Stroke is a major global health burden. According to the World Health Organization estimates, some 15 million people experience stroke worldwide each year. Of these, 5 million die and another 5 million are left permanently disabled. Studies in many industrialized countries demonstrate that individuals with low socioeconomic status (SES) whether measured by income, occupational group, or by level of educational attainment have an elevated risk of dying from cardiovascular diseases (CVDs), including stroke. In 2 reviews of SES and stroke, a consistent pattern of higher stroke incidence and mortality was found in lower SES groups than in higher SES groups. The mechanisms through which low SES affects stroke risk and outcomes are unclear, but some studies suggest that the comparatively high prevalence of predisposing risk factors, such as hypertension, diabetes mellitus, and smoking, among poorer people could account for some of the variation. As a result, reducing socioeconomic inequalities in health has been an important goal of health policy. Although socioeconomic inequalities in CVD, such as stroke, have long been documented among European populations, they have remained inconsistent among migrant populations. The general expectation is that a socioeconomic gradient will eventually emerge in migrant groups in line with the diffusion theory of the epidemic of coronary heart disease. This theory suggests that coronary heart disease struck more affluent communities of the rich nations first as they were the first who could afford unhealthy behaviors, which increase the risk of coronary heart disease. However, we assessed socioeconomic inequalities in relation to stroke incidence among major ethnic groups in the Netherlands.

Methods—A nationwide register-based cohort study was conducted (n=2,397,446) between January 1, 1998, and December 31, 2010, among ethnic Dutch and ethnic minority groups. Standardized disposable household income was used as a measure of socioeconomic position.

Results—Among ethnic Dutch, the incidence of stroke was higher in the low-income group than in the high-income group (adjusted hazard ratio, 1.18; 95% confidence interval, 1.16–1.20). Similar socioeconomic inequalities in stroke incidence were found among Surinamese (1.36; 1.17–1.58), Indonesians (1.15; 1.03–1.28), Moroccans (1.54; 0.97–2.43), Turkish (1.19; 0.97–1.46), and to a lesser extent among Antilleans (1.24; 0.84–1.84). When compared with ethnic Dutch, the incidence of stroke was lower in Moroccans, similar in Turkish, but higher in Surinamese among all income groups. The incidence of stroke was higher in Indonesian low- and high-income groups than in their ethnic Dutch counterparts. Among Antilleans, the risk of stroke was higher than ethnic Dutch but only in the low-income group.

Conclusions—Our findings reveal socioeconomic inequalities in stroke incidence among all ethnic groups. Reduction of socioeconomic inequalities in stroke incidence among all ethnic groups may lead to a major public health improvement for all. Policy measures tackling socioeconomic inequalities should take into account the increased risk of stroke among ethnic minority populations.

Key Words: epidemiology • ethnicity • migration • minority groups • minority health • Netherlands • stroke
as the epidemic matures, the disease spread to the poor communities as living standards improved. When the epidemic started to decline, the rich people were again the first to benefit as they were the first to adopt the healthy behavioral changes. Evidence also suggests widening inequalities in both income and CVD risk factors in different populations in recent years, but the effects of these changes on stroke outcomes, particularly among ethnic minority and migrant groups, are still unknown.15,16

The aim of this study was to assess socioeconomic inequalities in stroke incidence among major first-generation ethnic minority groups in the Netherlands: Surinamese, Moroccans, Turkish, Antilleans, Indonesian, and the Dutch majority population (henceforth, ethnic Dutch). In addition, we assessed differences in the incidence of stroke between the ethnic Dutch and ethnic minorities within income groups.

Methods

Cohort Enrollment

Data were obtained from the following Dutch national registers: Population Register, Hospital Discharge Register, Cause of Death Register, and Regional Income Survey. The registers were used to acquire information on demographic factors, stroke hospitalizations and comorbidities, fatal stroke events, and income. The registers have been described in detail previously.17 The reliability of Dutch national registers for stroke has been proven to be high.18 By linking previous registers with a personal identifier, a cohort was built, starting at January 1, 1998, when 15,431,715 Dutch citizens were registered in the Population Register. Only Population Register unique population can be identified in the Hospital Discharge Register (unique with respect to the combination of the variables date of birth, sex, and 4 digits of the postal code), nonunique population were excluded. This left a cohort of 13,421,681 (87.0%) people. Because a low number of strokes are expected in the young, only people of ≥30 years of age were included (n=8,185,247; 61.0%). The SES indicator was based on the disposable income on household level in 1997 (the year before baseline), which was available for about one third of the Dutch population. People without available information about their income were excluded (n=5,543,796; 67.7%). The basic characteristics of the people without income data were similar to the people with income data in terms of age (median age, 51 versus 49 years) and the distribution of sex (men, 48% versus 50%), degree of urbanization (urban, 39% versus 36%), ethnic composition (ethnic Dutch, 95.2% versus 94.7%), and comorbidity (Charlson Index, ≥1: 8.3% versus 7.3%). People without income data were, however, less likely to be married or living together than people with income data (65% versus 76%). After excluding migrant groups not under study (n=106,635), the final cohort comprised 2,397,446 people (Figure 1).

Follow-Up

People were followed up from baseline until their first stroke. A first event was defined as any hospital admission with a primary or secondary diagnosis of stroke (International Classification of Diseases, Ninth Revision, code 430–438) or as a fatal event with stroke as the primary or secondary cause (International Classification of Diseases, Tenth Revision, code I60-I69, G45). The positive predictive values of these codes have been shown acceptable; ≥75% for code 430, 285% for code 431, and 285% for codes 434 to 436.19–21 People who already had a previous hospital admission for a stroke between January 1, 1995, and December 31, 1997, were not included as having a first event of that specific type. People were censored in case of death, emigration, or the end of the study period (December 31, 2010), whichever came first.

Determinants

Ethnic Background

The migrant groups were constructed based on the country of birth of the resident and his/her parents, according to the definition of Statistics Netherlands.20 An individual is considered a migrant if he/she was born abroad. For this study, migrants from Suriname (n=33,785), Morocco (n=15,114), Turkey (n=31,206), Netherlands Antilles (n=8,145), Indonesia (n=37,707), and ethnic Dutch (n=2,271,489)
were included. People of whom both parents were born in the Netherlands were indicated as ethnic Dutch. For simplicity, we refer to the first-generation ethnic groups in general as migrant groups and the respective countries of origin as Surinamese, Moroccans, Turkish, Antilleans, and Indonesians. The migration histories of these populations have described in detail elsewhere.2,23

**Explanatory Variables**

**Socioeconomic Status**

The SES was based on income data registered in the Regional Income Survey.24 The Regional Income Survey started in 1994 with a selected representative sample of 1.9 million Dutch citizens. Each year, the sample was corrected for emigration and mortality, on one hand, and immigration and birth, on the other. All individuals that belonged to the households of the sample population (approximately one third of the Dutch population) were included in the Regional Income Survey. SES was defined as the standardized disposable household income with adjustment for number of household members in the year before baseline. The standardized disposable household income was subsequently categorized into SES tertiles in 2 ways: (1) by dividing the income of the total cohort in tertiles (total income) and (2) by dividing the income of every migrant group separately in tertiles (within-group income). The first tertile represents the lowest income group, the second tertile represents the medium income group, and the third tertile represents the highest income group.

**Comorbidity**

Charlson Index Score25 was used to assess the presence and extent of comorbidity, based on discharge diagnosis within 3 years before baseline (1995–1997). The Charlson Index Score ranges from zero to 6 (cutoff value), with zero representing no comorbidity. This score was subsequently categorized into 4 categories (0, 1–2, 3–4, and ≥5). The Charlson Index Score has proven to be a reliable and valid method to measure comorbidity in clinical research.26

**Data Analysis**

Baseline characteristics were analyzed on January 1, 1998. Absolute incidence of stroke was calculated as the number of events per 100,000 person-years at risk and subsequently age-standardized to the age distribution of the European population (using the direct method) with 10-year age bands. For the calculation of relative incidence rates of total stroke, Cox proportional hazard regression analyses were used. Using the within-group SES indicator, incidence differences between people with a low SES and people with a high SES (reference) in every migrant group and in the ethnic Dutch were investigated. All analyses were adjusted for age, sex, marital status, degree of urbanization, and Charlson Index Score. Also incidence differences between migrant groups and ethnic Dutch (reference) within every SES tertile were investigated with the total SES indicator. These analyses were additionally adjusted for disposable household income to overcome the problem of important income differences between ethnic groups. Results were expressed as hazard ratios with corresponding 95% confidence intervals. We used SPSS software, version 14.0 (SPSS Inc, Chicago, IL). All analyses were performed in accordance with privacy legislation in the Netherlands.

**Results**

**Characteristics of the Study Population**

The characteristics of the study population are shown in Table 1. Migrant populations were younger than the ethnic Dutch population except for Indonesians. Turkish and Moroccans were the most and Antilleans and Surinamese were the least to be married or to live together with a partner. Indonesians had the highest and Moroccans had the lowest median household income. All the migrant populations tended to be more concentrated in urban centers than the ethnic Dutch.

**Incidence Rates by Income Gradient Within Each Ethnic Group**

Table 2 shows age-standardized absolute incidence rates per 100,000 person-years, and Figure 2 shows hazard ratios for stroke incidence by income group in each ethnic group. As expected, among ethnic Dutch, the incidence of stroke was higher in people with medium- and low-income than in their high-income peers (1.10; 1.08–1.12 for medium income and 1.18; 1.16–1.20 for low income). Among the migrant groups, similar strong socioeconomic inequalities in stroke incidence were found. The incidence of stroke was higher in people with low-income than in their high-income counterparts among Surinamese (1.36; 1.17–1.58) and Indonesians (1.15; 1.03–1.28), Moroccans (1.54; 0.97–2.43), Turkish (1.19; 0.97–1.46), and Antilleans (1.24; 0.84–1.84). Except for Indonesians, migrants with a medium-income also had a higher stroke incidence than their high-income counterparts although the differences were significant only for Turkish (1.39; 1.14–1.69) and Antilleans (1.63; 1.12–2.36).

**Differences in Stroke Incidence Between Ethnic Dutch and Migrant Groups Within Income Categories**

**Discussion**

Our present findings suggest socioeconomic inequalities in the incidence of stroke in both ethnic Dutch and migrant groups. Within each income group, the incidence of stroke was higher in most ethnic groups than in ethnic Dutch.
The importance of SES as predictors of stroke incidence, mortality, and effect has previously been discussed. Although socioeconomic inequalities in CVD have been recognized in industrialized communities, the evidence on ethnic minority and migrant groups has remained patchy and inconclusive. Analysis in the early 1970s by Marmot and Mustard, for instance, found a strong social class gradient in coronary heart disease among England and Wales general population but did not find a relationship among South-Asian migrants living in England and Wales. Similar observations were found in the Netherlands in the early 1990s where strong socioeconomic inequalities in cardiovascular mortality were noted among the ethnic Dutch population but not among migrant groups. Consequently, the need to keep track on socioeconomic inequalities with respect to stroke among minority populations has been emphasized. The higher risk of stroke among the poor in migrant communities in the present study is consistent with recent findings of socioeconomic inequalities in other CVD outcomes in migrant groups and fits into the popular diffusion theory of the epidemic of cardiovascular mortality.

### Table 1. Population Characteristics of the Ethnic Groups Between 1998 and 2010

<table>
<thead>
<tr>
<th>Ethnic Group</th>
<th>n</th>
<th>Person-years at risk</th>
<th>n events, %</th>
<th>Median age (IQR)*</th>
<th>Married or living together, %*</th>
<th>Median income (IQR)†</th>
<th>SES, %‡</th>
<th>Degree of urbanization, %§</th>
<th>Charlson Index, %*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethnic Dutch</td>
<td>2271489</td>
<td>23270517</td>
<td>85524</td>
<td>49.7</td>
<td>76.2</td>
<td>15967</td>
<td>Tertile 1</td>
<td>Very urban</td>
<td>13.4</td>
</tr>
<tr>
<td>Surinamese</td>
<td>23785</td>
<td>322541</td>
<td>1007</td>
<td>47.1</td>
<td>48.0</td>
<td>13498</td>
<td>Tertile 2</td>
<td>Urban</td>
<td>22.7</td>
</tr>
<tr>
<td>Moroccan</td>
<td>15114</td>
<td>144216</td>
<td>112</td>
<td>56.5</td>
<td>84.1</td>
<td>10193</td>
<td>Tertile 3</td>
<td>Urban/rural</td>
<td>24.6</td>
</tr>
<tr>
<td>Turk</td>
<td>31206</td>
<td>309378</td>
<td>580</td>
<td>55.0</td>
<td>87.9</td>
<td>11333</td>
<td>Very urban</td>
<td>Rural</td>
<td>24.6</td>
</tr>
<tr>
<td>Antillean</td>
<td>8145</td>
<td>76674</td>
<td>175</td>
<td>47.6</td>
<td>44.4</td>
<td>12688</td>
<td>Tertile 1</td>
<td>Very rural</td>
<td>17.1</td>
</tr>
<tr>
<td>Indonesian</td>
<td>37707</td>
<td>371665</td>
<td>1924</td>
<td>47.7</td>
<td>40.4</td>
<td>16839</td>
<td>Tertile 2</td>
<td>Urban/o rural</td>
<td>22.9</td>
</tr>
</tbody>
</table>

IQR indicates interquartile range; and SES, socioeconomic status.

*At baseline.

†In the year before baseline.

‡Based on income of total population in the year before baseline.

§Population density (number of residents per km²) at baseline. Very urban ≥2000, urban=1001 to 2000, urban/rural=501–1000, rural=251–500, very rural ≤251.

### Table 2. Age-Standardized Incidence Rates* With 95% Confidence Intervals of Stroke per 100,000 Person-Years at Risk, Stratified by Socioeconomic Status†

<table>
<thead>
<tr>
<th>Ethnic Group</th>
<th>Low-Income Group</th>
<th>Medium-Income Group</th>
<th>High-Income Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n Events</td>
<td>Incidence Rate</td>
<td>n Events</td>
</tr>
<tr>
<td>Ethnic Dutch</td>
<td>36571</td>
<td>273 (269–278)</td>
<td>25527</td>
</tr>
<tr>
<td>Surinamese</td>
<td>431</td>
<td>397 (305–489)</td>
<td>288</td>
</tr>
<tr>
<td>Moroccan</td>
<td>45</td>
<td>108 (63–152)</td>
<td>36</td>
</tr>
<tr>
<td>Turk</td>
<td>190</td>
<td>178 (134–222)</td>
<td>218</td>
</tr>
<tr>
<td>Indonesian</td>
<td>684</td>
<td>280 (248–312)</td>
<td>620</td>
</tr>
</tbody>
</table>

*Standardized to the age distribution of the European population.

†Based on income within each ethnic group.
Although the reasons for socioeconomic inequalities in stroke incidence are not entirely clear, the distribution of vascular risk factors across socioeconomic groups may play an important role.\(^6\)\(^-\)\(^8\) In the Netherlands, data on socioeconomic inequalities in risk factors among ethnic minority and migrant groups are rare and outdated, and they only partly support the observed socioeconomic inequalities in stroke outcomes.\(^2\)\(^8\),\(^2\)\(^9\) A study performed in the early 2000s found higher smoking rates only among Surinamese, Turkish, and Moroccan men with lower SES than among those with higher SES.\(^2\)\(^8\) Another study on socioeconomic inequalities in metabolic syndrome in early 2000s found low education to be associated with increased prevalence of metabolic syndrome among ethnic Dutch people but not among ethnic minority groups.\(^2\)\(^9\) The lack of clear socioeconomic gradients in vascular risk factors among ethnic minority groups in these earlier Dutch studies is consistent with earlier studies from the United Kingdom.\(^1\)\(^1\),\(^3\)\(^1\) The emerging data showing clear socioeconomic inequalities in CVD outcomes among migrant populations support the need to assess the current socioeconomic gradient in relation to vascular risk factors, such as hypertension, diabetes mellitus, as well as access to healthcare, and compliance with therapy. Such an assessment might explain why low socioeconomic individuals have an elevated risk of stroke.

Surinamese had a higher incidence of stroke than ethnic Dutch in all income strata. These differences persisted even after adjusting for income differentials with social strata, suggesting that other unmeasured factors might play a role in the observed ethnic differences in stroke incidence. Some of these factors might be the higher prevalence of hypertension and diabetes mellitus, as well as poorer blood pressure control in Surinamese than in ethnic Dutch.\(^3\)\(^0\),\(^3\)\(^1\) Similar mechanisms might be present in Indonesians although data on risk factors among this population are currently lacking. By contrast, Moroccans had a lower stroke incidence than ethnic Dutch in all income groups. The low incidence of stroke among Moroccans as observed in the current study has been linked to the low prevalence of hypertension and smoking\(^3\)\(^2\),\(^3\)\(^3\) and a Mediterranean diet.\(^3\)\(^4\)

Our findings have important health implications. To date, the literature on socioeconomic inequalities in relation to migrant health has largely focused on SES as an explanatory factor for ethnic differences in health outcomes.\(^9\),\(^2\)\(^7\)-\(^2\)\(^9\) Our finding of socioeconomic inequalities in stroke incidence clearly suggests the need to pay attention to socioeconomic inequalities in the distribution of vascular risk factors.
within migrant groups. However, the socioeconomic processes that shape health differentials both within and between ethnic and migrant groups are evidently multifaceted and context specific. These complexities make the assessment of the role of SES on ethnic differences in health outcomes difficult, particularly for the first-generation migrants in whom information on key SES indicators are generally lacking. The recent Scottish Health and Ethnicity Linkage Study found that across ethnic groups, SES indicators were inconsistently associated with CVD hospitalization or mortality. Given these complexities, assessing socioeconomic inequalities in health outcomes within ethnic and migrant groups may be a more viable option. The magnitudes of the differences between the low- and high-income groups among most migrant groups were generally greater than among the ethnic Dutch, despite the overlapping 95% confidence intervals for some migrant groups because of small numbers. If the stroke incidence rates of the low-income migrant groups could be reduced to the level of the high-income groups, particularly among migrant groups with high risks such as Surinamese and Indonesians, this would lead to a major health improvement in these groups regardless of the persistent ethnic disparities in stroke outcomes.

Strength and Limitations
A key strength of our current study is that it is based on a nationwide database with large sample sizes, which allowed us to study incidence of stroke in several migrant groups. There are also limitations to our study. As in many national-level databases, we lack data on risk factors, such as hypertension and diabetes mellitus, and duration of stay in the country. As a result, we were unable to assess the direct contribution of the various risk factors to the observed socioeconomic inequalities. We also lack data on changes in household income over time, such as before and after retirement from work. Evidence indicates that retirement is significantly associated with changes in income patterns after retirement. Stroke commonly occur after retirement age, which may affect our study conclusions. Nonetheless, in the Netherlands, when individuals reach the retirement age, their pension benefits are settled based on their past earnings, and the effect of retirement on income is on average 4.8%. In addition, our study cohort was based on only individuals with income data. It is possible that our study population differs from the population without income data, which might have biased our study results. Nevertheless, the basic characteristics of the population without income data were generally similar to our study population in terms of age and the distribution of sex, degree of urbanisation, ethnic composition, and Charlson index. Furthermore, this limitation applies to all ethnic groups under study. It is, therefore, unlikely that this could have affected our study results in a significant way. Moreover, our SES was based on household income only because data on other socioeconomic measures, such as educational level, occupational class, and childhood SES, were not available. It has been emphasized that different measures of SES may affect health through different pathways and causal mechanisms. Nonetheless, the disposable household income was based on taxes, which gives a more accurate picture of socioeconomic health differentials than the use of self-reported SES or other surrogate markers of SES, such as neighbourhood income. It has been established that more accurate characterization of SES leads to substantially wider health differentials than lesser precise measures of SES. Furthermore, we were unable to assess socioeconomic inequalities stratified by sex and in the various stroke subtypes because of smaller numbers. Finally, the migrant groups were constructed on the basis of country of birth. Country of birth may represent ethnic groups fairly well in some migrant groups, but it might be an unreliable measure of ethnicity for other groups, such as Surinamese, who are ethnically diverse. Notwithstanding, our previous studies showed that major risk factors for stroke, such as hypertension and type 2 diabetes mellitus, are higher in both African-Surinamese and South-Asian Surinamese than in ethnic Dutch people.

In conclusion, our findings show socioeconomic inequalities in stroke incidence among all ethnic groups. Within each income group, the incidence of stroke was higher in most migrant groups than in ethnic Dutch. Reduction of socioeconomic inequalities in stroke incidence among all ethnic groups may lead to a public health improvement for all. Policy measures tackling socioeconomic inequalities should take the increased risk of stroke among ethnic minority populations into account.

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Disclosures
The other authors report no conflicts.

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Socioeconomic Inequalities in Stroke Incidence Among Migrant Groups: Analysis of Nationwide Data

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