ORIGINAL ARTICLE

The Projected Burden of Stroke in the German Federal State of Hesse Up to the Year 2050

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SUMMARY

Introduction: The aging of the population in Germany will lead to an increased number of stroke patients, but at present there are hardly any concrete estimates of how many stroke patients can be expected in the future.

Methods: This study provides estimates of future numbers of stroke patients in the German federal state of Hesse up to the year 2050. The calculations are based on data obtained from a state-wide quality assurance program for stroke, as well as on demographic data provided by the Statistical Office of the state of Hesse.

Results: The annual number of stroke patients in Hesse is projected to increase steadily from 20 846 in 2005 to more than 35 000 in 2050. By the year 2050, the majority of stroke patients will be 75 years or older. The proportion of severely handicapped stroke patients will increase above average.

Discussion: The projected increase in the number of stroke patients will require substantial changes in health care services unless the incidence of stroke falls in the future, e.g. as the result of improved primary prevention. The development of strategies to prevent stroke in elderly persons should be given a high priority from a health policy perspective.

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Key words: stroke, epidemiology, demographic change, projection, health services research

According to the population projections of the state and federal statistical offices (1), rising life expectancies and falling birth rates will change Germany's demographic structure drastically over the coming decades. In addition to socioeconomic and social problems, the healthcare system will be affected substantially. The burden of disease entities whose incidence increases with age will rise over the coming decades in Germany. In this context, stroke is of particular relevance; even now it is the acute event that results most often in permanent invalidity and need for care (2, 3). The effects of stroke on the healthcare system are enormous even nowadays. According to a recent study, the direct medical costs of stroke care in Germany in 2004 were 7.1 billion euros, and the lifetime costs per case were more than 43 000 euros (4).

On the background of the demographic development in Germany, the number of stroke patients may be assumed to increase appreciably in the coming years. In order to optimize the healthcare system in line with what will be required, it is of utmost importance to characterize the number of stroke patients over the coming years as precisely as possible (5).

This study is based on a state registry for quality assurance in stroke care in the German state of Hesse and on population projections for 2050 from the state statistical office. The registry aimed to capture all cases of stroke treated on an inpatient basis in Hesse in 2005. We aim to show future changes in the frequency of stroke on the basis of current hospitalization data from stroke patients and data on the demographic change.

Methods

Stroke database Hesse

On 1 June 1995, a contract between Hesse's hospital association and the associations of Hesse's statutory health insurances came into force; the objective was quality assurance in inpatient care in Hesse. The registry for quality assurance in stroke care, which was established by the Gesellschaft für Qualitätssicherung Hessen (www.gqhnet.de, a state-wide quality assurance program for stroke) on the legal basis mentioned above, was introduced in 1996, initially in a pilot phase. Since 2003, it became mandatory for all acute hospitals

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Participants in quality assurance in stroke treatment in Hesse (>20 cases/year). The numbers reflect the number of centers at each location.

participating in stroke care in Hesse (this includes neurology hospitals but also hospitals for internal medicine and acute geriatric institutions, $n > 100$) to document inpatients treated for stroke in an IT supported database (a list of participating hospitals and further details can be found at www.gqhnet.de [in German language only]).

All patients over the age of 16 were to be documented who reached a hospital within seven days after the acute event if their diagnosis was transitory ischemic attack (TIA, ICD-10: G45), ischemic infarction (I36), intracerebral hemorrhage (I61), or a stroke that is not defined as ischemia or hemorrhage (I64) (6). Data from patients with subarachnoid hemorrhages have been collected in Germany only since 2007 and are not included in this analysis. *Figure 1* shows the participating hospitals – with more than 20 documented cases per year – marked on a map of Hesse, which illustrates the statewide data collection. In addition to baseline data such as age and sex, data including severity of stroke (classified according to the modified Ranking Scale [mRS] at admission and discharge), vascular risk factors, diagnosis and treatment, etiology, and discharge modality were prospectively documented. The discharge diagnoses were ICD-10 coded and encrypted.

A comparison between Hesse's stroke database and the data from the Statistical Office on hospitalization of stroke patients in Hesse showed that for 2005, 84% of all TIA patients (G45) and 86% of all patients with ischemic stroke (I63) were captured in the stroke

Age pyramids of Hesse's population for 2005 (a) and 2050 (b). Source: Hesse State Statistical Office

TABLE 1a

**Stroke incidence in 2005 per 100 000 population in Hesse
(cases of first stroke and recurrent stroke treated on an inpatient basis)**

	All	Male	Female	G45	I63	I61	AC	I64
18–24	5	4	6	1	2	1	0	0
25–34	15	15	15	4	9	1	0	0
35–44	40	46	33	13	23	4	0	0
45–54	129	162	95	37	77	12	0	3
55–64	354	467	242	92	217	34	3	11
65–74	845	1042	666	209	537	70	10	28
75–84	1967	2127	1868	499	1211	153	29	103
> 84	3088	3023	3112	756	1915	183	20	235
Total	342	334	350	87	212	27	4	16

G45, transient cerebral ischemic attack (ICD-10, G45); I63, cerebral infarction; I61, intracerebral hemorrhage; AC, anticoagulant associated hemorrhage (proportion of I61); I64, undefined stroke; all, all strokes (G45, I61, I63, I64).

database. 68% of intracerebral hemorrhages were captured. It should be noted that the Hesse State Statistical Office also collects data on strokes with symptom onset after seven days and transferred patients, which are not entered in the stroke database. For ischemia and TIA patients, we assume that 90% of all hospitalized acute stroke patients were captured.

For our analysis, we selected from the entire database all cases with a hospital admission date between 1 January and 31 December 2005 (n = 20 873). Data sets that had discharge diagnoses other than these four, and data sets in which age and sex were missing, were excluded. Our final analysis therefore included data sets from 20 846 patients, 9961 men and 10 885 women. For 15 644 patients, no further stroke events were known

from their medical histories other than the event that was documented in the database.

Population projections in Hesse

Population projections for the federal state of Hesse (7) were calculated by the state's Statistical Office up to 2050 (figure 2). The population as at 31 December 2005, categorized by age and sex, forms the basis of the current projections at state level. The projections follow the component projection method, in which the population is segmented by age and projected on the basis of demographically different probabilities for births, deaths, and migrations. The three components are based on certain assumptions (according to the most probable variant – 1) about birth rates (1.36 children per woman), life

TABLE 1b

Incidence of first strokes in 2005 per 100 000 population in Hesse

	All	Male	Female	G45	I63	I61	AK	I64
18–24	5	4	6	1	2 (0)	1 (0)	0	0 (0)
25–34	13	14	13	4	8 (3)	1 (1)	0	0 (0)
35–44	36	41	30	11	20 (14)	4 (0)	0	0 (0)
45–54	109	137	81	32	65 (64)	10 (24)	0	3 (0)
55–64	285	363	207	75	173 (147)	28 (31)	2	9 (0)
65–74	635	774	509	159	397 (426)	56 (71)	8	22 (5)
75–84	1413	1471	377	360	861 (976)	121 (206)	21	71 (33)
> 84	2225	2116	2265	569	1352 (1 681)	142 (62)	18	162 (374)
Total	257	247	265	66	157 (–)	22 (–)	3	11 (–)
Norm*	163	187	140	43	99 (104)	14 (19)	2	7 (5)

G45, transient cerebral ischemic attack (ICD-10, G45); I63 cerebral infarction; I61, intracerebral hemorrhage; AC, anticoagulant associated hemorrhage (proportion of I61); I64, stroke, not specified as hemorrhage or infarction; all, all strokes (G45, I61, I63, I64).

In parentheses: corresponding incidence rates from the Erlangen stroke registry.

*, adjusted to European standard population (1988).

Total number of stroke patients to 2050; TIA transient ischemic attack; mRS, modified Rankin Scale

FIGURE 3

	2005	2010	2020	2030	2040	2050
Population of Hesse						
Total	6 092 354	6 069 900	5 963 800	5 781 300	5 503 200	5 145 200
Men	2 983 150	2 974 700	2 921 300	2 826 500	2 683 100	2 503 900
Women	3 109 204	3 095 200	3 042 400	2 954 800	2 820 100	2 641 300
> 84 years	116 404	147 600	184 200	243 200	299 300	426 300
Strokes by age						
Total	20 846	22 491	25 995	29 616	33 438	35 085
18–24 years	23	23	21	18	17	15
25–34 years	113	110	110	95	82	81
35–44 years	419	356	293	291	251	218
45–54 years	1 128	1 278	1 126	937	929	804
55–64 years	2 539	2 681	3 330	2 982	2 498	2 490
65–74 years	5 443	5 632	5 721	7 293	6 595	5 620
75–84 years	7 586	7 850	9 715	10 511	13 848	12 735
> 84 years	3 595	4 561	5 679	7 489	9 218	13 122
Strokes by diagnosis						
TIA (G45)	5 313	5 724	6 606	7 493	8 454	8 850
Infarction (I63)	12 906	13 928	16 088	18 358	20 706	21 706
Hemorrhage (I61)	1 659	1 775	2 043	2 294	2 553	2 607
Discharge/transfer to:						
Home	11 267	12 077	13 837	15 584	17 261	17 693
Rehab institution	4 368	4 661	5 362	6 063	6 760	6 819
Care home	1 340	1 491	1 784	2 111	2 531	2 874
mRS 4–5	4 179	4 587	5 397	6 302	7 381	8 165

Decrease > 50 %		No change		Increase 10–30 %
Decrease 30–50 %				Increase 30–50 %
Decrease 10–30 %				Increase >50 %

expectancies (increase to 2050 in male neonates from 76.7 to 83.5 years and in female neonates from 81.9 years to 88 years), and net immigrations.

According to these calculations, Hesse's population will shrink slightly in the next few years, but population decrease will accelerate from 2020. In 2050, Hesse's population will number 5.1 million, some 15% less than today. Especially the proportion of older people (aged >85 years) in the population is set to rise notably, from 116 000 in 2005 to 426 000 in 2050 (+266%).

Statistics

On the basis of the statewide stroke data for 2005, we calculated as a first step incidence rates per age category for the total number of strokes and for the different subtypes (first strokes and recurrent strokes). In a second step, we projected from the development of the projected population size per age category and the calculated

incidence rates the absolute number of stroke patients for 2010 to 2050.

Results

Incidence of stroke in Hesse

In 2005, 20 846 patients were admitted to hospital in Hesse with TIA, cerebral infarction, or intracerebral hemorrhage. Assuming complete capture in the Hesse stroke database, the incidences of hospitalized stroke patients for 2005 can be calculated (table 1a). According to the calculations, 342 hospitalized stroke patients (including TIA) per 100 000 population and year can be expected in Hesse. 212/100 000 of these will be cerebral infarctions and 27/100 000 will be intracerebral hemorrhages. In order to better compare these data with the published literature on the incidence of stroke, we excluded all patients with a prior stroke and also calculated incidence rates for first strokes in Hesse (table 1b).

As comparators, corresponding values from Erlangen's stroke registry are presented, which is to date the most important population based study of stroke incidence in Germany. For Hesse, the calculated incidence of first (hospitalized) strokes (including TIA) was 257/100 000 population and year. The incidence of cerebral infarctions was 157/100 000 and of intracerebral hemorrhages, 22/100 000. When the rates from Hesse and Erlangen are adjusted to a European standard population, which adjusts for the different age structures of the two populations, the values in both registries are comparable for cerebral infarctions (Hesse 99/100 000, Erlangen 104/100 000) and cerebral hemorrhages (Hesse 14/100 000, Erlangen 19/100 000). Data about the incidence of TIA (66/100 000) and anticoagulant associated hemorrhage (3/100 000) can be presented for Germany for the first time.

Projection of stroke numbers in Hesse

If incidence rates are assumed to be constant, the total number of stroke patients will increase to 35 000 (+68%; figure 3) because of the demographic development in Germany alone. In 2005, 0.34% of the total population was hospitalized with stroke; in 2050 this proportion will have doubled to more than 0.68%.

Especially the proportions of older stroke patients will increase notably in the future (age 75 to 84 years: +68%, >84 years: +265%) (figures 4 und 5). The proportion of older people in all stroke patients (age >74 years) is currently 54%; this will rise to 74% by 2050. The proportion of younger stroke patients (age <65 years), however, will fall from 20% currently to some 10%. As far as stroke subtypes are concerned, intracerebral hemorrhages will rise disproportionately slowly, and their proportion in all stroke patients will fall (TIA +67%, cerebral infarction +68 %, intracerebral hemorrhage +57%). As far as the status at discharge is concerned, the proportion of patients who can be discharged directly to their homes will rise disproportionately slowly (+57%). The proportion of patients, however, who will be transferred directly to a care home without prior rehabilitation, will rise disproportionately fast and will more than double from 1340 in 2005 to 2800 in 2050 (+114%).

Discussion

In terms of healthcare provision and health policy, estimating the numbers of future stroke patients is of crucial importance. Our study shows that demographic developments in the coming decades will in all probability lead to a clear increase. In spite of a drop in the population in Hesse by some 15%, the number of stroke patients in our study will rise by 68% by 2050. The overwhelming majority of those affected will be older than 74.

From the data it can be concluded easily that – if admission behaviors remain unchanged – the bed capacities in acute hospitals and rehabilitation institutions that are available for stroke patients' care will have to be expanded substantially over the coming years. Because of the notable increase especially of older stroke patients,

Population trends and numbers of stroke patients in Hesse. The number of patients requiring serious care with modified Rankin Scale (mRS) 4–5 and patients with intracerebral hemorrhages (ICD-10: I61) are listed separately.

who remain in need of care for longer than younger patients, the demand for care home places will also rise disproportionately.

From the perspective of healthcare provision, one advantage for our analysis is the fact that in order to establish the status quo, data from a hospital based registry within an entire federal state were available. In contrast to population based registries – which are methodologically optimal for collecting data on stroke incidence rates from an epidemiological perspective – the database we used for our analysis did not include stroke patients who received care on an outpatient basis or in care homes. By contrast, a hospital based registry enables exact calculations of the current (and future) care provision capacity that is required for inpatient stroke care.

The predictions for Hesse can be transferred to other federal states or the entire Federal Republic of Germany only to a limited extent. According to the 11th population projection by the federal government (1), the number of people older than 64 will rise by 43% in Hesse from 2010 to 2050. In the average of all federal states, this value is only 31%. The absolute number of older people will rise particularly strongly in Hamburg (+57%), Baden-Württemberg (+53%), Berlin (+49%), and Bavaria (+49%). The increases will be particularly low in Saarland (+15%), Thuringia (+15%), Saxony (+10%), and Saxony-Anhalt (+5%). For the former, the prediction will probably underestimate the number of future stroke patients and for the latter, it will overestimate the number.

We investigated exclusively the question of how stroke numbers will develop as a result of demographic changes. The authors did not make any assumptions about possible changes in stroke incidence. It is therefore possible that the numbers of future stroke patients in the projections were radically overestimated or underestimated. It is particularly possible that primary prevention measures (such as hypertension treatment, anticoagulation treatment of patients with atrial fibrillation, improved patient education and risk factor control, etc) may in future lead

Age composition of all strokes in Hesse in 2005 (on the left) and in 2050 (on the right). The number of patients older than 74 will increase notably; the number of younger stroke patients will decrease.

to a decrease in age related stroke incidence rates, similar to the trend that is already detectable for myocardial ischemias (3). It has thus far not been possible to confirm a similar trend for stroke to date (8). Results from recently published studies are not consistent; some show stable incidence rates (9–12), some show incidence rates that eventually fall slightly (13–15). We compared data from Hesse (incidence of ischemic cerebral infarction 99/100 000) with data from Erlangen (incidence 104/100 000), which indicates mostly stable age adjusted incidence rates, although the two data collections are 13 years apart. If in spite of all this, more effective primary prevention measures will yield a 10% decrease in age adjusted stroke incidence rates, demographic developments would still mean an over 50% increase in strokes by 2050. Identical or decreasing stroke numbers in 2050 as in 2005 (the basis of the calculation) could be expected only in the context of a decrease of age adjusted stroke incidence by at least 40%. On the other hand it is not impossible that if other risk factors continue to increase – such as obesity, diabetes, metabolic syndrome, etc. – the number of future stroke patients in this analysis was underestimated.

A comparison with similar prognoses from other countries supports the core finding of our analysis. A US study (16) predicts an increase in absolute stroke mortality by 98% between 2002 and 2032. A recently published Swedish study (9) used a similar method to calculate a 59% increase in annual first strokes by 2050. These results are similar to our own. A Dutch study (5) predicts a 27% increase in patients with stroke from 2000 to 2020. A study based on data from Erlangen (4) also predicts a notable rise in stroke numbers in future.

Error sources for our analysis may be due to the particularities of the stroke registry that the study is based on. In spite of mandatory documentation and the assumption that absolutely all hospitalized stroke patients were captured it is likely that a small percentage of stroke patients treated in hospital were not captured. Further it is likely that a percentage of patients with intracerebral hemorrhage were treated in neurosurgery hospitals, and for these, data collection has been mandatory only since 2007. And finally, there is an unknown quantity of stroke patients who did not receive inpatient care in a hospital setting. In the Erlangen stroke project (17), however, the proportion of stroke patients treated in hospital was 95%, so that it is likely that in Hesse too, the vast majority of stroke patients were treated on an inpatient basis and thus included in our study. Finally, the fundamental limitation of this analysis is that projections become less exact the further they reach into the future.

Principally, it will be possible in future to model the efficacy of preventive measures on the background of demographic developments. If the therapeutic effect of an intervention is known from a large, controlled study then the effect can be calculated at the population level. This should make it possible to model the effects of optimized treatment of common risk factors – such as hypertension, atrial fibrillation, and asymptomatic carotid stenoses – on stroke incidence in an aging population. What is certain is that prevention programs that aim specifically to prevent strokes in older people should be given a high priority in terms of health policy.

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Conflict of interest statement

The authors declare that no conflict of interest exists according to the guidelines of the International Committee of Medical Journal Editors.

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REFERENCES

1. Eisenmenger M, Pötsch O, Sommer B: Bevölkerung Deutschlands bis 2050 – 11. Koordinierte Bevölkerungsvoraberechnung. Statistisches Bundesamt <http://www.destatis.de>
2. Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJ: Global and regional burden of disease and risk factors 2001: systematic analysis of population health data. *Lancet* 2006; 367: 1747–57.
3. Rosamond W, Flegal K, Friday G et al.: Heart disease and stroke statistics – 2007 update: a report from the american heart association statistics committee and stroke statistics subcommittee. *Circulation* 2007; 115: 69–171.
4. Kolominsky-Rabas PL, Heuschmann PU, Marschall D et al.: Lifetime cost of ischemic stroke in Germany: results and national projections from a population-based stroke registry: the Erlangen stroke project. *Stroke* 2006; 37: 1179–83.
5. Struijs JN, van Genugten ML, Evers SM, Ament AJ, Baan CA, van den Bos GA: Modeling the future burden of stroke in the Netherlands: impact of aging, smoking, and hypertension. *Stroke* 2005; 36: 1648–55.

6. Foerch C, Misselwitz B, Sitzer M, Berger K, Steinmetz H, Neumann-Haefelin T: Difference in recognition of right and left hemispheric stroke. *Lancet* 2005; 366: 392–3.
7. Hessisches Statistisches Landesamt: Bevölkerung in Hessen 2050. Wiesbaden; 2005.
8. Feigin VL, Lawes CM, Bennett DA, Anderson CS: Stroke epidemiology: a review of population-based studies of incidence, prevalence, and case-fatality in the late 20th century. *Lancet Neurol* 2003; 2: 43–53.
9. Hallstrom B, Jonsson A-C, Nerbrand C, Norrving B, Lindgren A: Stroke incidence and survival in the beginning of the 21st century in southern Sweden. Comparisons with the late 20th century and projections into the future. *Stroke* 2008; 39(1): 10–5.
10. Bejot Y, Giroud M, Rouaud O et al.: Trends in stroke incidence and case-fatality rates over a 20-year period (1985–2004) in Dijon, France. *Bull Acad Natl Med* 2007; 191: 305–22.
11. Kleindorfer D, Broderick J, Khoury et al.: The unchanging incidence and case-fatality of stroke in the 1990s: a population-based study. *Stroke* 2006; 37: 2473–8.
12. Heinemann LA, Barth W, Garbe E, Willich SN, Kunze K: Epidemiologic data of stroke. Data of the WHO-MONICA project in Germany. *Nervenarzt* 1998; 69: 1091–9.
13. Rothwell PM, Coull AJ, Giles MF et al.: Change in stroke incidence, mortality, case-fatality, severity, and risk factors in Oxfordshire, UK from 1981 to 2004 (Oxford vascular study). *Lancet* 2004; 363: 1925–33.
14. Anderson CS, Carter KN, Hackett ML et al.: Trends in stroke incidence in Auckland, New Zealand, during 1981 to 2003. *Stroke* 2005; 36: 2087–93.
15. Mayo NE, Nadeau L, Daskalopoulou SS, Cote R: The evolution of stroke in Quebec: a 15-year perspective. *Neurology* 2007; 68: 1122–7.
16. Elkins JS, Johnston SC: Thirty-year projections for deaths from ischemic stroke in the united states. *Stroke* 2003; 34: 2109–12.
17. Kolominsky-Rabas PL, Sarti C, Heuschmann PU et al.: A prospective community-based study of stroke in Germany – the Erlangen stroke project (ESPRO): incidence and case fatality at 1, 3, and 12 months. *Stroke* 1998; 29: 2501–6.

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