The future health (care) burden of chronic diseases in the Netherlands
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Modeling the Future Burden of Stroke in the Netherlands Impact of Aging, Smoking, and Hypertension
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Chapter 5

Modeling the Future Burden of Stroke in the Netherlands Impact of Aging, Smoking, and Hypertension


Abstract

Background In the near future, the number of stroke patients and their related healthcare costs are expected to rise. The purpose of this study was to estimate this expected increase in stroke patients in the Netherlands. We sought to determine what the future developments in the number of stroke patients due to demographic changes and trends in the prevalence of smoking and hypertension in terms of the prevalence, incidence, and potential years of life lost might be.

Methods and data A dynamic, multistate life-table was used, which combined demographic projections and existing stroke morbidity and mortality data. It projected future changes in the number of stroke patients in several scenarios for the Dutch population for the period 2000 to 2020. The model calculated the annual number of new patients by age and sex by using incidence rates, defined by age, sex, and major risk factors. The change in the annual number of stroke patients is the result of incident cases minus mortality numbers.

Results Demographic changes in the population suggest an increase of 27% in number of stroke patients per 1000 in 2020 compared with 2000. Extrapolating past trends in the prevalence of smoking behavior, hypertension, and stroke incidence resulted in an increase of 4%.

Conclusions The number of stroke patients in the Netherlands will rise continuously until the year 2020. Our study demonstrates that a large part of this increase in the number of patients is an inevitable consequence of the aging of the population.
Introduction

Stroke is a major disease in aging societies. Not only the disease impact, but also the health care impact of stroke is substantial (1-3). Stroke mortality is the third largest cause of death in the Netherlands. Overall, 8.5% of the deaths in the Netherlands in 2001 was caused by stroke (4). As in most other developed countries, in the 1970s and 1980s a substantial decline in stroke mortality was observed in the Netherlands (2,5,6). Between 1974 and 1986 the annual stroke mortality dropped by 2.7% for men and 3.6% for women (6). From 1990 onwards, the decline in mortality rates has leveled off. Stroke incidence rates have been stable since the 1980s (7). Likewise, the prevalence rates of stroke in the Netherlands have been stable over the last decade, although they show a slight increase in the last years (7).

For health policy it is important to have insight into the (future) trends in morbidity and mortality as it enables priority setting in health care. It is particularly important in countries with an aging population, like the Netherlands. Insight into the future number of stroke patients allows health care policymakers to make rational decisions about related health care needs, to plan the health care facilities of stroke patients in the medium term and long term and to develop preventive measures for specific target groups and can lead to new priority setting regarding the prevention and health care organization of stroke.

The future burden of stroke in the Netherlands has been previously studied and future changes in stroke epidemiology were projected for the period of 1985 till 2005 by using calculated trend values based on data of 1979 till 1989 (8). However, from approximately 1990 onwards the calculated decline in stroke mortality and stroke incidence rates started to diverge from the observed trends in stroke mortality rates and stroke incidence rates. The divergence between the projections by Niessen et al. (8) and the observed trends over the period 1985 and 2005 can be explained by an unexpected leveling off of the decline in mortality rates and stroke incidence rates. Furthermore, the study by Niessen et al. (8) did not include trends in stroke risk factors (such as hypertension and smoking) in estimating the future number of stroke patients.

Hypertension is the most important modifiable risk factor for stroke for both men and women (9-11). A reduction of 10-12 mm Hg of the systolic blood pressure and of 5-6 mm Hg of the diastolic blood pressure result in a reduction of 38% in the stroke incidence rates (12). Smoking is another major risk factor for stroke (13-15). In a meta-analysis, the overall relative risk of stroke associated with smoking was 1.5 compared to non-smoking individuals (14). Therefore, a study investigating the future burden of stroke should pay attention to the effect of changes in the prevalence of the major risk factors of stroke in the population, besides the demographic changes.

The purpose of this study is to estimate the effects of aging of the population together with changes in trends in major risk factors for stroke (i.e. hypertension and smoking) in the Dutch population for the year 2000 till 2020 in terms of incidence, prevalence and potential years of life lost (PYLL).

Methods

Model

A dynamic multistate life-table is used to estimate future stroke incidence, prevalence and mortality in the Dutch population over the period 2000-2020. An earlier version of the model was used to forecast the future burden of chronic obstructive pulmonary disease (COPD) (16-18). A full description of the model is in appendix 5.1, which is available from the first author.

The model calculates the annual number of new patients by age and gender by using incidence rates, defined by age, gender and major risk factors (hypertension and smoking). In the stroke model, demographic data, relative risks and transitions probabilities are used. The input data of the model consist out of age- and sex-specific population numbers, age- and sex-specific input data on
incidence rates, prevalence rates and case fatality rates which are estimated by using various sources. In addition, age- and sex-specific input data, relative risks and transition probabilities for hypertension and for smoking in the Dutch population were estimated. The input data, relative risks and transitions probabilities are described in appendix 5.2, which is also available from the first author.

In Figure 5.1, the basic structure of the model is schematically presented. The boxes represent specific health states in the model and the arrows represent transitions (e.g. changes in smoking behavior or transitions from disease free to stroke). The change in the annual number of stroke patients is the result of incident cases minus mortality numbers. Mortality consists of stroke mortality and mortality due to other causes. We calculated the potential years of life lost (PYLL) due to stroke for each age group (5-year age classes) by multiplying the number of deaths by the difference between mean life expectancy in each age and gender group and the mean age at death in each age and gender group. Potential years of life lost correspond to the sum of the products obtained for each age and gender group.

**Scenarios**

To estimate future number of stroke patients, we formulated the following five scenarios:

1. A **baseline scenario** in which the incidence and prevalence figures for the year 2000 are calculated. This baseline scenario will be used as reference scenario.
2. A **demographic scenario** in which the future prevalence of stroke only depends on demographic changes, while assuming that age- and gender- specific incidence rates remain at their 2000 levels. The projected changes in prevalence therefore reflect only the impact of changes in the composition and size of the population.
Given the aging of the population in the Netherlands, the demographic changes are taken into account in each of the following scenarios.

3. A hypertension scenario in which the age- and gender-specific incidence rates depend on the past trends in prevalence of hypertension. Future hypertension prevalence is calculated by means of trend exploration.

4. A smoking scenario in which the age- and gender-specific incidence rates depend on the trend in smoking prevalence. Future smoking prevalence is based on trend exploration.

5. A combined hypertension and smoking scenario in which both risk factors are simultaneously taken into account.

Scenario 2-5 are based on the middle variant of the demographic prognosis of Statistics Netherlands (4). The results of the scenarios will be presented in terms of incidence, prevalence and potential years of life years lost (PYLL).

**Sensitivity analysis**

In the combined hypertension and smoking scenario, the most elaborated scenario, we assessed the univariate sensitivity of the key variables related to: 1) incidence, 2) prevalence, and 3) case fatality rates. In addition, we performed multivariate analyses to test the outside plausible range of the future number of stroke patients. We adjusted all assumptions in the same direction to create a best-case and worst-case scenario.

**Results**

**Incidence**

Figure 5.2 shows the number of incident stroke patients in 2000 (baseline scenario) and the four scenarios for 2020 for men and women, expressed as the number of patients per 1,000.

![Figure 5.2: Stroke incidence in 2000 and projections for 2020 in different scenarios for men, women and the total population, the Netherlands](image-url)
The incidence of stroke in the year 2000 was 1.8 per 1,000 for men, 2.5 per 1,000 for women, and 2.2 per 1,000 for the whole population (baseline scenario). Based on changes in the size and composition of the population in the demographic scenario the incidence will increase to 2.3 (+27%), 2.7 (+6%) and 2.5 (+15%) per 1,000 for men, women and the whole population respectively, by the year 2020.

The figure shows that the effects of trends in the prevalence of hypertension are relatively small, and result in similar incidence figures of 2.4, 2.6 and 2.5 per 1,000 for men, women and the whole population, respectively. Adding the trend in smoking prevalence to the demographic scenario, the incidence figures are estimated at 2.3, 2.8 and 2.5 per 1,000 for men, women and the whole population respectively, for the year 2020. Projections in the smoking and hypertension scenario result in incidence figures of 2.3, 2.8 and 2.5 per 1,000 for men, women and the whole population respectively. The incidence rate for men will increase more than for women. Hence, the total effects of the demographic changes and the changes due to the trends in hypertension and smoking behavior in the population result in an increase of the incidence per 1,000 of 17% for the whole population. The incidence rate for women is expected to rise till about 24,000 incidence cases by the year 2020 and till about 20,000 incident cases for men if all risk factors are taken into account.

**Prevalence**

Figure 5.3 shows that the prevalence of stroke in the year 2000 was estimated at 7.7 per 1,000 for men, 7.2 per 1,000 for women and 7.5 per 1,000 for the whole population respectively. The prevalence was estimated at 118,500 (60,500 for male and 58,000 for female). In the demographic scenario, the prevalence rate per 1,000 is estimated to have increased to 8.2, 8.9 and 8.6 per 1,000 by the year 2020. The prevalence rates per 1,000 for women will increase more than for men. This difference is due to the higher number of women in the higher age classes than men during the aging process in the coming 20 years in the Netherlands.

![Figure 5.3: Stroke prevalence in 2000 and projections for 2020 in different scenarios for men, women and the total population, the Netherlands](image-url)
When the trends in the prevalence of hypertension and smoking are also taken into account, the prevalence rate per 1,000 will increase to 8.7 per 1,000 by the year 2020 (risk factor scenario). The effects of the major risk factors on the prevalence figures are fractional small compared to the effects of the demographic changes. In total, the prevalences increase to 71,000 stroke cases for men and to 81,000 stroke cases for women by the year 2020.

**Potential years of life lost**

Figure 5.4 shows the potential years of life lost (PYLL) for the year 2000 to 2020 for the combined smoking and hypertension scenario including the changes in size and composition of the population. Based on our input data, in 2000 almost 250 thousand life years were lost owing to premature death among patients with stroke. The projection in the combined hypertension and smoking scenario leads to an increase of approximately 30% to 335 thousand years of life loses by the year 2020. Compared with the general population, a female stroke patient loses on average 8.9 year of life expectancy, whereas a male stroke patient loses on average 8.4 year of life expectancy (not shown in Figure 5.4).

![Figure 5.4: Life years lost due to stroke for men, women and total population, the Netherlands, 2000-2020](image-url)
Sensitivity analysis
We found that the estimates of the future number of stroke patients were not particularly sensitive to variations in the rates of case fatality and changes in transition rates, in the prevalence of hypertension, and in smoking prevalence. The single effect of a 10% change in transition rates for hypertension or smoking was at most 2% in incidence, prevalence and mortality. A 10% decrease in case fatality rates for all age and gender classes resulted in an increase of 8% in the total number of prevalent stroke cases in 2020. The future number of patients estimates appeared to be more sensitive to variations in the incidence and prevalence rates of stroke in the Netherlands. When applying the lowest incidence and prevalence stroke rates from the Dutch GP registrations (19) in the combined hypertension and smoking scenario, the effect is a 20% decrease in the total number of stroke incident cases and an 18% decrease in prevalent stroke cases by the year 2020. However, when applying the highest incidence and prevalence stroke rates (20), the incidence and prevalence will increase with 19% and 16%, respectively.

Discussion
This study aimed to predict the future burden of stroke in the Netherlands. Besides the effects of demographic changes, we estimated the effects of trends in two major risk factors for stroke, i.e. hypertension and smoking, in terms of incidence, prevalence and life years lost.

The dynamic multistate life-table approach demonstrates that changes in the size and composition of the population result in an increase of stroke incidence from 1.8 per 1,000 in 2000 to 2.3 per 1,000 in 2020 for men (28%) and from 2.5 per 1,000 to 2.8 per 1,000 for women (12%). The stroke prevalence was also estimated to increase substantially in the near future, i.e. from 7.7 per 1,000 in 2000 to 8.2 per 1,000 for men (7%) and from 7.2 per 1,000 to 8.9 per 1,000 for women (24%).

The trend in prevalence of hypertension has a fractionally smaller effect on both incidence and prevalence for both men and women. The input data of hypertension may have contributed to the marginal effects on the future number of stroke patients. Patients who use antihypertensive medication are no longer defined as hypertensives when normal blood pressure levels are achieved in our input data. Therefore, current improved detection and treatment of hypertension control may have diminished the effect of hypertension. The trend in smoking prevalence in the Dutch population has also a relatively small effect on the future number of stroke patients in the medium term. This is caused by the large time lag between the decrease in smoke prevalence in society and its effect on stroke incidence rates. Current high stroke prevalence rates for men and lower prevalence rates of women are mainly due to past trends in smoking behavior. The higher increase of stroke prevalence rates for women in 2020 in our projections are due to past smoking behavior, with women showing a smaller decrease in smoking prevalence than men in the last few decades.

Combining the effects of the trends in hypertension prevalence and smoking prevalence results in an additional increase of 4% in stroke prevalence in 2020. Our model projection shows that the slightly advantageous effects of the trend in prevalence of hypertension in the Dutch population are overshadowed by the adverse effects of the trend in prevalence of smoking in the Dutch population, especially in women.

Our model demonstrates that the increase in prevalence is associated with an increase of life years lost of more than 30% in the period 2000 to 2020. The annual amount of life years lost increases with a stable percentage in each different time period.
Comparing our results over the period 2000 till 2020 with the results of the earlier study (8) for the period 1985 till 2005 reveals that they differ considerably for the stroke incidence rates. Niessen et al. projected for the period 1985-2005 a decline of 19% in absolute numbers of stroke incident cases for men (current study: an increase of 28% per 1,000 between 2000-2020 which corresponds with an increase of 39% in absolute incident stroke numbers) and about a 17% decline for women (current study: increase of 12% per 1,000 between 2000-2020 which corresponds with an increase of 20% in absolute incident stroke numbers). Niessen et al. estimated an annual decline in stroke incidence rates based on calculated trend values, but empirical data till the year 2000 do not confirm this decline (7). Also, the effects of the ongoing aging of the population are different for the two time periods (1985 till 2005 versus 2000 till 2020) which in turn leads to different effects on the number of incident stroke cases. Finally, the effects of trends in risk factors as accounted for in the current study result in a growing number of stroke patients. However, these effects do not have a great impact on the future number of new stroke patients.

Our study predicts an increase in stroke prevalence rates of 24% per 1,000 for women, which corresponds with an increase of 40% in absolute prevalence rates. This increase is twice as large as the increase predicted by Niessen et al. (8) (an increase of 19%). However, the increase in prevalence rates for men in current study (an increase of 7% per 1,000 which corresponds in an increase of 18% in absolute stroke numbers) is comparable with the results of Niessen et al. (an increase of 25%). The larger increase in women observed in our study is related to the different number of incident cases and the differences in stroke mortality rates used in the two studies. Niessen et al. (8) predicted an annual decline in stroke mortality rates, but this prediction has not been confirmed by the empirical data (7). The study of Niessen et al. (8) did not calculate the potential years of life lost, so a comparison with current study can not be made.

Some remarks need to be made. In our model, assumptions have to be made to fill gaps in knowledge. However, when applying the maximum and minimum values of the most sensitive variables, the projections in our model are robust in terms of incidence, prevalence and life years lost. Using the Dutch GP registrations, we were limited in our ability to specify the subtypes of stroke. The Dutch GP registrations do not allow a specification of subtypes of stroke as they do not differentiate between ischemic stroke and hemorrhagic strokes. In reality the risk profiles of ischemic stroke and hemorrhagic strokes differ, although hypertension and smoking are common risk factors for both ischemic and hemorrhagic stroke (15;21-23). Differences between stroke subtypes may play an important role in projecting and understanding the dynamics of the future stroke morbidity and mortality. Furthermore, recent figures of the prevalence of hypertension in the Dutch population are lacking. Therefore, we used the most recent data available. Varying the prevalence rates of hypertension in our sensitivity analysis, hardly effects the results in terms of incidence, prevalence and life years lost change very little.

The number of stroke patients in the Netherlands will rise continuously until the year 2020. Our study demonstrates that a large part of this increase in the number of patients is an inevitable consequence of the aging of the population. The increase in prevalence is larger for women (40%) than for men (18%). For the medium term, the increase in prevalence is marginally explained by expected changes in smoking behavior and changes in the prevalence of hypertension. Only a reduction of smoking and hypertension rates in the population will substantially reduce the prevalence of stroke in the long run. Such a population based approach will be more effective in reducing the prevalence of stroke in the long run than current prevention strategies which are only focused on individuals with high risks.
Despite our conclusion that a large part of the increase in stroke patients is inevitable, we still believe that more attention should be paid to primary prevention. New priority setting regarding primary prevention of stroke is necessary in order to reduce the number of stroke patients in the long run.

References
Appendix 5.1: Formal description of the stroke model

**Stroke model**
The stroke model is a dynamic multi-state life-table based on the life-table method. The model has a Markov property. This means that the likelihood of moving from one particular state to another state is independent from the preceding state and depends only on the present state defined by disease state, sex and age (1). As a consequence, all relevant information for the transition probabilities has to be included in the present state. Hence, the influence of duration and past disease history is to be ignored in the model (2).

The most important assumptions of the model are:

- **Conditional independence between transitions**
  Conditional of the risk factor class, the different transition rates are assumed to be mutually independent, i.e. that when a transition rate is changed, the other transition rates remain the same. Thus, the mortality rate of stroke patients does not depend on their risk factor, for example whether or not they have hypertension.

- **Homogeneity within states**
  Irrespective of duration of stay in current state and past disease history and previous states all persons have the same transition rate to go to another state within one state. In real world this will not be the case. A person who has been in a state for a long time, will have a higher transition probability than someone who just entered the state.

- **Constant transition rates**
  It is assumed that the probability rates are constant over time (stability assumption). In reality there will be some time trends. The stroke model allows for adjustment for time trends.

The stroke model is basically a combination of a demographic model and a disease model. For every one-year time step the demographic model calculates the mortality and migration (and birth) for different (sub)populations.

The demographic model is in formula:

\[ POP_{t+1} = POP_t - MORT_t + MIGR_t + B_t \quad (1) \]

where \( POP_t \) represents the population numbers at the end of year \( t \), \( MORT_t \) represents the number of death due to stroke or other causes of death during year \( t \), \( MIGR_t \) represents the net migration during year \( t \), and \( B_t \) represents the number of newborns in year \( t \). The latter are irrelevant for the stroke model because stroke is a disease of the elderly.

**Estimation of the mortality**
Total mortality in the population is made of two mortality rates: stroke mortality and mortality due to other causes. Formally the total mortality is

\[ MORT_t = MORT_{stroke} + MORT_{other} \quad (2) \]
Where $MORT_s$ is representing the case fatality and $MORT_{other}$ is representing the number of death due to all other causes of death among the disease-free population. The case fatality is again divided into two mortality rates: the ‘acute case fatality’ and the ‘long term case fatality’ and is calculated as:

$$MORT_s = CF_a \times INC_t + CF_c \times PREV_t$$  \hspace{1cm} (3)

Where acute $CF_a$ is the case fatality rate during the first year after the onset of stroke, $INC_t$ is the incidence of stroke during year $t$, $CF_c$ is the yearly case fatality rate after the first year after the onset of stroke, and $PREV_t$ is the number of stroke patients of year $t$. The case fatality rates of stroke are estimated on data of 760 hospitalized stroke patients from the Research On Stroke Amsterdam study (ROSA). For detailed information of the study we refer to (3;4).
The curve estimation of the case fatality rates per day in ROSA is

$$CF_t = -31 + 474 \times \frac{1}{(t+20)} + 6 \times \log(\text{age}) - 88 \times \frac{\log(\text{age})}{t+20}$$  \hspace{1cm} (4)

Where $t = \text{days after the onset of the stroke}$ and $\text{age}$ is the age at the onset of the stroke.

This formula enables us to calculate the case fatality rate after 365 days specified for age. A lot of studies have reported case fatality rates and these rates have a wide variation (5-12). We made a pooled estimate of the case fatality found in the literature in order to compare the case fatality with our estimate of the case fatality rates. After adjustment for age the case fatality rates of the ROSA study were slightly higher than the case fatality rates reported in the literature.

Note that $MORT_{stroke}$ is representing the mortality among stroke patients and not only the mortality among stroke patients due to stroke. Stroke patients who die from other causes than stroke are also counted as case fatality. The ROSA data do not allow us to know the cause of death of the stroke patients. It is highly likely that the vast majority of deaths among stroke patients is due to the consequences of stroke.

The mortality numbers for the disease free population due to other causes is calculated as:

$$MORT_{other} = mort_{other} \times (POP_t - INC_t - PREV_t)$$  \hspace{1cm} (5)

where $mort_{other}$ is the mortality rate for all other causes. The $mort_{other}$ is derived from the cause-of-death registration of Statistics Netherlands (13). The cause-specific mortality rates were obtained for the total population. The stroke mortality is subtracted from the overall mortality. Formally the overall mortality per 1,000 is defined as:

$$mort_{other} = \frac{N_{overall \ mort}}{POP_t} - \frac{N_{stroke \ mort}}{POP_t}$$  \hspace{1cm} (6)

where $N_{overall \ mort}$ is the total number of deaths in the Netherlands in 2000 and $N_{stroke \ mort}$ is the total number of stroke deaths in the Netherlands in 2000.
**Estimation of the stroke prevalence**

The model describes the changes in disease prevalence numbers over time specified by age and gender. The prevalence numbers change due to stroke incidence, mortality and recovery. Annual changes of prevalence are calculated as:

\[
PREV_{t+1} = PREV_t + INC_t - MORT_{stroke,t} - REC_{stroke,t} \quad (7)
\]

with \(PREV_t\) representing the number of stroke patients at the end of year \(t\), \(INC_t\) representing the incidence of stroke during year \(t\), \(MORT_{stroke,t}\) representing the case fatality during year \(t\), and \(REC_{stroke,t}\) representing the recovery of stroke patients during year \(t\).

In the model there is the possibility that stroke patients go from a disease state to a non-disease state. However, we assume that no stroke survivors will return to the non-disease state. Therefore, the recovery rate in the stroke model is assumed to be zero. The annual changes of stroke prevalence in the model is:

\[
PREV_{t+1} = PREV_t + INC_t - MORT_{stroke,t} \quad (8)
\]

**Estimation of the stroke incidence**

The incidence rate of non-smokers is defined as the number of cases per 1,000 people from the GP registration specified by age and gender. The incidence rates of smoker and former smokers are expressed as the incidence rate of non-smokers multiplied by a relative risk. The relative risk of non-smokers equals one. The incidence risk of non-smokers is calculated as the total observed incidence divided by the sum of relative risks multiplied by the relative sizes of all smoking classes.

Formally, the incidence rate of a smoking class \(k\) with a given age and gender is:

\[
INCs\ (k) = INC_{non} * rr(k) \quad (9)
\]

\[
INC_{non} = INCs/ \sum_k pop(k) * rr(k) \quad (10)
\]

with \(INCs\ (k)\) being the incidence rate for smoking class \(k\) expressed as the number of cases per 1,000 people in the group, \(INC_{non}\) the incidence rate of the non-smokers also expressed as rate per 1,000, \(pop\ (k)\) the fraction of people belonging to the smoking class \(k\) per 1,000 in the group, and \(rr(k)\) is the relative risk of smoking class \(k\) compared to non-smokers.

For calculating the incidence rate for hypertensive people the same procedure is used. The incidence rate for hypertensive people is expressed as the incidence rate of non-hypertensives multiplied by a relative risk. As a consequence the relative risk of the non-hypertensives is one. The relative risk of the hypertensive people is derived from the literature (14-17). The incidence rate of people with hypertension is

\[
INCh = INC_{nh} * rr(h) \quad (11)
\]

where \(INCh\) is the incidence rate per 1,000 for the hypertension class, \(INC_{nh}\) is the incidence rate per 1,000 for people with no hypertension. Note that for non-hypertensives the \(rr(h)\) is again 1, so the \(INC_{nh}\) for non-hypertension equals \(INC_{nh}\).
The incidence rate for hypertensive smokers slightly differs from the previous formulas. The incidence rate for people in smoking class $k$ with hypertension is calculated as the incidence rate of smoking class $k$ multiplied by the incidence rate of the people with hypertension multiplied by a relative risk. The relative risk for hypertensive smokers is derived from the literature (18). So formally the incidence rate of smoking class $k$ with hypertension is

$$INC_{s,h} = rr(k,h) \times INC_s \times INC_h$$  \hspace{1cm} (12)

Here $INC_{s,h}$ is the incidence number for hypertensive smokers, and $rr(k,h)$ is the relative risk for hypertensive smokers.

References

(2) Nusselder WJ. Compression or expansion of morbidity? a life-table approach [Thesis]. Erasmus University Rotterdam, Rotterdam, the Netherlands, 1998.


### Appendix 5.2: Input data model

#### Demographic data

Table A2.1 presents the input data, relative risks and transition probabilities used in the stroke model. The age- and sex-specific demographic data for the year 2000 in the model, i.e. mortality numbers and birth- and migration prognoses, are derived from Statistics Netherlands (1). The incidence based on data from 5 GP-registrations (2-6) till the year 2000 are combined into an age- and gender-specific average, to obtain the most recent estimates for the incidence of stroke in the Netherlands (7). The same is done for data on stroke prevalence. Registrations (2-4) for which

<table>
<thead>
<tr>
<th>Arrow in figure A2.1</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;65 years</td>
<td>65-74 years</td>
</tr>
</tbody>
</table>

#### Epidemiology

| Stroke incidence (per 1,000) # | 0.61 | 7.87 | 15.97 |
| Stroke prevalence (per 1,000)# | 3.13 | 45.06 | 85.11 |
| First year case fatality rate | 1 | 0.156 | 0.336 | 0.465 |
| Long-term case fatality rate | 1 | 0.018 | 0.055 | 0.072 |
| Excess mortality in disease free | 2 | 261 | 2,803 | 7,459 |

#### Hypertension

<table>
<thead>
<tr>
<th>Prevalence (transition probability)</th>
<th>&lt;65 years</th>
<th>65-74 years</th>
<th>75-84 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1 (&lt;120 mmHg)</td>
<td>42.6 (0.0256)</td>
<td>36.5 (0.028)</td>
<td>7.5 (0.003)</td>
</tr>
<tr>
<td>Category 2 (120-139 mmHg)</td>
<td>10.9 (0.0248)</td>
<td>25.1 (0.050)</td>
<td>21.5 (0.051)</td>
</tr>
<tr>
<td>Category 3 (140-159 mmHg)</td>
<td>10.0 (0.0539)</td>
<td>20.1 (0.069)</td>
<td>20.4 (0.045)</td>
</tr>
<tr>
<td>Category 4 (160-179 mmHg)</td>
<td>12.6 (0.2887)</td>
<td>13.5 (0.109)</td>
<td>22.8 (0.052)</td>
</tr>
<tr>
<td>Category 5 (≥180 mmHg)</td>
<td>14.9 (0.000)</td>
<td>34.6 (0.000)</td>
<td>46.9 (0.000)</td>
</tr>
</tbody>
</table>

#### RR stroke

| RR stroke current smoker | 3.96 | 3.04 |
| RR stroke former smoker | 1.42 | 1.25 |

#### Additional RR smoking and hypertension

| 10 | 1.3 | 1.3 | 1.3 |
the year prevalence rates of stroke were available are used to estimate the prevalence rates of stroke in the Netherlands. Age- and gender-specific case fatality rates are estimated using data from the Research On Stroke Amsterdam study (ROSA) (8,9). This multi-center study followed a large sample of hospitalized stroke patients (n=760) up to five years after hospital admission. Data were collected at 6 month, 3 years and 5 years after stroke, and include the date of onset of stroke and on date of death. After a goodness-of-fit test of the curve estimation of the case fatality data, we calculated age- and gender-specific case fatality rates for the first year after the onset of stroke (from now on: the first year case fatality) and for the subsequent years (from now on: the long-term case fatality).

<table>
<thead>
<tr>
<th>Age Group</th>
<th>&gt;85 years</th>
<th>&lt;65 years</th>
<th>65-74 years</th>
<th>75-84 years</th>
<th>&gt;85 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;85 years</td>
<td>25.71</td>
<td>0.48</td>
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Risk factors
The age- and gender-specific prevalence of hypertension in the Netherlands is estimated on the basis of two studies and used to determine the prevalence rate of hypertension in the Netherlands for a full age range. The prevalence of hypertension till the age of 65 was estimated from the Monitoring Project on Risk Factors for Chronic Diseases (MORGEN-study) (10), and the prevalence of hypertension above the age of 65 was estimated from the Rotterdam Ergo study (11). The age-specific relative risks of hypertension for stroke were based on four studies (12-15). Results of these four studies are combined in an age-specific average relative risk (5-year age classes). The age- and gender-specific prevalence rates of smokers and former smokers in the Netherlands were derived from the yearly population monitoring studies of the Foundation on Smoking and Health (16), for the time period 1997-2000, specified by gender and 5-year age classes and the three groups of never smokers, former smokers and current smokers. The age- and gender-specific start, stop and restart rates are computed from the observed trends over the period 1997-2000. The relative risks of former and current smokers are derived from several studies (17-21). The reported data of these studies are combined into an age- and gender-specific average (5-year age classes). The additional relative risks of stroke for people with the combination of hypertension and smoking are calculated based on data from the one available study of Shaper (22).

Modified Figure A2.1: Basic structure of the stroke model including possible health states (disease free population, stroke population and death) and possible transition rates which are represented by arrows (number of arrows correspond with the numbers in Table A2.1)
References