Life Expectancy after Stroke Based On Age, Sex, and Rankin Grade of Disability: A Synthesis

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Background: Stroke is a leading cause of death and disability in the developed world. The major factor affecting long term survival (other than age) is known to be the severity of disability. Yet to our knowledge there are no studies reporting life expectancies stratified by both age and severity. Remaining life expectancy is a key measure of health. *Methods:* We identified 11 long-term follow-up studies of stroke patients that reported the multivariate effects of age, sex, the modified Rankin Scale (mRS) grade of disability, and other factors. From these we computed the composite effects of these factors on survival, then used these to calculate age-, sex-, and mRS-specific mortality rates. Finally we used the rates to construct life tables, and hence obtain life expectancies. *Results:* Life expectancy varies by age, sex, and mRS. The life expectancies of males age 70, for example, were 13, 13, 11, 8, 6, and 5 years for Rankin Grades 0-5, respectively, representing reductions of 1, 1, 3, 6, 8, and 9 years from the corresponding general population figure. *Conclusions:* These figures demonstrate the importance of rehabilitation following stroke, and can be used in discussion of public policy and benchmarking of future results.
Key Words: Survival—severity—ischemic—hemorrhagic—life table—epidemiology—cerebrovascular disease—intracranial hemorrhage

Stroke is the leading cause of disability and the fourth leading cause of mortality in the United States.[1] The consequences of a stroke can vary considerably. In the mildest cases there is no residual impairment; in the most severe, the patient may be bedbound and fully dependent for all activities of daily living. Much has been written about prognosis after stroke, including many studies on short-term survival, recurrence, and recovery. There is very little, however, regarding life expectancy (i.e., the mean long-term survival time). This gap in the knowledge base is surprising given the high prevalence of stroke and the large costs associated with long-term care.[2]

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Life expectancy is a useful summary measure of health, and is commonly reported by national statistical agencies for entire populations. It is computed using standard scientific methods. These same methods have been used across a wide range of medical conditions. Some recent examples include cancer,[3] diabetes,[4] heart failure,[5] chronic kidney disease,[6] HIV,[7] and spinal cord injury.[8] Such studies typically include a comparison with the general population life expectancy, thereby providing an indication of the burden of disease. By contrast, most of the published studies of stroke survival have reported only survival probabilities or hazard ratios, which can be more difficult to interpret.

Recovery of function after stroke is an important outcome measure[9] and is a key component of health.[10] Indeed, functional ability has long been recognized as a key prognostic factor for survival at older ages,[11-15] and in persons with disabilities due to either congenital or acquired brain injury.[16,17] It is a matter of observation that the severity of disability following stroke is one of the most important factors related to long-term survival: the reported relative risks of mortality for various measures of functional ability are nearly always much larger than those of other risk factors such as age, sex, or hypertension. Slot et al.[18] concluded that "Functional status of patients 6 months after onset of an ischemic stroke has a significant and substantial effect on their long term survival." Similarly, Kammersgaard[19] wrote: "The 2 most prominent factors that determine both short- and long-term survival after stroke are age and stroke severity at onset."

In practical work there is often a need for evidence-based guidance for counseling, financial planning, and medical decision making for individual patients. The most useful studies for this purpose stratify results according to patient sex, age, and relevant indicators of the severity of the condition.

Numerous stroke studies have reported short-term survival probabilities based on either age or severity, but apparently not both simultaneously. One study provided life expectancies based on age, sex, and type of stroke.[20] Yet to our knowledge there have been no studies reporting life expectancies stratified by the 2 most important factors: age and severity of disability. In this article we report life expectancies stratified by age, sex, and severity, as measured by the modified Rankin Scale (mRS).[21] This is not based on any original analysis of patient data; instead we have synthesized results from the existing medical literature.

Methods

Based on computerized searches of the medical literature (PubMed.gov and Google), and successive examination of the reference citations given in the identified studies, we identified all stroke studies meeting the following four criteria:

1. The follow-up was for at least 1 year post stroke;
2. Severity of disability was evaluated using the mRS; and
3. Mortality occurring in the first few months after stroke was excluded;
4. Survival analyses were performed using a multivariate model that controlled for age, sex, mRS, and at least some possible comorbid factors.

Strokes of all types, subtypes, and etiologies were included (for rationale, see the Supplement, sections H and I). The multivariate survival models in the identified studies yielded relative risks (RRs) of mortality for each of the considered variables (also called covariates or risk factors). For example, an RR of 1.3 for diabetes indicates that persons with diabetes have, on average, 30% higher mortality than those who do not, after controlling for the other factors in the model.

The first of the 4 conditions reflected our interest in long-term survival, and the second our focus on long-term severity of disability. We imposed the third to exclude the effects of acute mortality risk, and to measure survival only after the patient had stabilized; several studies have shown that improvement plateaus at 3 months,[22,23] and thus disability was mainly assessed at 3 to 6 months post stroke. The final criterion was necessary because mRS is highly correlated with older age, male sex, and an adverse past medical history. We did not require that the study be of patients who had suffered their first ever stroke, though all but 2 studies met this requirement. We return to all 4 of these selection issues and related items in both the Discussion and Supplement.

In what follows we use the notation mRSi (where i = 0-5) to refer to a patient at grade i (i = 0-5) of the mRS, and RRi to refer to the relative risk of mortality (compared with some baseline group) for persons in that mRS group. From the 11 identified studies we computed summary RRs for mRS0-5. Briefly, these RRs are a synthesis of the RRs given in the 11 studies (essentially a weighted average of the stated RRs); we did not perform complex statistical modeling or estimation, per se.

We used the above RRs to calculate age- and sex-specific mortality rates for each of the 6 grades of the mRS. We then used the resulting mortality rates to construct life tables[24] for males and females for each of mRS05, from which we obtained life expectancies and survival curves. Technical details and a glossary are provided in the Supplement.

The stroke life expectancies were compared with those of the current U.S. general population[25] (GP; i.e., "the normal figures") and also with those of persons in the PVS (permanent vegetative state; i.e., the most severe neurological disability class).[26] These comparisons provide reasonable upper and lower bounds on life expectancy for persons with a history of stroke.

Results

Table 1 lists the 11 studies we identified. Boxes around more than 1 cell in the table indicate that the study combined those particular grades of the mRS. Only studies nos. 1-3 provided complete information on the effects of mRS1-mRS5 compared with mRS0. The weighted average RRs (weighted by the number of deaths in the studies) across only these 3 rows can be shown to be 1, 1.11, 1.62, 2.10, 2.95, and 4.95. For example, for mRS2 we find RR2 = (308*1.74 +100*1.54+470*1.55)/(308+100+470) = 1.62.

The other 8 studies were used to increase the precision of the above estimates. As noted, technical details on all the computations are given in the Supplement. The resulting summary figures for mRS0-5 are shown in the last row of the Table: 1, 1.11, 1.64, 2.04, 3.03, and 4.66. These are evidently quite similar to the six figures noted above; that is, the composite RRs are robust to the inclusion of the 8 additional studies. Also, as can be demonstrated, removal of any one study (sensitivity analysis) does not significantly change the RRs or resulting life expectancies.

Table 2 shows life expectancies by age, sex, and mRS, with values for the GP and PVS provided for comparison. For example, at age 70, which is roughly the mean age in the studies considered here, the life expectancies in years for males are: 14 (reference GP), 13, 13, 11, 8, 6, 5 (mRS0-5), and 3 (reference PVS).

Table 1. *Principal studies relied upon and the summary relative risks (RRs) by modified Rankin Scale grade. The key findings are in the last row of the table*

#	Author - year	Study years	Country	n	Deaths	PercentMale	Age ± SD	Av FU	Av FU Age	RRs by modified Rankin Scale (mRS)					
										0	1	2	3	4	5
1	Slot et al.[18] LSR	1990-2003	UK	2054	308	53	68 ± 13	4	70	1	0.98	1.74	2.58	3.89	4.98
2	Slot et al.[18] OCSP	1981-1991	UK	539	100	50	73 ± 12	5	76	1	1.20	1.54	2.04	1.82	1.25
3	Huybrechts et al.[38]	1992-2004	Greece	1816	470	62	70 ± 12	3	72	1	1.18	1.55	1.80	2.57	5.72
4	Suto et al.[39]	1999-2002	Japan	692	83	58	72 ± 12	2	73		1		0.89	2.27	3.12
5	Eriksson et al.[22]	2001-2006	Sweden	15,959	4000	52	73 ± 9	3	74		1		1.739	2.531	3.809
6	Magalhaes et al.[23]	1998-2007	Portugal	313	157	45	72 ± 8	6	75		1		2.39		4.47
7	Chiu et al.[40]	2006-2009	Taiwan	1,032	116	59	68 ± 12	1	68			1			4.69
8	Kimura et al.[29]	1999-2000	Japan	10,981	604	60	70 ± 11	1	70		1			2.57	
9	Slot et al.[18] IST	1991-1998	UK	5117	1354	52	73 ± 11	4	75		1			1.63	
10	Petty et al.[32]	1985-1993	USA	442	245	41	76 ± 12	3	78		1		1.27		3.47
11	Melkas et al.[41]	2003-2008	Korea	486	347	51	71 ± 8	8	75			1		2.02	
	Summary RRs									1	1.11	1.64	2.04	3.03	4.66

Abbreviations: Av FU, average follow-up time in years; Av FU Age, average age plus half of Av FU; IST, International Stroke Trial (UK patients only); LSR, Lothian stroke register; OCSP, Oxfordshire community stroke Project; SD, standard deviation.

As can be seen, the life expectancy of stroke patients is similar to that of the GP for persons with mRS0, and decreases as severity increases. It is also clear that (1) age is a significant factor, and (2) sex affects survival more amongst the less severely disabled (mRS0-2) than amongst the more severely disabled (mRS3-5).

Discussion

Most survival curves given in the published literature are not stratified by either age or sex; thus the effects of mRS are necessarily confounded with these factors. The present results, however, explicitly control for age and sex. Some caution is therefore necessary when making comparisons with prior results. Nevertheless, the survival results given here are consistent with those of prior studies. For example, Figures 1 and 2 show that the 5-year survival probabilities for males/females age 70 with mRS 0-5 are respectively 78%/85%, 70%/78%, 64%/71%, 53%/59%, 42%/46%, and 30%/30%. For patients in the Lothian Stroke Registry, with average age 68 ± 13 and 53% male, Figure 2 of Slot et al.,[18] gives corresponding probabilities (males and females combined) of 82%, 75%, 67%, 43%, 36%, and 31%. As is evident, the figures from Slot et al.[18] are intermediate to those given here for mRS0-2 and very similar for mRS5, though modestly lower for mRS3 and mRS4. Of

Table 2. *Life expectancy (years) by age, sex, and grade on the modified Rankin Scale*

Age*		Modified Rankin Scale Grade						
Male	GP	0	1	2	3	4	5	PVS
50	30	28	27	22	17	13	9	7
60	22	20	19	16	13	9	7	5
70	14	13	13	11	8	6	5	3
80	8	7	7	6	5	4	3	2
Female								
50	33	32	30	25	19	14	9	7
60	25	24	22	18	14	10	7	6
70	17	16	15	12	9	7	5	4
80	10	9	9	7	6	4	3	3

Abbreviations: GP, General population life expectancies.[25] PVS = Persistent vegetative state; values taken or derived from Shavelle et al.[26]

Grade Description:

0: No symptoms or disabilities due to stroke.

1: No significant disability following stroke, despite symptoms: Able to carry out all usual duties and activities.

2: Slight disability: Unable to carry out all previous activities but able to look after own affairs without assistance.

3: Moderate disability: Requiring some help with daily activities, but is able to walk without assistance.

4: Moderately severe disability: Unable to walk without assistance, and unable to attend to own bodily needs.

5: Severe disability: Bedridden, incontinent, and requires constant nursing care and attention.

*Age = Age at follow-up, rather than at stroke onset.

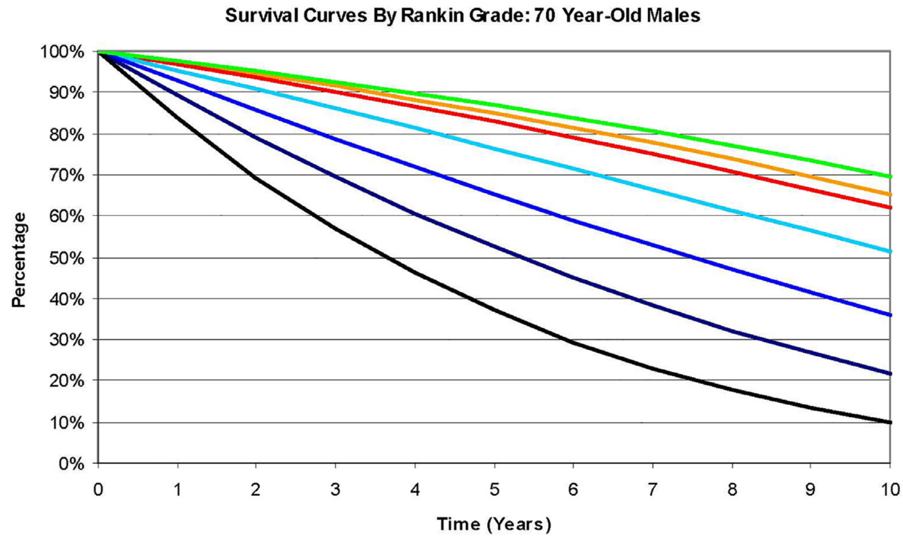

Figure 1. *Survival curves by Rankin Grade for 70 year-old males. The top (green) curve is the general population. The other curves, in order from top to bottom, are for mRS0-5. (Color version of figure is available online.)*

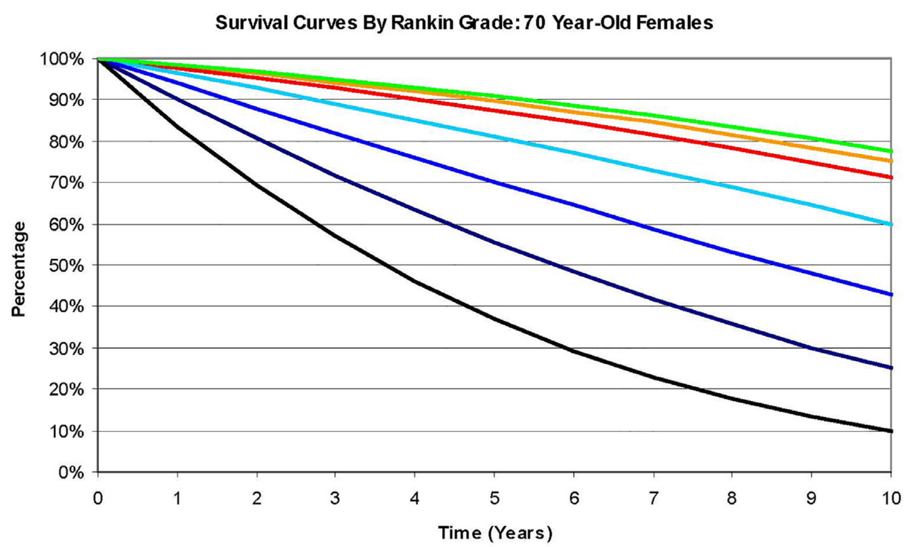

Figure 2. *Survival curves by Rankin Grade for 70 year-old females. The top (green) curve is the general population. The other curves, in order from top to bottom, are for mRS0-5. (Color version of figure is available online.)*

note is that the survival curve for mRS3 in Slot et al. drops sharply between years 6 and 7, due to small sample size. At year 6, though, their survival is 54%, compared with 59% here for males and 64% for females.

That there are significant differences in life expectancies between the grades demonstrates the importance of rehabilitation. Appropriate and timely interventions can lead to improvement in functional status, which increases both quality and quantity of life. Conversely, patients who do not receive such care may not recover to the maximum extent possible; as a result, their life expectancy may be lower than it would have been under more ideal circumstances.

A related issue is that of functional deterioration. For example, a patient now at mRS4 who was previously at mRS2 may have a different prognosis from one in mRS4 continuously since the time of stroke. We are not, however, aware of any empirical evidence on this topic. In addition, it may be worthwhile to determine whether rehabilitation efforts were insufficient; for example, a patient narrowly at mRS grade 3 (rather than grade 4) only due to intensive rehabilitation may have a worse prognosis than one in the same grade who did not recover as well as they otherwise would have under more ideal circumstances.

The survival figures derived here may be useful in public policy discussions, given that stroke is a leading cause of death in the developed world, the leading cause of disability, and a significant financial commitment on public medical funds. Indeed, the cost to society would be significantly lessened if rehabilitation were more effective.[42]

Further, the results given here can be practically used by epidemiologists and medical researchers for benchmarking. Specifically, the empirical survival results in any (future) study may be evaluated in light of those given here. This could take the simple form of comparing the observed and expected survival curves,[43] or instead by comparing the observed and expected number of deaths,[44] in both cases after controlling for important patient differences in age, sex, and severity of disability. One could then determine if survival in the new study group was better, worse, or similar to these baseline values.

Study Limitations

As noted, the synthesis here is based on patients who survived at least 3 months post stroke. This research is therefore not relevant to medical decision-making during the acute period. It may, however, prove helpful in situations where the patient's remaining life expectancy is a factor in treatment decisions regarding other medical conditions, as has been the case in cancer screening[45,46] and choice of valve replacement type.[47]

The results given here are predicated on the assumption that the patient has become largely stable. While studies do indicate improvement in both motor and cognitive disability late after stroke, provided that patients continue to receive appropriate rehabilitation intervention,[27] Magelhaes et al.,[23] showed that very few improve in mRS after 3 months. We are not aware of any evidence to suggest that significant motor or mRS improvement frequently occurs after, say, 6 months following stroke, but to the extent it is possible the results given here may be optimistic. Further, we made no allowance for the time since onset of stroke. That is, all else being equal (same age, sex, and mRS), the life expectances are presumed to be the same for persons who are 1 year post stroke, for example, or 10 years post stroke. We are aware of only one study that addressed this issue. This is Slot et al.,[18] who reported that survival did not vary between the 414 persons observed 1 year post stroke and the remaining 2054 who were followed from 6 months post, and also that use of the mRS at 1-month post stroke gave results similar to that at 6-months post.

A further assumption is that there have not been major improvements in stroke survival relative to the general population in recent years. Slot et al.[18] wrote: "Our analyses of survival during different time periods showed, as one might expect, that survival did indeed slightly improve over time." On the other hand, Poon et al.,[28] in a review article published in 2013, reported "These [stroke] long-term survival rates do not appear to have changed over time." Similarly, such secular trends have not been found for adults disabled due to traumatic brain injury.[17]

As noted in Methods, we did not restrict attention to patients who had suffered a first ever stroke, though most of the studies met this requirement (the 2 exceptions are Kimura et al.[29] and VanWijk et al.[30]). Melkas et al.[31] reported that prior stroke was not a significant factor for subsequent survival, while Petty et al.[32] and Carter et al.[33] suggested that there is higher mortality for those who had a prior stroke. Kimura reported that the effect of prior stroke was a relative risk of 1.28. Prior stroke is correlated with both older age and greater severity of stroke, and thus this relative risk may in fact be confounded with those factors. Further, Kimura used only a simple measure of severity (mRS3-5 versus 0-2), which is an additional reason to remain cautious. Nevertheless, if the existence of a prior stroke is indeed a significant independent risk factor then the figures given here may be slightly too high if applied to persons who have had more than one stroke and too low for those who have not.

It is not surprising that persons with Rankin Grade 0 or 1 have a modest reduction in life expectancy − the underlying reasons for the stroke may still apply (e.g., smoking). Similarly, is it not surprising that persons with Rankin 5 have very low life expectancies, similar to those in the PVS, as both groups are bed bound, very severely disabled, and unlikely to improve in function.

The results given here are applicable to a given person who is of the stated age and sex, and whose clinical condition is "typical" of the stated Rankin grade. For persons whose disabilities appear intermediate to 2 grades it may be appropriate to interpolate between the stated life expectancies. The person's clinical profile of comorbid factors should be fairly typical of the mRS group, as can be determined by examination of the population characteristics delineated in the many studies listed here. If an individual has an unusual and significant comorbidity, or an etiology predisposing to increased risk of recurrence, an adjustment can be made using standard methods, as discussed in the Supplement. Note that the list of possible comorbid factors is extensive (e.g., heart disease, cancer, and any other medical condition), whilst there is at best limited evidence on the marginal effect of any one of these (i.e., after age, sex, and the severity of stroke have been taken into consideration).

The mRS is a widely used measure of global disability following stroke.[34] It has found use as a predictor of future stroke, functional recovery, and mortality. The scale is highly correlated with mobility and ADLs, but less so with cognitive and social functioning.[35] While it is known to be less sensitive to small changes in function than, for example, the Barthel Index and Functional Independence Measure (FIM),[36] it can be quickly applied[35] and has excellent reliability.[37] The limitations most relevant to the present work, are (1) the comparatively few steps on the scale, and (2) the rather wide gap in functional ability between levels 3 and 4. (Specifically, it is not clear how to grade someone who cannot walk without assistance but who can nevertheless care for their own bodily needs.) Future long-term survival studies of stroke patients might therefore usefully be based instead on the FIM.

Conclusions

In any synthesis such as the present work, various studies are compiled and weighted in some fashion in order to obtain summary results. The composite relative risks derived here were from patients followed from as early as 1981 to as late as 2009; in countries including Sweden, the United States, and Japan; with some models accounting for the possible effects of stroke subtype and hypertension, for example, and others that did not. Yet the resulting RRs from these studies indicate a robust similarity. While a single RR from a single study may be higher or lower than the average, perhaps due to a small sample size or under- or over-specified survival model, the composite figure nonetheless represents our best summary of the extant empirical evidence. The life expectancies derived here therefore indicate the current state of knowledge regarding long-term survival after stroke. Notably, life expectancy is strongly related to age, sex, and the severity of disability, as measured, for example, by the modified Rankin Scale. The results given here may thus be useful in public policy discussions, to establish the cost-effectiveness of rehabilitation, and for benchmarking of future studies.

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Supplementary materials

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