THE NEW ZEALAND MEDICAL JOURNAL
Vol 117 No 1202 ISSN 1175 8716

Diurnal, weekly, and seasonal variations in stroke occurrence in a population-based study in Auckland, New Zealand

Neil Anderson, Valery Feigin, Derrick Bennett, Joanna Broad, Megan Pledger, Craig Anderson, Ruth Bonita

Abstract

Aims To determine (via a population-based study in Auckland, New Zealand) if there are diurnal, weekly, or seasonal variations in the occurrence of stroke.

Methods All new stroke events in Auckland residents were traced. Time of onset of the stroke was defined as the time when neurological symptoms were first noticed. The day of the week and month of onset were analysed for all strokes.

Results 1711 patients were registered over 1 year. The rate ratios for the onset of stroke in each 6-hourly interval compared with reference interval (1800–2359 hours) were 0.74 (95% CI: 0.61–1.10) for 0000–0559 hours, 2.88 (95% CI: 2.48–3.34) for 0600–1159 hours and 1.74 (95% CI: 1.49–2.05) for 1200–1759 hours. Rate ratios of the seasonal occurrence of stroke compared with spring were 0.75 (95% CI: 0.65–0.86) for summer, 0.83 (95% CI: 0.73–0.95) for autumn and 1.08 (95% CI: 0.96–1.23) for winter. No weekly pattern of stroke occurrence was observed.

Conclusions Strokes were less likely to occur during the summer and autumn than in the winter or spring. There was an increase in the occurrence of stroke in the late morning. The results have implications for the provision of acute stroke services in the community and in hospital.

Temporal variations in the occurrence of stroke may provide insight into the factors that trigger the onset of a stroke. Most studies have identified a circadian variation in the time of onset of stroke with peak occurrence between 0600 and 1200 hours.[1]

There is less information available on variations in the day of the week and season of onset of stroke. Conflicting results in previous studies can be explained by differences in study design (hospital-based versus population-based studies), environmental conditions, risk factor profiles, and relatively small numbers of events available for analysis. There is little information available on the temporal patterns of stroke occurrence in countries with a temperate climate.

Comparison of incidence studies of stroke in various climates may help to identify the mechanisms underlying seasonal variations in stroke onset. The aim of our study was to analyse the diurnal, weekly and seasonal variations in the occurrence of stroke in a large population-based study in Auckland, where there is relatively little variation in temperature throughout the year.[2]

Methods

The methods used in the Auckland Stroke Study have been described previously.[3] All new stroke events in residents of the Auckland region (study population approximately 945,000) in the 12 months

beginning 1 March 1991 were traced through multiple case-finding sources. These included patients who died before they were seen by a doctor, patients managed at home or in long-term care institutions, and Auckland residents who had been admitted with a stroke to a hospital outside the study area.

A stroke was defined as rapidly developing symptoms and/or signs of a focal or, at times, global loss of cerebral function lasting more than 24 hours or leading to death, with no apparent cause other than that of vascular origin. Subarachnoid haemorrhages were included in the main study, but data on the diurnal, weekly, and seasonal onset of subarachnoid haemorrhage were not included in this report.[4] We report only first-ever in a lifetime events.

The date and time of onset of the stroke was obtained during an interview conducted by a study nurse. For fatal events or severely disabled patients, the interview was held with close relatives or other observers who were familiar with the patient's health, but otherwise the interview was with the patient. Interviews were conducted as soon after the event as possible, except for fatal cases in which the interview was deferred for 6 weeks. The time of onset of the stroke was defined as the time when the patient or an observer first noticed neurological symptoms or signs.

The time of onset was distributed into six hourly intervals: 0000–0559, 0600–1159, 1200–1759, and 1800–2359 hours. When the time of onset was unknown (either because symptoms were first noticed on awakening, or the history was unreliable and the patient was alone at the time of onset), the patient was excluded from analysis of the diurnal variation in the time of onset.

A sensitivity analysis was performed to evaluate the possible effect of excluding patients who first noticed symptoms on awakening. The results were reanalysed by including these patients and assuming that the time of stroke onset was evenly distributed over the first eight hours of the day. The day of the week and month of onset were analysed for all strokes. The month of onset was analysed in seasonal quarters: summer (December–February), autumn (March–May), winter (June–August), and spring (September–November).

Rate ratios (RRs) were computed using Poisson regression allowing for under- and over-dispersion, in which incidence rates of stroke occurrence for a particular time interval were compared with that of a reference interval. Corresponding 95% confidence intervals (CI) were estimated. The population at risk was included in the models as offsets. We evaluated effects of age and sex by means of stratified analyses and adjustment. Age of the patients was conventionally dichotomised into two groups: 15–64 years and 65 years or more. All calculations were performed using SAS version 8.0 software.[5]

Results

A total of 1711 patients (excluding patients with subarachnoid haemorrhage) were registered for the study period of 1 year. The time of day of the onset of stroke was available for 1497 of the stroke events. Reliable information on the time of onset was not available for the other 214 patients (12.5%). The day of the week and the season of onset were known for all events. The age and gender structure of the patient population and the rate of hospitalisation have been reported elsewhere.[3]

Diurnal, weekly and seasonal distribution of the onset of strokes are presented in Tables 1, 2, and 3. The crude rate ratios of the temporal patterns of stroke occurrence are shown in Table 4.

The rate of occurrence of stroke was highest in the late morning (0600–1159 hours) compared with other times of the day, regardless of gender or age group of the patients. The risk of stroke in the afternoon (1200–1759 hours) was approximately two times higher as compared with the evening. If patients who had awakened with symptoms were included, and the time of onset was evenly distributed over the first 8 hours of the day, there was still a significant peak occurrence between 0600 and 1159 hours (Table 5).

Table 1. 24-hour distribution of onset of stroke by 6-hour periods (number of events and rate per 100,000 person-years)

	Men						Women					
Time	<65 years		≥65 years		total		<65 years		≥65 years		total	
Interval (hr)	n	rate	n	rate	n	rate	n	rate	n	rate	n	rate
0000-0559	35	133	57	1673	92	310	19	71	64	1509	83	262
0600-1159	79	301	241	7072	320	1080	44	164	313	7380	357	1127
1200-1759	57	217	122	3580	179	604	36	134	195	4598	231	730
1800-2359	35	133	84	2465	119	401	24	89	92	2169	116	366

Table 2. Distribution of onset of stroke by day of the week (number of events and rate per 100,000 person-years)

	Men						Women					
Day	<65 years		≥65 years		total		<65 years		≥65 years		total	
	n	rate	n	rate	n	rate	n	rate	n	rate	n	rate
Monday	23	50	90	1238	113	208	22	49	110	1883	132	260
Tuesday	38	83	66	908	104	192	20	44	111	1900	131	258
Wednesday	30	65	91	1252	121	223	16	36	132	2260	148	291
Thursday	28	61	80	1100	108	199	13	29	114	1951	127	250
Friday	39	85	99	1362	138	254	18	40	131	2242	149	293
Saturday	38	83	91	1252	129	238	13	29	100	1712	113	222
Sunday	25	54	61	839	86	158	31	69	81	1387	112	220

Table 3. Seasonal distribution of onset of stroke (number of events and rate per 100,000 person-years)

	Men						Women					
Season	<65 years		≥65 years		total		<65 years		≥65 years		total	
	n	rate	n	rate	n	rate	n	rate	n	rate	n	rate
Summer	40	52	115	1141	155	177	20	25	171	1194	191	204
Autumn	43	54	136	1320	179	200	37	46	174	1188	211	220
Winter	65	82	170	1649	235	262	50	62	225	1537	275	287
Spring	73	93	157	1540	230	259	26	32	209	1443	235	254

Table 4. Crude rate ratios of temporal patterns of stroke occurrence (RR and 95% CI)

Variable	Crude RR
Time of 24-hour day	
0000–0559	0.74 (0.61–1.10)
0600–1159	2.88 (2.48–3.34)
1200–1759	1.74 (1.49–2.05)
1800–2359*	reference
Day of the week	
Monday*	reference
Tuesday	0.96 (0.80–1.15)
Wednesday	1.10 (0.92–1.31)
Thursday	0.96 (0.80–1.15)
Friday	1.17 (0.99–1.39)
Saturday	0.99 (0.83–1.18)
Sunday	0.81 (0.67–0.97)
Season	
Summer	0.75 (0.65–0.86)
Autumn	0.83 (0.73–0.95)
Winter	1.08 (0.96–1.23)
Spring*	reference

*Reference variable; RR=rate ratio; CI=confidence interval.

Table 5. Sensitivity analysis: crude rate ratios of stroke occurrence including patients who awakened with symptoms

Time of 24-hour day	Crude RR (95% CI)
0000–0559	1.29 (1.09–1.53)
0600–1159	3.24 (2.80–3.75)
1200–1759	1.74 (1.49–2.05)
1800–2359*	reference

*Reference variable; RR=rate ratio; CI=confidence interval.

The risk of stroke was lowest in the summer, when there was a reduction of about 25% compared with spring. The risk in autumn was about 20% lower than in spring. There was a statistically insignificant trend towards an increased risk of stroke in winter. No particular weekly pattern of stroke occurrence was observed.

Discussion

The major strength of this study was its population-based design with the use of multiple overlapping sources of recruitment that ensured complete case ascertainment. This, together with the uniformly conducted, structured interview of patients and their relatives, minimised selection and information biases. The main drawback of the study was the low rate of imaging. For this reason, it was not possible to obtain reliable information about the temporal occurrence of different subtypes of stroke.

Diurnal patterns—In Auckland, there was a significant increase in occurrence of strokes between 0600 and 1159 hours. Our findings are consistent with a systematic review of 31 studies that reported the time of onset in more than 11,000 strokes.[1] In this review, there was a 49% increase in the occurrence of all types of stroke between

0600 and 1200 hours compared with the number expected if no circadian variation was present. Ischaemic and haemorrhagic strokes each had a significantly higher risk of occurrence between 0600 and 1200 hours, and lowest risk between midnight and 0600 hours.

A peak occurrence of stroke in the late morning appears to refute the concept that a nocturnal reduction in blood pressure and cerebral blood flow is an important trigger for atherothrombotic ischaemic stroke. Diurnal variation in blood pressure parallels the circadian rhythm of stroke, tending to be highest between 0600 and 1200 hours.[6]

An increase in blood pressure may precipitate an ischaemic stroke by triggering haemorrhage into an atherosclerotic plaque, or initiating the coagulation cascade. Therapeutic reduction of blood pressure in the morning may help to prevent stroke. Circadian variations in haemostatic function also may account for a predominance of strokes at the same time.

Circaseptan patterns—A consistent variation in the timing of strokes during the week has not been observed in previous studies.[6–12] The results of our study did not support a particular weekly pattern in the occurrence of strokes. Variations in the occurrence of stroke within the week in different studies may be explained by chance variation.

Seasonal patterns—Most studies on the seasonal variation of stroke have shown a peak occurrence in mortality,[13] and hospital admission rates[14–16] during the winter. The winter peak occurrence of stroke is inversely correlated with environmental temperature.[13] Hospital admission rates and mortality may not mirror the incidence of stroke. Higher hospital admission rates with stroke in the winter may reflect a greater need for hospital admission in cold weather rather than a higher incidence.[17] Pneumonia is a common cause of death in patients who have had an acute stroke. An increase in case fatality during the winter may reflect a higher frequency of respiratory tract infections in the winter.[17]

Conflicting results on the seasonal variation in the occurrence of stroke have been reported in population-based studies. In some of these studies there was a peak in incidence in the winter, or the winter and spring,[18–20] but there were no significant seasonal variations in the overall incidence of stroke in population-based studies in Oxfordshire,[17] Framingham,[7] and Italy.[21] Seasonal variations in the occurrence of different stroke subtypes were seen in Oxfordshire and Framingham.[7,17]

Most studies on seasonal variations in the occurrence of stroke have been conducted in countries that experience extremes in temperature between seasons. No seasonal variation in stroke occurrence, or hospital admissions was observed in subtropical countries.[22,23]

Admissions to hospital with an ischaemic stroke were more common on hot days in some subtropical countries,[22,24] and peaks in stroke mortality may occur during heat waves.[13,25] There may be a U-shaped relation between temperature and mortality from cerebral infarction.[26]

By contrast, mortality from intracerebral haemorrhage decreased with increasing temperature in China,[26] and the occurrence of intracerebral haemorrhage doubled on cold days compared with warm days in Taiwan.[23] In Auckland, there was a significant seasonal variation in the onset of strokes, even though there is relatively little

variation in temperatures during the year. Mean monthly air temperatures in Auckland vary from 10.8°C to 19.8°C.[2]

Seasonal variations in the occurrence of stroke may reflect fluctuations in risk factors. Blood pressure is significantly higher during the winter.[27] Lower environmental temperatures may predispose to development of a stroke by increasing blood pressure through induction of peripheral vasoconstriction.

Seasonal variations in the frequency of infections also may contribute to a higher incidence of ischaemic stroke in the winter.[28] Respiratory infections may increase the risk of arterial thrombosis by increasing plasma fibrinogen and inhibition of fibrinolysis by endotoxins. An alternative explanation for the apparent association between infection and stroke is that patients with cerebrovascular disease may be more vulnerable to develop or die from infections and these deaths are then attributed to the stroke.

Thrombolytic treatment improves the long-term outcome of patients with acute ischaemic stroke, but treatment must be started in the first three hours after the onset of symptoms.[29] Patients who wake up with symptoms can not receive thrombolytic treatment because the time of onset is uncertain.

Identification of the peak time of onset of strokes has implications for the provision of acute stroke services. In Auckland, 45% of strokes occurred between 0600 and 1200 hours. An acute general practice consultation is more difficult to obtain before 0900 than at other times of the day. This may explain why stroke patients who seek general practice consultation take longer to reach hospital than if they call the ambulance service.

Hospital stroke specialists are often committed to ward rounds and outpatient clinics in the morning, and may not be immediately available to assess patients who present at this time with an acute stroke. Recognition of these delaying factors may facilitate changes in management that will lead to earlier treatment of acute ischaemic stroke.

Author information: Neil Anderson, Neurologist, Department of Neurology, Auckland Hospital, Auckland; Valery Feigin, Senior Research Fellow and Associate Professor; Derrick Bennett, Statistician, Clinical Trials Research Unit, University of Auckland, Auckland; Joanna Broad, Epidemiologist, Section of Epidemiology and Biostatistics, School of Population Health, University of Auckland, Auckland; Megan Pledger, Statistician, Centre for Social and Health Outcomes Research and Evaluation, Massey University, Auckland; Craig Anderson, Professor, Clinical Trials Research Unit, University of Auckland, Auckland; Ruth Bonita, Director Surveillance, Office of the Assistant Director-General of Health, World Health Organization, Geneva, Switzerland

Acknowledgements: We thank the Health Research Council of New Zealand, the National Heart Foundation of New Zealand, and the Julius Brendel Trust for their financial support.

Correspondence: Dr Neil Anderson, Department of Neurology, Auckland Hospital, Park Road, Grafton, Private Bag 92024, Auckland. Fax: (09) 375 4309; email: neila@adhb.govt.nz

References:

1. Elliott WJ. Circadian variation in the timing of stroke onset: a meta analysis. Stroke. 1998;29:992–6.
2. NIWA. Climate data. Available online. URL: http://www.niwa.cri.nz/edu/resources/climate Accessed September 2004.
3. Bonita R, Broad JB, Beaglehole R. Changes in stroke incidence and case-fatality in Auckland, New Zealand, 1981-91. Lancet. 1993;342:1470–3.
4. Feigin VL, Anderson CS, Anderson NE, et al. Is there a temporal pattern in the occurrence of subarachnoid hemorrhage in the southern hemisphere? : pooled data from 3 large, population-based incidence studies in Australasia, 1981 to 1997. Stroke. 2001;32:613–9.
5. Statistical Analysis System Institute Inc. SAS Version 6.12 SAS Inc., 1997, Cary, NC.
6. James GD, Toledano T, Datz G, Pickering TG. Factors influencing the awake-sleep difference in ambulatory blood pressure: main effects and sex differences. J Hum Hypert. 1995;9:821–6.
7. Kelly-Hayes M, Wolf PA, Kase CS, et al. Temporal patterns of stroke onset. The Framingham Study. Stroke. 1995;26:1343–7.
8. Wroe SJ, Sandercock P, Bamford J, et al. Diurnal variation in incidence of stroke: Oxfordshire community stroke project. BMJ. 1992;304:155–7.
9. Wang H, Sekine M, Chen X, Kagamimori S. A study of weekly and seasonal variation of stroke onset. International Journal of Biometeorology. 2002;47:13–20.
10. Pasqualetti P, Natali G, Casale R, Colantonio D. Epidemiological chronorisk of stroke. Acta Neurol Scandinav. 1990;81:71–4.
11. Johansson BB, Norrving B, Widner H, et al. Stroke incidence: circadian and circaseptan (about weekly) variations in onset. Progress in Clinical & Biological Research. 1990;341A:427–36.
12. Haapaniemi H, Hillbom M, Juvela S. Weekend and holiday increase in the onset of ischemic stroke in young women. Stroke. 1996;27:1023–7.
13. Lanska DJ, Hoffmann RG. Seasonal variation in stroke mortality rates. Neurology. 1999;52:984–90.
14. Gill JS, Davies P, Gill SK, Beevers DG. Wind-chill and the seasonal variation of cerebrovascular disease. J Clin Epidemiol. 1988;41:225–30.
15. Sobel E, Zhang ZX, Alter M, et al. Stroke in the Lehigh Valley: seasonal variation in incidence rates. Stroke. 1987;18:38–42.
16. Tsementzis SA, Kennet RP, Hitchcock ER, et al. Seasonal variation of cerebrovascular diseases. Acta Neurochir. 1991;111:80–3.
17. Rothwell PM, Wroe SJ, Slattery J, Warlow CP. Is stroke incidence related to season or temperature? The Oxfordshire Community Stroke Project. Lancet. 1996;347:934–6.
18. Christie D. Stroke in Melbourne, Australia: an epidemiological study. Stroke. 1981;12:467–9.
19. Shinkawa A, Ueda K, Hasuo Y, et al. Seasonal variation in stroke incidence in Hisayama, Japan. Stroke. 1990;21:1262–7.
20. Jakovljevic D, Salomaa V, Sivenius J, et al. Seasonal variation in the occurrence of stroke in a Finnish adult population. The FINMONICA Stroke Register. Finnish Monitoring Trends and Determinants in Cardiovascular Disease. Stroke. 1996;27:1774–9.
21. Carolei A, Marini C, De Matteis G, et al. Seasonal incidence of stroke. Lancet. 1996;347:1702–3.
22. Woo J, Kay R, Nicholls MG. Environmental temperature and stroke in a subtropical climate. Neuroepidemiol. 1991;10:260–5.
23. Chen ZY, Chang SF, Su CL. Weather and stroke in a subtropical area: Ilan, Taiwan. Stroke. 1995;26:569–72.

24. Berginer VM, Goldsmith J, Batz U, et al. Clustering of strokes in association with meteorologic factors in the Negev Desert of Israel: 1981-1983. Stroke. 1989;20:65–9.

25. Keatinge WR, Donaldson GC, for theEurowinter Group. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. Lancet. 1997;349:1341–6.

26. Pan WH, Li LA, Tsai MJ. Temperature extremes and mortality from coronary heart disease and cerebral infarction in elderly Chinese. Lancet. 1995;345:353–5.

27. Woodhouse PJ, Khaw KT, Plummer M. Seasonal variation of blood pressure and its relationship to ambient temperature in an elderly population. J Hypertension. 1993;11:1267–74.

28. Grau A, Buggle F. Infection, atherosclerosis and acute ischemic cerebrovascular disease. Revista de Neurologia. 1999;29:847–51.

29. Life after stroke. New Zealand guideline for management of stroke. Best practice evidence-based guideline. Stroke Foundation of New Zealand and New Zealand Guidelines Group; 2003. Available online. URL: http://www.nzgg.org.nz/guidelines/0037/Appendix_1.pdf Accessed September 2004.