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Variations in 'avoidable' mortality: a reflection of variations in incidence?

Henriëtte F Treurniet, Caspar WN Looman, Paul J van der Maas and Johan P Mackenbach

Background	Variations in 'avoidable' mortality may reflect variations in the quality of care, but they may also be due to variations in incidence or severity of diseases. We studied the association between regional variations in 'avoidable' mortality and variations in disease incidence. For a selection of conditions we also analysed whether the proportion of in-hospital deaths can explain the regional variations in incidence-adjusted mortality.
Methods	Relative risks for mortality, incidence, incidence-adjusted mortality and in-hospital mortality (1984–1994) were calculated by log-linear regression. Linear regression was used to examine the relationship between mortality and incidence on the one hand, and between incidence-adjusted mortality and in-hospital mortality on the other.
Results	Significant regional mortality variations were found for cervical cancer, cancer of the testis, hypertensive and cerebrovascular disease, influenza/pneumonia, cholecystitis/lithiasis, perinatal causes and congenital cardiovascular anomalies. Regional mortality differences in general were only partly accounted for by incidence variations. The only exception was cervical cancer, which no longer showed significant variations after adjustment for incidence. The contribution of in-hospital mortality variations to total cause-specific mortality variations varied between conditions: the highest percentage of explained variance was found for mortality from CVA (60.1%) and appendicitis (29.2%).
Conclusions	Incidence data are a worthy addition to studies on 'avoidable' mortality. It is to be expected that the incidence-adjusted mortality rates are more sensitive for quality-of-care variations than the 'crude' mortality variations. Nevertheless, further research at the individual level is needed to identify possible deficiencies in health care delivery.

Keywords	Avoidable, mortality, incidence, variation, quality of care
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Mortality rates for diseases amenable to medical care have been proposed as indicators of health care quality. The idea of using mortality data to identify problems in health care was developed by Rutstein *et al.*[1,2] who systematically identified health outcomes (death, disease and disability) that may be considered 'avoidable' given current medical knowledge. 'Avoidable' here means that the (excess) occurrence of these outcomes points to potential problems in health care.

Many investigators have used the lists of Rutstein *et al.* to describe variations in 'avoidable' mortality, in time, between areas or populations.[3–13] In most of these studies, the association between mortality and health care characteristics was found to be weak and inconsistent. One of the possible explanations for this finding is that mortality variations simply reflect variations in incidence or severity of the conditions under study rather than quality-of-care differences. Until now, however, only a few researchers were able to include morbidity data in their study.[4,11]

The present study examines whether regional variations in 'avoidable' mortality in the Netherlands (1984–1994) are associated with variations in disease incidence. Incidence for the purposes of this study means 'incidence, as measured by hospital discharge data'. For those conditions where in-hospital care may be important for the outcome, we also analysed whether the proportion of hospitalized patients that died in hospital explains the regional variations in incidence-adjusted mortality.

Erasmus University, Department of Public Health, PO Box 1738, 3000 DR Rotterdam, The Netherlands.

Data and Methods

For the period 1984–1994, numbers of deaths by age, sex, year, region and cause of death were obtained from Statistics Netherlands. Twelve regions were identified, the so-called provinces, with a median population size of 985 739 in 1984 and 1 050 341 in 1994. The causes of death that were selected for analysis are presented in Table 1. They form a selection from a larger number of conditions listed by Rutstein *et al.*[1]. The analysis was restricted to those causes for which the total number of deaths during the study period was larger than 200. Mortality data for the six largest regions were given in 5-year age groups (0, 1–4, 5–9, ..., 84+). For the four middle-size regions and the smallest ones a less detailed classification was used to protect confidentiality (respectively 0, 1–14, 15–24, 35–44, 45–49, ..., 84+ and 0, 1–24, 25–44, 45–54, 55–64, 65–69, ..., 84+). Population numbers by age (0, 1–4, 5–9, ..., 84+), sex, year and region were also provided by Statistics Netherlands.

Incidence data were obtained from the National Information System on Hospital Care of Health Care Information Netherlands. During the period 1984–1994 this registry on average contained data on 99.2% of all discharged patients in general and academic hospitals. The following information (1984–1994) was obtained for each patient with a primary diagnosis mentioned in Table 1: age (0, 1, 1–4, 5–9, ..., 84+ years), sex, year of discharge, region where the patient lives, diagnosis at discharge and discharge status (dead or alive). The analysis included only the 'first discharges', i.e. those patients who had not been admitted to hospital with the same diagnosis earlier that year or during the four previous years. These 'first discharges', in this article referred to as incidence, were identified by screening the database on patients with identical birth date, sex, diagnosis (according to the 16 groups in Table 1) and municipality. Furthermore, regional data were obtained on the total number of age and sex-specific hospital discharges, irrespective of diagnosis. Finally, cause-specific in-hospital mortality was calculated as the fraction of patients that died in the hospital after admission for a specific disease.

Log-linear regression analysis was used to obtain estimates for age- and sex-adjusted levels of mortality, incidence and in-hospital mortality. This method was recently described by Bithell *et al.*[14] Age categorization was accounted for by using *k-1* dummy variables (0 or 1) for *k* age categories in the regions with the most detailed age categories. In the regions with the less detailed age categories we used values between 0 and 1, denoting which fraction of the observed number of events could be assumed to belong to the most detailed age categories. The regression equation had the following structure:

$$E(Y_{ijr}) = N_{ijr} \cdot e^{\alpha_i + \beta_{1,\ldots,12} \cdot REG_{1,\ldots,12}}$$

in which:

$E(Y_{ijr})$ = absolute number of events as expected under the model by age, sex, year and region
N_{ijr} = person-years at risk by age, sex, year and region
$e^{\alpha i}$ = national rates for age and sex category i
REG = dummy variable for region
$\beta_1, \ldots \beta_{12}$ = regression coefficient for the regional level

Standardized mortality levels were calculated with $E(Y_{ijr})$ as the number of deaths and N_{ijr} as populations numbers. Age- and sex-adjusted incidence levels were in the first place calculated with $E(Y_{ijr})$ as the number of diagnosis-specific discharges and N_{ijr} as population numbers. Parallel analyses were performed with N_{ijr} being replaced by the total number of discharges, irrespective of diagnosis, in order to adjust for regional variations in admission policy. As both analyses yielded the same results, only the analysis with population numbers will be presented. Finally, standardized in-hospital mortality rates were obtained with $E(Y_{ijr})$ as the number of in-hospital deaths and N_{ijr} as the number of cause-specific discharges.

Calculations were performed with the GLIM package, specifying a Poisson regression model.[15] The GLIM package produces maximum likelihood estimates using an iteratively reweighted least squares procedure. The change in deviance after omitting REG was compared with a χ^2 distribution. A significant effect means that significant regional variations exist. The term e^{β} can be interpreted as the regional relative risk (RR), i.e. $e^{\beta} = 1.5$ in the model with mortality means that a 50% increased age- and sex-adjusted mortality risk exists in that region as compared to the national risk. These RR are almost equal to the 'classical' standardized mortality ratio (SMR), which could also have been obtained by fitting the model without REG and calculating $\Sigma O/\Sigma E$ per region (with O being the observed and E the expected number of deaths).

The relationship between the RR for mortality and the RR for incidence was examined in a linear regression analysis. The percentage of mortality variation explained by variation in incidence was calculated and the level of significance of the correlation was tested. For all causes of death a visual inspection of scatterplots showing the relationship between mortality and incidence was performed. Even where correlations were low, we did not find any non-linear relationship. The RR for incidence was then added to the Poisson model described above (with mortality as the dependent variable) as a new predictor,

Table 1 Causes of death selected for analysis

ICD-9	Cause of death	Age range
1. 010–018 in 137	Tuberculosis	5–64
2. 180	Cervical cancer	15–64
3. 186	Cancer of the testis	0–64
4. 201	Morbus Hodgkin	5–64
5. 204–208	Leukaemia	0–44
6. 390–398, 424	Rheumatic heart disease	5–44
7. 401–405, 430–438	Hypertensive and cerebrovascular disease	35–64
8. 480–486, 487	Influenza/pneumonia	0–74
9. 540–543	Appendicitis	5–64
10. 574–575.1, 576.1	Cholecystitis and -lithiasis	5–64
11. 600	Benign prostatic hyperplasia	0–74
12. 745–747	Congenital cardiovascular anomalies	1–14
Perinatal causes:		
13. 761	Complications of pregnancy	<1
14. 762, 763, 767	Birth injury	<1
15. 760, 764–766, 768–779	Other perinatal causes	<1
16. 760–779	All perinatal causes	<1

The selection is mainly based on the lists of Rutstein *et al.*[1,2] Cancer of the testis is added as evidence on the effectiveness of medical care is available.

Table 2 Regional variations in mortality risks in the Netherlands, 1984–1994

Cause of death	No. of deaths	Lowest RR	Highest RR	Significance of regional difference (*P*-values)
Tuberculosis	280	0.34	1.66	0.125
Cervical cancer	1401	0.82	1.32	0.005
Cancer of the testis	289	0.51	2.09	0.003
Morbus Hodgkin	777	0.77	1.22	0.491
Leukaemia	1673	0.87	1.12	0.598
Rheumatic heart disease	233	0.59	1.28	0.457
Hypertensive and cerebrovascular disease	12 914	0.76	1.14	0.000
Influenza/pneumonia	5136	0.68	1.18	0.000
Appendicitis	587	0.54	2.02	0.343
Cholecystitis/lithiasis	307	0.63	1.66	0.020
Benign prostatic hyperplasia	239	0.76	1.65	0.921
Congenital cardiovascular anomalies	353	0.64	1.50	0.034
Perinatal causes:				
Complications of pregnancy	400	0.70	1.38	0.652
Birth injury	927	0.66	1.34	0.093
Other perinatal causes	4671	0.72	1.13	0.007
All perinatal causes	5972	0.72	1.16	0.000

besides region (REG). A significant effect of omitting the variable REG from this model means that significant regional mortality variations exist after adjustment for incidence. The model without REG but including the RR for incidence was used to calculate $\Sigma O/\Sigma E$ per region (see above). This ratio represents the regional, incidence-adjusted RR for mortality.

Finally, linear regression was used to relate the RR for in-hospital mortality to the RR for incidence-adjusted mortality in order to find out whether a higher mortality risk is associated with a higher in-hospital mortality risk. This analysis was performed only for those diseases for which (1) more than 50% of all deaths occurred in hospital and (2) the acute hospital care may be important for the outcome.

Results

Table 2 shows the mortality variation among regions. Statistically significant variations were found for seven of the 16 (groups of) causes of death: cervical cancer and cancer of the testis, hypertensive and cerebrovascular disease (CVA), influenza/pneumonia, cholecystitis/lithiasis, perinatal causes and congenital cardiovascular diseases. Even some of the minor causes of death, cancer of the testis and cholecystitis/lithiasis, showed large significant variations.

The standardized incidence of each of the diseases under study was found to vary significantly between regions ($P < 0.0002$). The correlation between mortality and incidence appeared to be positive for all of the diseases under study. The strongest and statistically significant associations were found for tuberculosis, cervical cancer, leukaemia, CVA, influenza/pneumonia and birth injury (Table 3). Despite the association found for these diseases, regional mortality differences in general were only partly accounted for by variations in disease incidence. The only exception was cervical cancer, which no longer showed significant variations after adjustment for incidence.

Each of the causes of death proved to have its own geographical distribution. The incidence-adjusted mortality from influenza/pneumonia, for example, was found to be higher in the middle of the country, whereas high risks for cholecystitis/lithiasis mainly existed in the South Eastern part of the country. In contrast, incidence-adjusted mortality from perinatal causes, cancer of the testis and congenital cardiovascular diseases was relatively high in the more peripheral parts of the country. In general, no comparable geographical patterns were found within groups of conditions that share some types of curative interventions, i.e. infectious diseases (tuberculosis and influenza/pneumonia), 'surgical' conditions (appendicitis, benign prostatic hyperplasia and cholecystitis/lithiasis) and malignant neoplasms. Exceptions were benign prostatic hyperplasia and appendicitis, which proved to have a comparable geographical distribution of incidence-adjusted mortality (correlation coefficient 0.68), and cancer of the testis and Hodgkin's disease, which both showed increased risks in the Sourthern part of the country (correlation coefficient 0.60).

Figure 1a shows the distribution of mortality risks for cervical cancer. Higher mortality risks were mainly found in the Western part of the country. The incidence showed a slightly different geographical pattern but again the Western part of the country was associated with relatively high risks (per cent mortality variation explained by incidence 59.7%) (Figure 1b). After adjustment for incidence, the mortality differences were no longer significant (Figure 1c).

In-hospital mortality was examined for four conditions: CVA, appendicitis, cholecystitis/lithiasis and benign prostatic hyperplasia. For each condition, significant regional variations in in-hospital mortality could be demonstrated (Table 4). The strength of the correlation between in-hospital mortality and total cause-specific mortality, however, varied between conditions. The highest percentages of mortality variation explained by in-hospital mortality variation were found for CVA (60.1%)

Table 3 Association between relative risks for mortality and incidence

Cause of death	% of mortality variations explained by variations in incidence	Significance of % of mortality variations explained by incidence (*P*-values)	Significance of regional incidence-adjusted mortality variations (*P*-values)
Tuberculosis	40.1	0.027	0.46
Cervical cancer	59.7	0.003	0.60
Cancer of the testis	1.3	0.727	0.01
Morbus Hodgkin	4.6	0.505	0.54
Leukaemia	36.1	0.039	0.63
Rheumatic heart disease	0.7	0.796	0.43
Hypertensive and cerebrovascular disease	34.6	0.044	0.00
Influenza/pneumonia	38.5	0.031	0.00
Appendicitis	1.1	0.744	0.28
Cholecystitis and -lithiasis	5.3	0.471	0.01
Benign prostatic hyperplasia	21.1	0.133	0.88
Congenital cardiovascular anomalies	5.4	0.467	0.04
Perinatal causes:			
Complications of pregnancy	8.6	0.356	0.63
Birth injury	64.9	0.002	0.82
Other perinatal causes	11.8	0.274	0.02
All perinatal causes	27.8	0.078	0.01

and appendicitis (29.2%), which means that a high death rate is associated with a high risk of dying in hospital.

Figure 2 illustrates the correlation between mortality, incidence and in-hospital mortality for CVA. The South Eastern part of the country proved to have increased mortality risks (Figure 2a). The incidence showed a slightly different distribution (percentage of explained mortality variation 34.5%) (Figure 2b). After adjustment for incidence, the increased mortality risks had moved up to the middle and Northern part of the country (Figure 2c). Note that this pattern is largely comparable to the distribution of in-hospital mortality risks (Figure 2d).

Discussion

This article describes regional mortality variations in the Netherlands for a selection of 'avoidable' causes of death. Significant differences were found for cancer of the testis and cervix uteri,

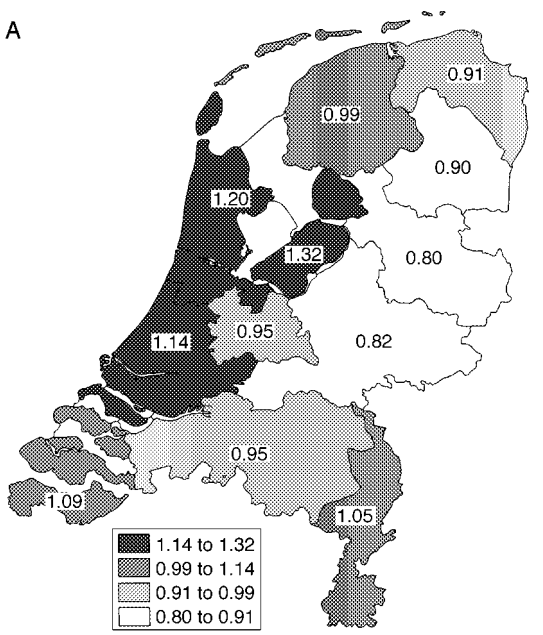

Figure 1a Regional variation in mortality from cervical cancer (relative risk)

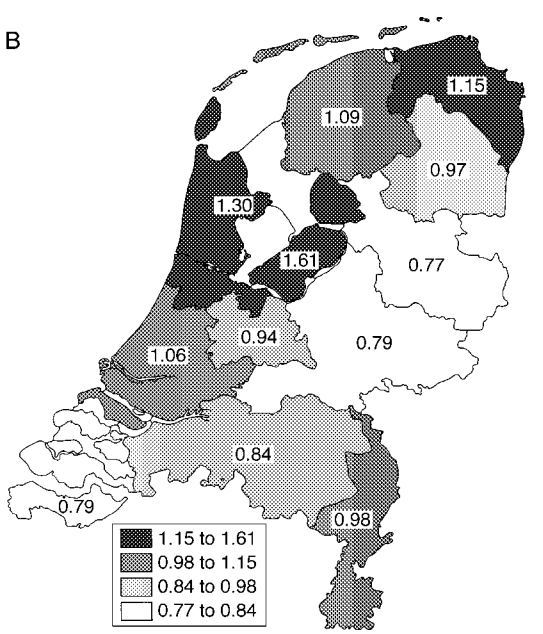

Figure 1b Regional variation in incidence of cervical cancer (relative risk)

Table 4 Regional variation in in-hospital mortality and association between the standardized death rate ratio after adjustment for incidence and the standardized in-hospital death rate[a]

Cause of death	No. of in-hospital deaths	% of total mortality that occurred in hospital	Significance of regional variation in in-hospital mortality[b] (*P*-values)	% of mortality variation explained by in-hospital mortality	Significance of % of mortality variation explained by in-hospital mortality (*P*-values)
Hypertensive and cerebrovascular disease	7226	56.5%	0.000	60.1%	0.003
Appendicitis	84	81.0%	0.002	29.2%	0.070
Cholecystitis/-lithiasis	208	81.9%	0.000	1.6%	0.700
Benign prostatic hyperplasia	196	84.4%	0.000	14.8%	0.217

[a] Only for those conditions for which (1) the acute medical management may be important for the outcome and (2) the proportion of deaths inside hospital as part of the total mortality >50%.

[b] The denumerator consists of discharge data.

CVA, influenza/pneumonia, cholecystitis/lithiasis, perinatal causes and congenital cardiovascular anomalies.

A first possible cause of mortality variations is variation in the certification of causes of death (coding is done centrally). In the Netherlands, this source of variation is probably of minor importance because a recent study on variations in certification of cardiovascular disease and coronary heart disease showed that significant differences existed by type of doctor (general practitioners versus others) but not between Dutch regions.[16]

Secondly, mortality differences may be caused by underlying variations in incidence (as measured by hospital discharge rates). All causes of death under study proved to be positively related to the incidence of the disease. This relationship suggests that mortality differences can, at least partly, be explained by incidence variations. For cervical cancer, the significance of mortality variations even disappeared after adjustment for incidence. As far as incidence can be modified by medical intervention, as is for example the case with cervical cancer, influenza and cerebrovascular disease, incidence variations may be considered as a possible indication for variations in the quality of (preventive) health care. Unfortunately, no data were available to distinguish between spontaneous incidence differences and variations that were caused by shortcomings in preventive care. In the case of cervical cancer for example, the higher incidence in the Western, urbanized part of the country may be due to either high risk behaviour (promiscuity) or to the induction of high incidence rates by screening. Additional data on stage distribution at diagnosis or on participation rates in screening, especially in high risk groups, would be useful to obtain a first indication of the impact of screening.[17]

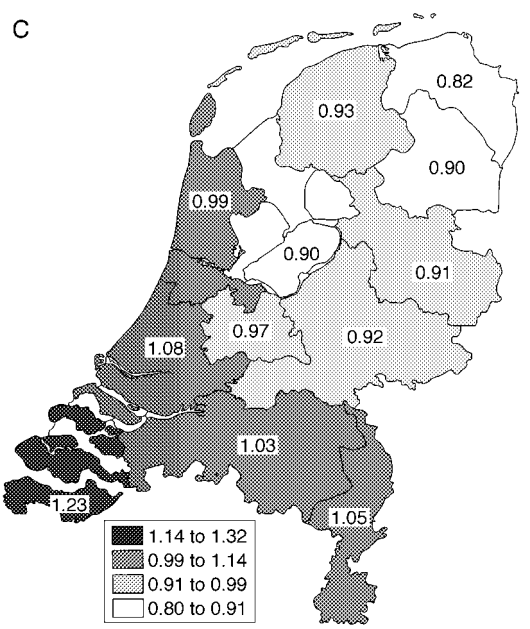

Figure 1c Regional variation in incidence-adjusted mortality from cervical cancer (relative risk)

A possible explanation for incidence-adjusted mortality variations is the case-fatality of conditions. In our study, in-hospital mortality was used as an indicator of case-fatality for those conditions where acute hospital care was considered to be an important determinant of outcome. For all of the conditions studied, statistically significant in-hospital mortality variations were found, but their contribution to the total mortality variations varied. The strongest, positive correlation between in-hospital and total mortality was demonstrated for CVA, suggesting that high mortality rates are associated with high in-hospital mortality risks. Before conclusions can be drawn, however, additional information is needed to decide whether increased in-hospital mortality risks are due to shortcomings in in-hospital care or to the fact that on average more severely diseased patients are admitted to the hospital. For CVA for example, the increased survival during the last decade has been ascribed to both improved supportive care ('stroke-units')[18] and a trend towards less severe strokes.[19] In fact, severity variations themselves may be a result of shortcomings in health care delivery, such as delay in arrival at the hospital.

In this study, hospital discharge data have been used as proxy for disease incidence. Four factors may invalidate the use of discharge data as incidence measures, i.e. (1) quality of data collection, (2) variations in admission policy, (3) multiple admissions and (4) lag time between the incidence, medical intervention and mortality. Firstly, the coverage of the hospital discharge registry is high (99.2%) and therefore the chance of selective registration is negligible. It is unknown however,

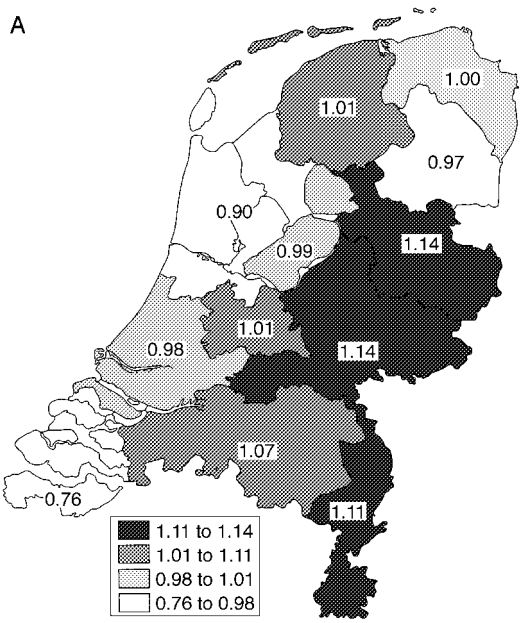

Figure 2a Regional variation in mortality from hypertensive and cerebrovascular disease (relative risk)

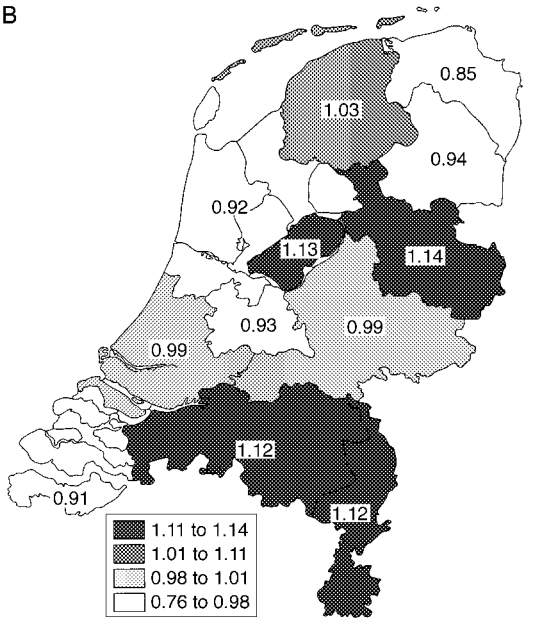

Figure 2b Regional variation in incidence of hypertensive and cerebrovascular disease (relative risk)

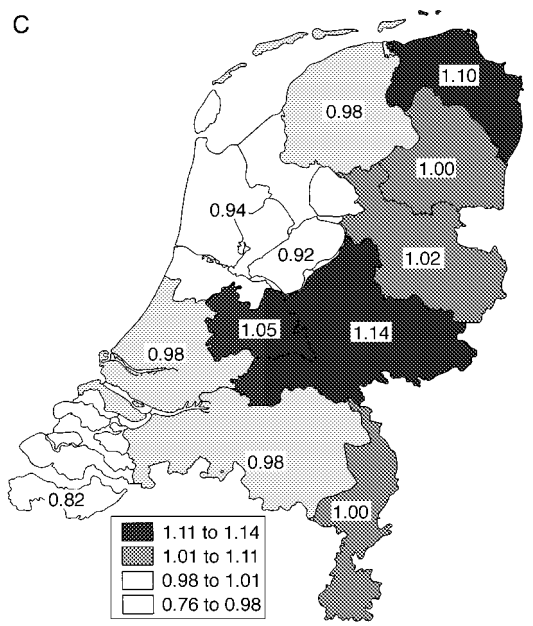

Figure 2c Regional variation in incidence-adjusted mortality from hypertensive and cerebrovascular disease (relative risk)

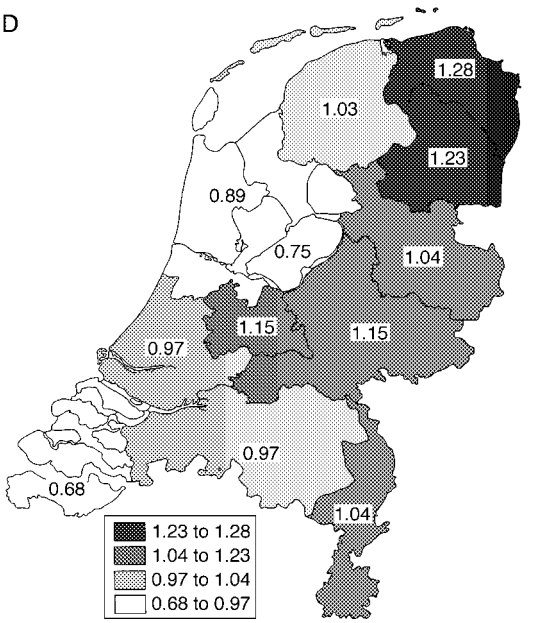

Figure 2d Regional variation in in-hospital mortality from hypertensive and cerebrovascular disease (relative risk)

whether regional variations in misclassification of conditions exist. If so, this may have led to an invalid reflection of the real incidence variations.

Secondly, 'artificial' incidence differences may be caused by regional variations in admission policy. Although we tried to adjust for those variations by taking into account the total number of admissions irrespective of diagnosis, admission criteria may still vary for a specific condition. In general, a less strict admission policy in a particular region will lead to an overestimation of the 'incidence' rate and vice versa. Unfortunately, no disease-specific data are available regarding regional policies on referral and hospital admissions.

Thirdly, hospital discharge data most accurately estimate the incidence of acute diseases which usually require one single hospital admission (e.g. appendicitis).[4] We developed a method that omitted re-admissions but we can only provide a crude indication of the validity of the method. As municipality is used as one of the keys to identify a re-admission, the validity of the

method is partly determined by regional variations in frequency of moving. In the Netherlands, 4% of inhabitants annually move to another village or town (mainly those under age 50), with a regional variation from 3.5% to 5.1%.[20] Therefore, a slightly varying overestimation of the incidence will have occurred, resulting in a relative underestimation of incidence-adjusted mortality.

Fourth, due to time lags between incidence (i.e. the first hospital admission for the disease) and mortality, the measured mortality may reflect incidence variations that existed before or only in the beginning of the study period. For conditions with a relatively long time lag (in our study mainly the malignant neoplasms), the incidence estimate will be most valid when the incidence remains constant over time. A first inspection of our data however, revealed that the incidence of cancer of the testis increased in eight regions (average yearly +1.3%) and decreased in four regions (average yearly –3.2%), while the incidence of cervical cancer increased in three regions (average yearly +1.0%) and decreased in nine regions (average yearly –3.7%). In general, declining incidence trends will lead to an underestimation of the real (historical) 'incidence' whereas the reverse is true for increasing incidence numbers. Time lags may also exist between the intervention and mortality. Fortunately, most of the selected conditions seem not to have very long (say, more than 5 years) time lags. Only rheumatic heart disease may be an exception as far as prevention by treatment of streptococcal infections is concerned.[21]

Finally, the causes of death extracted from the hospital registry sometimes differ from those in the death statistics. This is due to the fact that patients may die in hospital from disease A (registered in the death statistics), while being admitted for disease B (which is extracted as cause of death from the hospital registry). This misclassification may have led to an invalid estimation of the correlation between in-hospital mortality and total mortality.

Our study can be placed within a tradition of research on 'avoidable' mortality that started with the study of Charlton *et al.*[3] Most studies examined socioeconomic and/or health care variables in order to provide a first explanation of mortality variations. Bauer *et al.*[4] were the first to include incidence data. Just as in our study, positive correlations were found between incidence and mortality for a number of conditions. Westerling[11] studied the relationship between mortality and incidence for selected malignant neoplasms. In this study, the mortality variations for cervical cancer could only partly be explained by variations in incidence rates. In another study, Westerling[12] reported on the relationship between deaths outside hospital and total mortality for five (groups of) diseases. For CVA, the only condition that corresponded with our study, he reported that most of the mortality from CVA (85%) occurred in hospital, a higher percentage than we found in our study (57%). Part of this difference may be caused by the way of registering in-hospital mortality: in the study of Westerling *et al.* the death certificates included information on the place of death. Furthermore, Westerling *et al.* found no evidence that the place of death (in or outside hospital) could explain regional mortality variations for CVA, in contrast to our study in which 60% of the mortality variations could be explained by in-hospital mortality.

Our study is the first to combine 'avoidable' mortality and discharge data for a broad range of conditions. It is to be expected that the incidence-adjusted mortality rates are more sensitive for quality-of-care variations than the 'crude' mortality variations. Future monitoring of 'avoidable' mortality variations should therefore profit from the inclusion of incidence data. The incidence data should not necessarily be derived from one (hospital discharge) registry as was the case in this study. It may even be better to use other (disease-specific) registries, such as cancer registries, as they may contain more reliable incidence data and background information.

Even if the use of incidence data is a step forward in the analysis of 'avoidable' mortality variations, further research is still called for. There is already a tradition of studying individual 'avoidable' deaths in order to see whether these deficiencies in health care delivery can be traced (medical audit).[22] Until now however, only a few of these studies have been explicitly linked to the description of 'avoidable' mortality variations.[23,24] Audit studies may have considerable potential as part of a system of improving medical care and reducing 'avoidable' mortality.[25] A national audit in Scotland on deaths from cancer of the testis for example showed that only 51% of the patients received optimal treatment. The most frequent reason for treatment being assessed as suboptimal was 'poor therapeutic management', i.e. inappropriate chemotherapy or inappropriately delivered chemotherapy and delayed surgical referral.[26] It is clear that these findings offer some keys to improve the quality of care. The activities of professional groups will be indispensable for the data collection and peer assessment of the quality of the care process. The description of mortality variations, as presented in this article, may be useful as an identification of those conditions and/or regions that deserve further research.

References

[1] Rutstein DD, Berenberg W, Chalmers TC, Child CG, Fishman AP, Perrin EB. Measuring the quality of medical care: a clinical method. *N Engl J Med* 1976;**294:**582–89.

[2] Rutstein DD, Berenberg W, Chalmers TC, Fishman AP, Perrin EB, Zuidema GD. Measuring the quality of medical care: second revision of tables of indexes. *N Engl J Med* 1980;**302:**1146.

[3] Charlton JRH, Hartley RM, Silver R, Holland WW. Geographical variation in mortality from conditions amenable to medical intervention in England and Wales. *Lancet* 1983;**i:**691–96.

[4] Bauer RL, Charlton JRH. Area variation in mortality from diseases amenable to medical intervention: the contribution of differences in morbidity. *Int J Epidemiol* 1986;**3:**408–12.

[5] Carr-Hill RA, Hardman GF, Russel IT. Variations in avoidable mortality and variations in health care resources. *Lancet* 1987;**i:**789–92.

[6] Mackenbach JP, Stronks K, Kunst AE. The contribution of medical care to inequalities in health: differences between socio-economic groups in decline of mortality from conditions amenable to medical intervention. *Soc Sci Med* 1989;**29:**369–76.

[7] Schwartz E, Kofie VY, Rivo M, Tuckson RV. Black/white comparisons of deaths preventable by medical intervention: United States and the District of Columbia 1980–1986. *Int J Epidemiol* 1990;**19:**591–98.

[8] Pampalon R. Avoidable mortality in Québec and its regions. *Soc Sci Med* 1993;**37:**823–31.

[9] Pearce N, Pomare E, Marshall S, Borman B. Mortality and social class in Maori and nonMaori New Zealand men: changes between 1975–7 and 1985–7. *N Z Med J* 1993;**106:**193–96.

[10] Marshall SW, Kawachi I, Pearce N, Borman B. Social class differences in mortality from diseases amenable to medical intervention in New Zealand. *Int J Epidemiol* 1993;**22:**255–61.

[11] Westerling R. Components of small area variation in death rates: a method applied to data from Sweden. *J Epidemiol Community Health* 1995;**49:**214–21.

[12] Westerling R. Can regional variation in 'avoidable' mortality be explained by deaths outside hospital? A study from Sweden, 1987–1990. *J Epidemiol Community Health* 1996;**50:**326–33.

[13] Gaizauskiené A, Gurevicius R. Avoidable mortality in Lithuania. *J Epidemiol Community Health* 1995;**49:**281–84.

[14] Bithell JF, Dutton SJ, Neary NM, Vincent TJ. Controlling for socioeconomic confounding using regression methods. *J Epidemiol Community Health* 1995;**49(Suppl.2):**S15–S19.

[15] Dobson AJ. *An Introduction to Statistical Modelling*. London/New York: Chapman and Hall, 1983.

[16] Broer J, Mackenbach JP, Bijlsma F, Meyboom-de Jong B. Regionale verschillen in aangifte van hartvaatziekten als doodsoorzaak. *Tijdschr Soc Gezondheidsz* 1996;**74:**312–19.

[17] Bull AR, Hatton P, Bensley DC, Bull SJ, Fryers PT. Standardized mortality from cervical cancer: a measure of performance? *J Public Health Med* 1994;**16:**16–22.

[18] Langhorne P, Williams BO, Gilchrist W, Howie K. Do stroke units save lives? *Lancet* 1993;**342:**395–98.

[19] Wolf PA, Dáugostina RB, O'Neal MA *et al.* Secular trends in stroke incidence and mortality: the Framingham study. *Stroke* 1992;**23:**1551–55.

[20] Statistics Netherlands. *Maandbericht Statistiek van de Bevolking*. Voorburg, 1993.

[21] Mackenbach JP. *Mortality and Medical Care*. Rotterdam: Erasmus University, 1988 [thesis].

[22] Donabedian A. The study of preventability in adverse outcomes. In: *Explorations in Quality Assessment and Monitoring (Vol. 3): The Methods and Findings of Quality Assessment and Monitoring*. Michigan: Ann Arbor, Health Administration Press, 1985, pp.284–307.

[23] Payne JN, Milner PC, Saul C, Bowns IR, Hannay DR, Ramsau LE. A locally-based confidential enquiry into stroke and hypertensive deaths (CESHAD): the methodolgy and illustrative results from an average sized health district. *Br Med J* 1993;**307:**1027–30.

[24] Wolfe C. Deaths from stroke in younger people. Audit can identify the avoidable factors. *Br Med J* 1993;**307:**1020–21.

[25] Westerling R. Studies of avoidable factors influencing death: a call for explicit criteria. *Qual Health Care* 1996;**5:**159–65.

[26] Howard GCW, Clarke K, Elia MH *et al*. A Scottish mortality study assessing cause of death, quality of and variation in management of patients with testicular non-seminomatous germ-cell tumours. *Br J Cancer* 1995;**72:**1307–11.