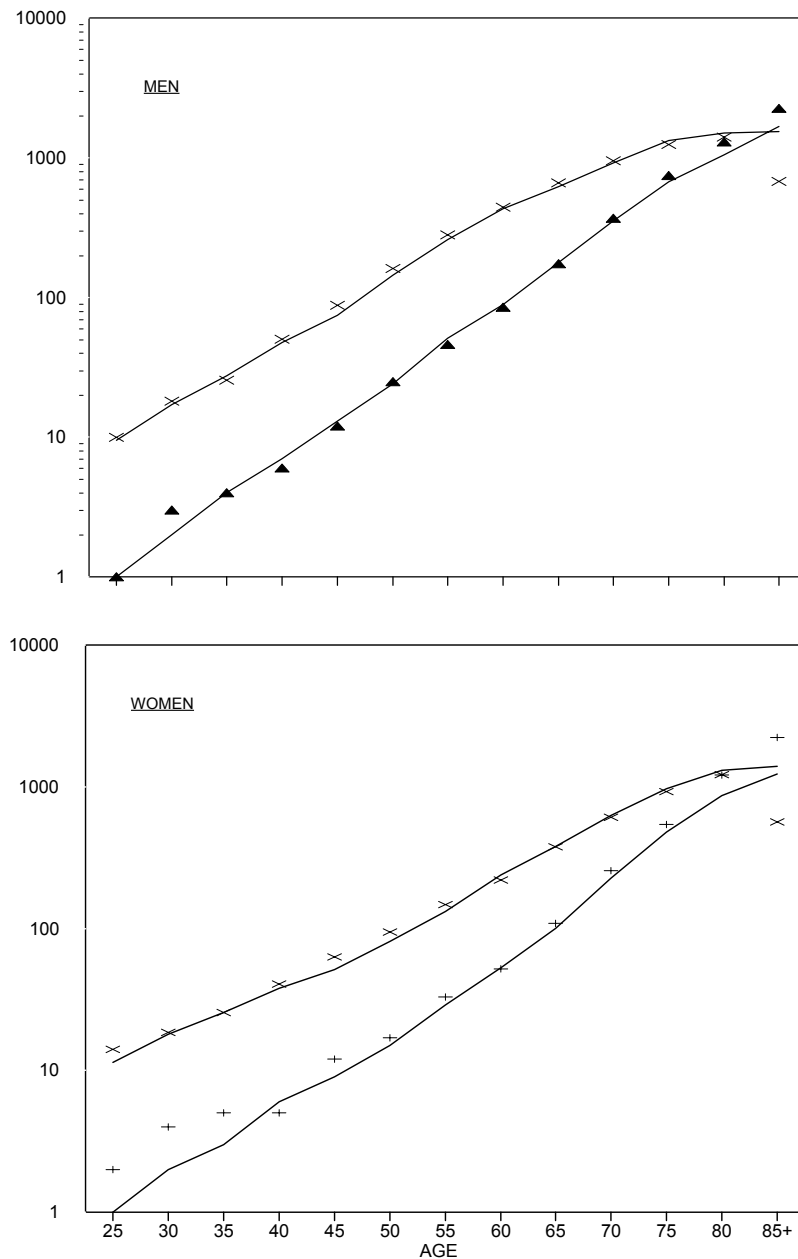


Figure 5.2. External validation of stroke model output: age-specific hospital admission rates (upper curves) and death rates (lower curves) for all strokes, in The Netherlands, 1985 according to national registries (CBS, 1985; Information Centre for Health Care, 1990) (markers) and as calculated by the model (lines). Rates are in 0/000. Model hospital admission rates are based on the model events rates for all strokes together multiplied by age-specific chances of admission (Information Centre for Health Care, 1990).

of each time interval is determined by least squares fit. The regression coefficient, or slope, of this line, is the annual percent change of the time series figures (Bonita et al., 1990). During computation, two sets of trends are used. One set consists of all

"attack" parameters: the risks of a TIA, first stroke, or recurrence. The other set includes all parameters regarding acute and late case-fatality of stroke accounting for the decreasing severity of stroke. This study focuses on the first stroke incidence and case-fatality trends.

These trends in transition probabilities are not very well documented. The Rochester study⁷ is the only study that produces age and gender specific data on the secular changes both in stroke incidence and fatality. We applied the Rochester incidence and case-fatality trends to the respective "attack" and "case-fatality" sets of trends within the model. This can be done as the Dutch incidence figures for TIA and stroke as well as case-fatality ratios over a single two-year period (vanden Hoogen et al., 1985; Herman et al., 1986) agree with comparable Rochester data. We ignored the recent, most likely temporary, incidence increase for Rochester caused by increased case finding because of the introduction of computerised tomography⁷. Trends in the two remaining transition probabilities, the risk of major stroke after stroke, and the chance of recovery from a major stroke are not known and are assumed constant. The application of the Rochester incidence and survival trends appear to reproduce almost identical sex-specific mortality trends as observed in the Netherlands from 1979 to 1989 (Bonita et al., 1990; CBS, 1985) (see table 5.2). This seems logical, as both populations are mainly Caucasian and comparable in most other aspects. Other combinations of trend values for incidence and case-fatality (Kotila, 1988; Howard et al., 1989; CBS, 1986; Garraway et al., 1983; Garraway et al., 1983; Malgren, 1987), however, can also account for the observed mortality decline. The difficulty is that trend values are reported mostly separately from each other and without corresponding overall mortality trend.

Scenario	men				women			
	annual trend (%)		fit		annual trend (%)		fit	
	incidence	case-fatality	X ² *	A [†]	incidence	case-fatality	X ²	A [†]
Upper	1.7	-1.7	1.02	>0.5	-2.3	-1.7	1.08	>0.5
Rochester	-1.9	-1.3	0.46	>0.5	-2.4	-1.3	0.55	>0.5
Lower	-2.1	-1.0	0.71	>0.5	-2.8	-1.0	0.72	>0.5

Table 5.2. Values of annual incidence and case-fatality trends applied in the stroke model as well as the goodness-of-fit of the corresponding model mortality trends with the empirical Dutch national mortality trend for 1979-1989. *Degrees of freedom: 10 (number of age groups-1)*(number of categories-1). † A is a goodness of fit parameter; > 0.5 indicates a good fit.

To solve this we used a two-way sensitivity analysis of incidence and case-fatality trends to determine a plausible range of values (*Figure 5.3*). In the analysis, for each value of one set of trends we calculated the corresponding value of the other set that, in combination, leads to the same mortality decline. Under the condition of a fixed mortality decline, the incidence and case-fatality trends are inversely proportional. When the incidence rates decrease, the case fatality rates have to increase five times as rapidly to outweigh the decreasing mortality decline. The main reason for this is that the case-fatality after a first stroke is 20%. This inverse relation leads to the iso-mortality lines in the figure. The area above the lines includes those values of trends

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that lead to a larger mortality decline. The area below includes the values that lead to a lesser mortality decline. The range of reported values for case-fatality trends is small (Broderick et al., 1989; Tuomilehto et al., 1991). Consequently, it defines a much more narrow range of values for a possible incidence decline than is reported in the literature.

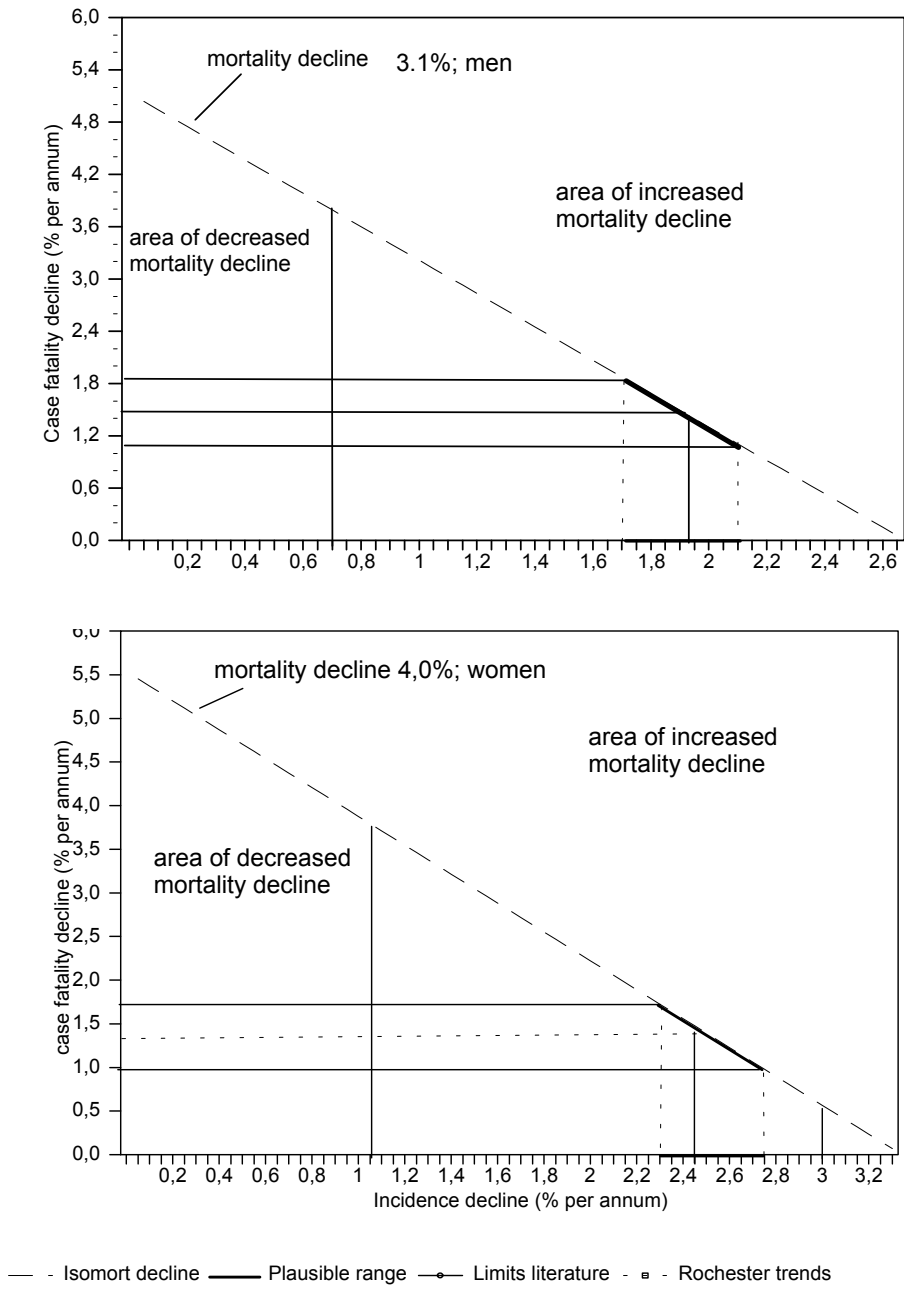


Figure 5.3. Plot of a two-way sensitivity analysis of two variables: the stroke incidence trend and the case-fatality trend. The iso-mortality lines shown are for Dutch men (3.1%) and women (4.0%) during the period 1979-1989. Rochester trends for men and women are plotted as well as the most extreme values for both trends found in the literature. The plausible range of incidence decline falls within the range of values in the literature (Broderick, 1989; Tuomilehto et al., 1991; Alo, 1986; Malgren, 1987).

The two-way sensitivity analysis determines the plausible range of values for the incidence trend that explains Dutch stroke mortality decline, given the reported survival improvement. *Figure 5.4* and *Table 5.2* shows that the values for the incidence trend range between 1.7% and 2.1% per year for men, and between 2.3% and 2.8% per year for women. The figure also demonstrates that, if one supposes no incidence decline⁷ an unreported annual improvement of survival of over 5% would be necessary to fit the observed mortality decline. On the other hand, an incidence decline of over 3%, for men, would, likewise, imply an unreported absence of survival improvement or even deterioration. In *Table 5.2* the results of a goodness-of-fit test of the model mortality trends and the empirical trend are given. This is for three plausible scenario's: one with the highest case-fatality improvement, one with the lowest case-fatality improvement and a Rochester-

like scenario that turns out to be in between these two case-fatality declines. Assuming no incidence decline and the highest known annual case-fatality improvement, the model computes a mortality decline that does not fit to the national figures.

Statistical testing of the results of the computations consists of a comparison of model results with observed national data. A chi-square goodness-of-fit test is used (Kirkwood, 1988; see appendix). An \mathcal{A} value above 0.5 we used to indicate a good fit of the computed results and the observed data. The goodness-of-fit of the model for the age-specific stroke mortality rates and stroke admission rates (first and recurrent strokes together) is given as well as of the trends in the model mortality rates.

5.4. RESULTS

Table 5.3 lists the aggregated model results for 1985 and the relative change of output results for year 2005. Here trend values are used assuming a continuing Rochester-like scenario and, hence, continuing mortality decline. All rates are decreasing and there are no major sex differences. As all attack rates, including risk of recurrence, are assumed to decrease, all stroke rates decrease more than first stroke rates. Due to improved survival, the drop in prevalence rates is considerably less. The projected decline in stroke death rate, is the same as during the past twenty year in the Netherlands (CBS, 1985; Bonita, 1990). This has been the basic assumption of this projection.

Resulting prevalence rates for major stroke are given in *Figure 5.5* and agree with the population-based rates found in Finland and Rochester (Alo, 1986). The same figure also demonstrates the trend dynamics by a step-wise inclusion of the two "attack" and "case-fatality" sets of trends that are based on the time series analysis of the Rochester data. A decreasing incidence of stroke results in decreasing major stroke prevalence and likewise, not illustrated, minor stroke prevalence. This decreasing effect on prevalence is nearly halved by an increase in survival, especially of major stroke patients and, to a lesser extent, of minor stroke and TIA patients who live longer with the risk of suffering a debilitating stroke. The effect of survival improvement on stroke prevalence increases with age. This results in an increase in stroke prevalence among the higher age groups.

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Figure 5.5 shows the projected age-specific absolute changes in prevalence rate over the twenty-year period. The decrease of age specific stroke mortality is largest for persons in their late sixties and seventies (CBS, 1985; Bonita, 1990). Case-fatality decline within these age groups has been limited also (Bonita, 1990), so for these

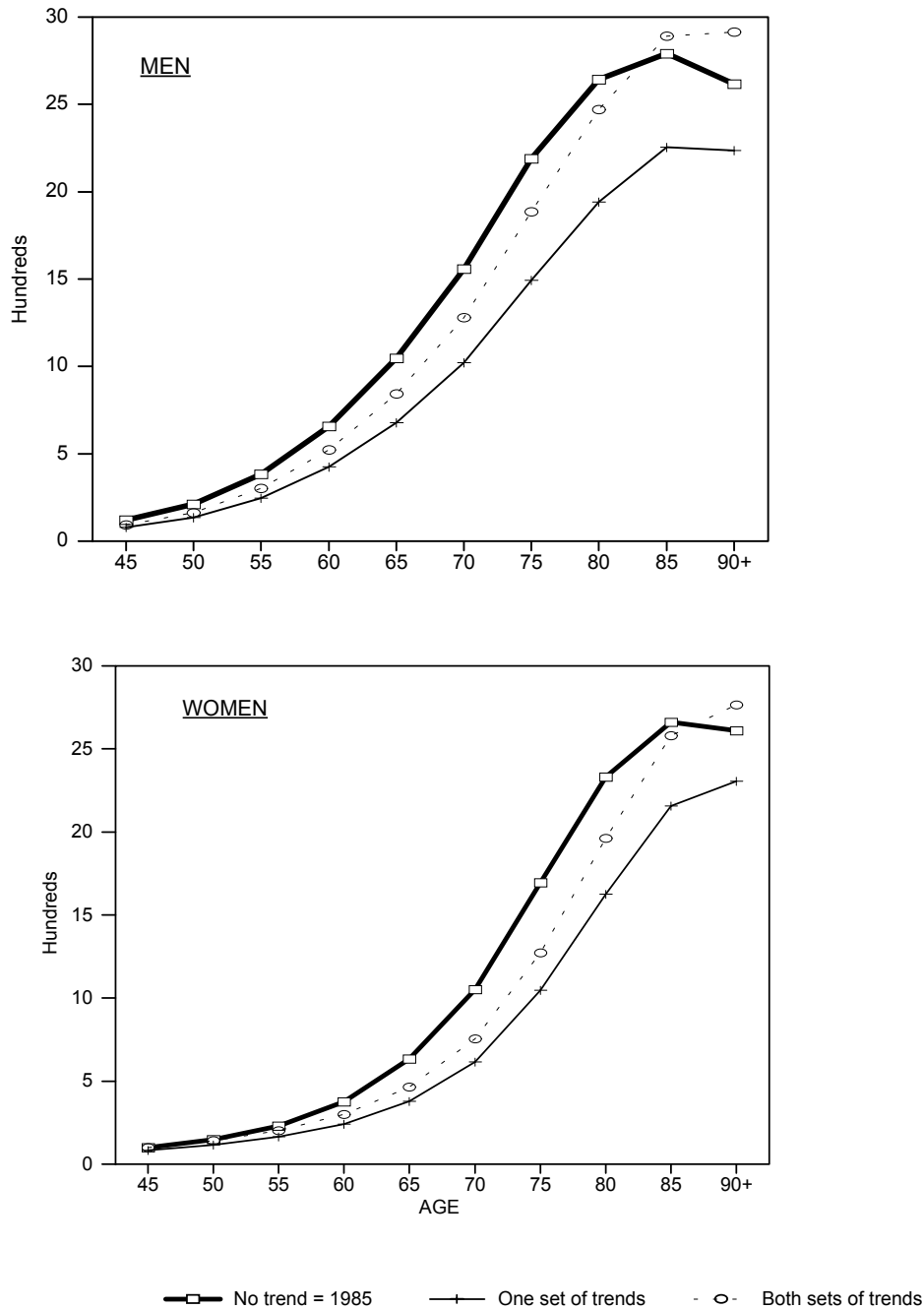


Figure 5.4. Major stroke prevalence rate for 1985 and 2005, by age and sex per 100,000. For 2005, the two runs are shown. During the first run, only the Rochester incidence trend (a decline) is applied to all "attack" parameters. During the second run, the Rochester case-fatality trend (also a decline) on all stroke case-fatality parameters is added.

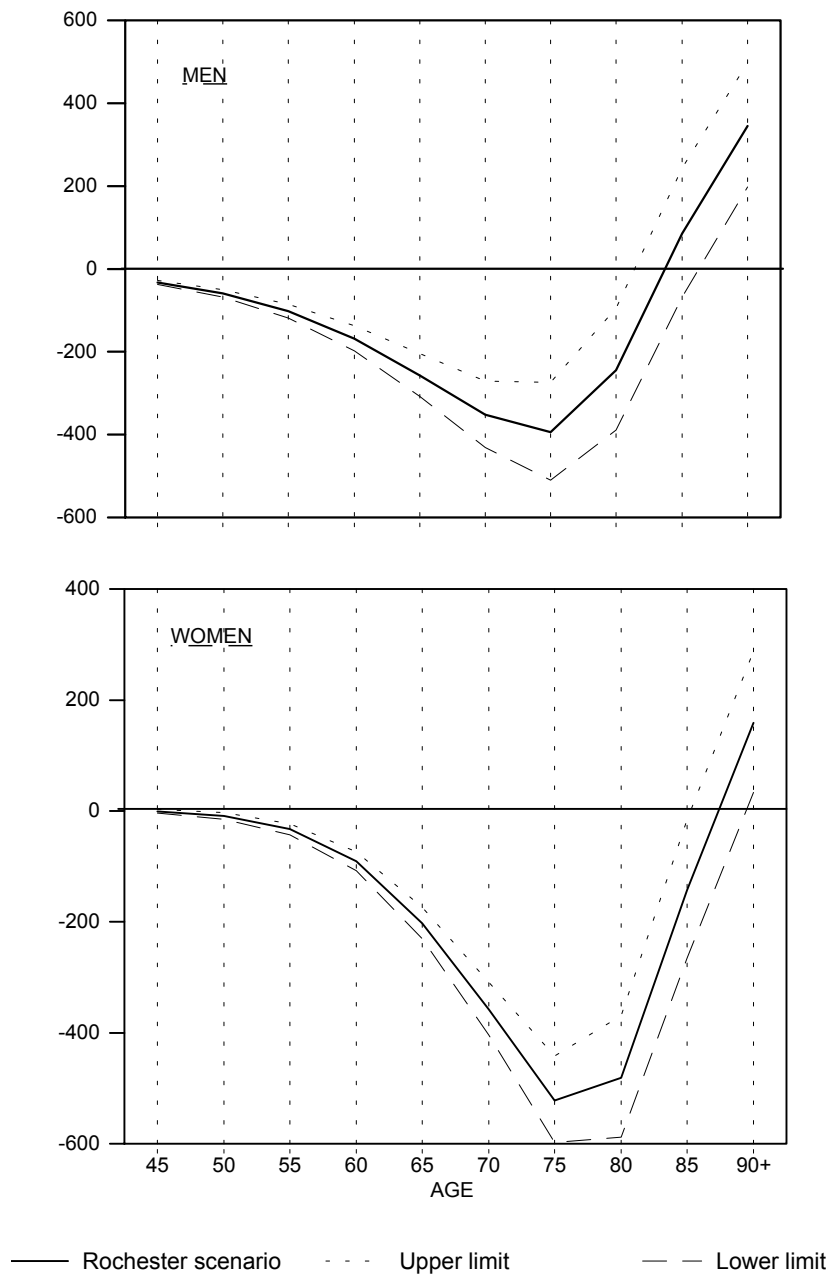


Figure 5.5. Computed absolute difference in stroke prevalence rate in The Netherlands for 1985-2005 by age and sex (per 100,000). The most plausible trends in incidence and case-fatality are assumed i.e. in continuation of a Rochester-like scenario. Upper and lower limits have been calculated using the extreme values of the range of plausible incidence and case-fatality trends (see sensitivity analysis in Figure 5.3)

persons a rather large incidence decline has to be assumed. Consequently, stroke morbidity among these groups is decreasing remarkably, for men at a younger age than for women. Later in life, the increase in survival results in a large increase in stroke prevalence, offsetting a relatively small incidence decline. In the figure, an upper and lower limit of the age specific prevalence changes is given. These limits are determined by the extreme values of the plausible ranges for incidence decline and

case-fatality decline as reported in *Figure 5.4*. A smaller incidence decline results in a smaller prevalence decline among the younger patients and a higher morbidity among the older groups. The resulting prevalence changes in these alternative scenarios, again assuming a constant mortality decline, however, are only slightly different.

The effect of the ageing of the post-war baby boom is shown in the shifts in absolute numbers: less of a decline in all stroke cases and even an increase in prevalent cases. The longer life expectancy of Dutch women is reflected in a smaller decrease of first stroke cases and stroke deaths. In general, the incidence decline outweighs the expected increase in absolute numbers of acute stroke episodes with the aging of the post-war generation. Nevertheless, increased survival increases the absolute number of prevalent cases considerably.

<i>Epidemiology</i>	<i>1985</i>		<i>2005 change %</i>	
	<i>Rates</i>	<i>Numbers</i>	<i>Rates</i>	<i>Numbers</i>
<i>Men</i>				
First strokes	171	10,600	-35	-16
All strokes	224	14,000	-37	-19
First major stroke	67	4,210	-34	-14
Prevalence major strokes	275	17,300	-15	+11
Prevalence minor strokes	700	43,900	-12	+15
Stroke deaths	68	4,170	-46	-30
<i>Women</i>				
First strokes	128	11,200	-36	-9
All strokes	159	15,000	-38	-17
First major strokes	46	4,260	-35	-15
Prevalence major strokes	200	18,400	-17	+8
Prevalence minor strokes	466	41,300	-13	+11
Stroke deaths	51	5,110	-45	-23

Table 5.3. Estimated standardised* stroke rates and absolute numbers† of stroke cases in the Netherlands for 1985. Projected future changes for the year 2005 of standardized stroke rates and absolute numbers of stroke cases relative to 1985, assuming continuing Rochester-like trends.

* European standard population; per 100,000.

† Population projections by Dutch Central Bureau for Statistics (1986).

5.5. DISCUSSION

Downward trends in the occurrence of ischemic heart disease and stroke characterize changes in health within the aging population: reduced disease-specific mortality results in a relatively limited increase in life expectancy but might cause a longer period of severe disability from the same disease (Tsevat et al., 1991). In the case of stroke, the major question is whether declining mortality rates are resulting in a, paradoxically, increasing burden of disease, especially among the oldest. The answer depends on whether one supposes mortality and morbidity to be compressed against an alleged fixed biological upper limit to the life span, or whether one supposes a mortality

decrease in the oldest age groups and a parallel expansion of morbidity. In the former scenario health care provision results in a decrease of morbidity but in the latter it may well result in an increase of chronic morbidity.

Our analysis is based on empirical data from different sources. None of the large population-based studies, or clinical trials have been comprehensive enough to be able to assess the extent of incidence decline and survival improvement in relation to stroke mortality decline. The results show a plausible range of a considerable incidence decline for the Netherlands. As mortality decline in the USA has been much higher (CBS, 1985), incidence decline, most likely, has been higher also. For the Netherlands, consequently, *Figure 5.5* confirms a most likely scenario for stroke with a compression of morbidity in the near future, but with an increase of major stroke prevalence among the very old. At a younger age dominant incidence decline results in a decrease in morbidity. For the oldest age groups, however, the decrease in case fatality is larger than the calculated incidence decline and, hence, the resulting mortality decrease is small i.e. about 1% annually (CBS, 1985). At these ages the result is, indeed, a trade-off of stroke mortality for morbidity. The projected changes in morbidity are supported by recent observations: age-adjusted admission rates for stroke are decreasing in the Netherlands (van der Meer and Smith, 1990) and definitely also in the USA among whites (Centers for Disease Control, 1992). In both countries the average age of stroke patients is increasing (van der Meer and Smith, 1990; Centers for Disease Control, 1992). In the Netherlands, the average age of patients admitted to long stay institutions, indicative for the prevalence of major stroke is increasing as well as the average disability score (van der Meer and Smith, 1990). This confirms the changes towards higher major stroke prevalence among higher age groups as reported in *Figure 5.5*. Similarly the average stay of severely disabled in nursing institutions is increasing and, consequently, the Dutch mortality statistics are showing a parallel increase of late cerebrovascular deaths (ICD code 438) among the oldest⁶. The increased institutionalisation is not explained by social factors, as the intensive home care programme has been expanding the last five years to cope with waiting lists of chronic patients with major stroke⁶.

Next to incidence and survival, stroke morbidity rates are determined by the risk of residual disability after stroke and the chance of recovery. In this respect, some groups are running larger risks after a stroke due to concomitant debilitating diseases like cardiovascular heart disease or due to other risk factors, like hypertension. Ongoing empirical studies, it is hoped, may be able to answer questions regarding stroke trends in these patient groups now that their survival is improving^{35,36}. In addition, empirical studies will have to answer related questions on co-morbidity and disability from other diseases among the aged.

An important question is whether stroke mortality will continue to decline. As most of the mortality decline is unexplained, nobody can be sure about the answer. The stroke model does not answer this question either. In fact, the early nineties have shown a flattening of the mortality decline for all ages. This probably is a period effect, so far unexplained. In its projections we have assumed continuing mortality decline, as this decline has been very constant in the Netherlands. Our model demonstrates the dynamics of stroke morbidity change. Both in the Netherlands and the USA there are still benefits to be gained from large-scale hypertension control (Casper et al., 1992;

McGovern et al., 1992; Gunning-Schepers, 1989; Dyken et al., 1984) and reduction of smoking (Tsevat et al., 1991; Gunning-Schepers, 1989; Dyken et al., 1984). Better intervention possibilities might further improve prognosis. Population benefits from recurrence prevention are limited, because of the relatively high first stroke fatality and relatively low recurrence risk. The effects of increasing cardiac disease prevention and treatment are already evident and will further increase survival.

The influence of demographic changes differs between the Netherlands and the USA. Stroke prevalence will increase less in the USA, due to a less extreme aging of the population. For blacks, stroke incidence and morbidity rates are higher. However, for this group mortality decline parallels the decline for whites⁴. With a mortality trend of the same magnitude, similar dynamics in stroke morbidity might be taking place. These issues can only be dealt with after including population-specific transition probabilities and demographic and epidemiological trends in the state-event model, which is possible.

In conclusion, this study supports evidence of a further decline in stroke incidence. It also supports the observation (Malmgren et al., 1989) that a further improvement of survival of higher age groups due to therapeutic interventions may result in a longer period of severe disability before death. The findings are of importance for setting health care priorities regarding the aged, especially regarding the nursing needs of stroke patients during the acute, rehabilitative and chronic phase of their illness.

APPENDIX

Testing the goodness-of-fit Age-specific computed stroke figures are compared with the national registry figures. This is done by using the standard formula for the chi-square test for larger tables: $X^2 = \sum ((O - E)^2 / E)$, $d.f. = (C-1)$ (Kirkwood, 1988). Here O represents the observed figure in both groups of data and E the expected figure. E is based on the calculation $(R * N)/T$ where R is the sum of the computed and the registry figure for the age group involved, N is the total of all age groups, and T the total for all age groups of the computed and registry figures together. C is the number of age groups. The number of degrees of freedom is the product of the number of age groups minus 1 and the number of categories (i.e. computed and observed) minus 1.

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