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EVALUATION OF INDIVIDUAL AND GROUP CHANGES IN SOCIAL OUTCOME AFTER ANEURYSMAL SUBARACHNOID HAEMORRHAGE: A LONG-TERM FOLLOW-UP STUDY

Elisabeth Svensson[1] and Jan-Erik Starmark[2]

From the [1]Department of Statistics (ESI), Örebro University, Örebro, and [2]Institute of Clinical Neuroscience, Section of Neurological Diseases, Sahlgrenska University Hospital, Göteborg, Sweden

Sixty-three patients operated on for an acute aneurysmal subarachnoid haemorrhage were evaluated comprehensively over 5 years. The level of social outcome was assessed by a Swedish eight-point version of the Glasgow Outcome Scale (S-GOS) at 0, 3, 6, 12, 24 and 60 months after discharge from a neurosurgical department. Stepwise comparisons of long-term changes in common to the group of patients were analysed separately from the level of individual changes of ordered categorical response variable of social outcome by a statistical method that takes account of the non-metric properties of the data. This study showed that the pattern of recovery was homogeneous, except for the first 3 months, where a considerably heterogeneous pattern of change was seen. A significant improvement in social outcome in common for the group was seen during the first 6 months and the recovery for the group did not continue beyond 1 year after discharge.

Key words: ordered categorical data, Glasgow Outcome Scale, rank-invariance, responsiveness.

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Correspondence address: Professor Elisabeth Svensson, Department of Statistics (ESI), Örebro University, SE-701 82 Örebro, Sweden. E-mail: elisabeth.svensson@esi.oru.se

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INTRODUCTION

Rating scales are commonly used in clinical studies, as many aspects of disease and outcome after treatment require assessments by clinical observers or by the patients themselves. Qualitative concepts, such as pain, severity of the disease, ability, functioning and health-related quality of life, can be used as primary or secondary outcome variables (1).

The Glasgow Outcome Scale (GOS) is a widely used single scale for the clinical assessment of global assessment of social outcome after traumatic head injury, taking into account the dimensions of neurological, psychological and psychiatric functioning (2, 3). The scale has been recommended as an international standard for comparisons between different centres of outcome after therapeutic regimens for traumatic brain injury (3). This recommendation has also been given for comparisons of clinical studies of treatment effect on aneurysmal subarachnoid haemorrhage (aSAH), usually 3 to 6 months after aSAH. An implicit assumption behind the recommendation of GOS for the assessment of disabilities after aSAH is that the recovery processes are the same for head injury as after aSAH (4, 5). There is a five- and an extended eight-point version of the GOS (3, 6). Drake (4) recommended the five-point scale for evaluation of outcome after aSAH.

In follow-up and longitudinal studies, repeated measurements of the same individual must have a high level of responsiveness, which means that they must be able to detect clinically important changes over time (7). The use of scales with a large number of clearly described categories should allow the detection of slight categorical changes.

Assessment of social outcome can be useful, at the group level, to define the end-point in follow-up studies, and also to determine a suitable end-point for insurance negotiations. At the individual level, assessment of outcome is important for individual rehabilitation planning. The time for evaluation of outcome after aSAH differs between studies (8). No recommendations have been published regarding the most appropriate time for evaluation of outcome after aSAH. Few studies on aSAH have reported a follow-up time longer than 1–2 years. Earlier works (3, 8, 9) show that, when using the five-point version of the GOS, the majority of patients with severe head injury reached their final level of outcome 6 months after the injury.

Assessments on rating scales produce ordered categorical data, the ordered categories representing only a rank order and not a numerical value. Hence, the data are non-metric and the number of categories and the labelling can be chosen arbitrarily (10–12). These rank-invariant properties of ordered categorical data mean that changes in ordered categorical responses cannot be defined by differences (13, 14). There are few rank-invariant methods available for analysis of change in ordered categorical data. Appropriate tests of the hypothesis of no change are the sign test and McNemar's test for paired proportions (15). Such summary tests, however, provide no information on the treatment effect for the individuals involved, and do not use the information in the data efficiently in a clinical perspective (16).

Svensson (17, 18) has developed a statistical method for comprehensive evaluation of qualitative outcome variables that takes into account the rank-invariant properties of ordered categorical data. The method makes it possible to identify and measure the level of change in ordered categorical responses

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Table I. *Short category descriptions of the Swedish eight-point form of the Glasgow Outcome Scale (S-GOS)*

S-GOS	Category descriptions
A. Death	Dead
B. Vegetative state	Vegetative state
	Conscious, but dependent
C. Severe disability, low	Communication is possible, minimally, by emotional response; dependent in performing daily life activities (ADL)
D. Severe disability, high	Partial independence in ADL, may require assistance for only one activity, such as dressing; many evident posttraumatic complaints and/or signs; resumption of former life and work not possible
	Independent, but disabled
E. Moderate disability, low	Independence in ADL, for instance, can travel by public transport; not able to resume previous activities, either at work or socially; despite evident posttraumatic signs, resumption of activities at a lower level is often possible
F. Moderate disability, high	Posttraumatic signs are present, which, however, allow resumption of most former activities, either full-time or part-time
	May have mild residual effects
G. Good recovery, low	Capable of resuming normal occupational and social activities; there are minor physical or mental deficits or complaints
H. Good recovery, high	Full recovery without signs or symptoms

attributed to a group separately from the level of individual variability within the group. The identification of the level of group change is a valuable tool for defining end-points of studies. Such evaluation of the homogeneity of group changes is also clinically important in rehabilitation, as it reflects the efficacy of a common treatment or intervention programme in the study group. If individual changes over time are greater than any common pattern of group change, individually tailored interventions are preferable.

The aim of this paper was to apply the statistical approach by Svensson to a comprehensive evaluation of change in global social outcome over time assessed by the eight-point S-GOS in patients operated on for acute aSAH, and to try to delineate the optimum time for evaluation of outcome on the group level but also estimate the magnitude of change on the individual level. The responsiveness of the eight-point outcome scale is also discussed.

MATERIAL AND METHODS

A Swedish version of a social outcome scale, S-GOS, developed from the eight-point version of GOS suggested by Maas et al. (6), was used for global evaluation of social outcome in patients after aSAH (Table I).

Between 1 November 1989 and 31 October 1990, a cohort of 75 consecutive patients was operated on, in the acute stage, for ruptured cerebral arterial aneurysm at the Department of Neurosurgery, Sahlgrenska University Hospital, Sweden. The Ethics Committee at the Faculty of Medicine, Göteborg University, approved the study.

Eight patients (11%) died after admission during the acute stage. All but one (a refugee lost to follow-up) of the surviving patients or their relatives consented to participate in a comprehensive neurological, neuropsychiatric and neuropsychological follow-up evaluation for 5 years. For various reasons, three patients refused to participate in the 24- and 60-month follow-ups. The remaining 63 patients (45 women, 18 men) were examined on discharge and 3, 6, 12, 24 and 60 months after discharge. The mean age at the aSAH was 54.0 years (SD 11.8, range 23 to 74 years). The localization regions for the aneurysm were: a. cerebri anterior ($n = 21$), a. media ($n = 19$), a. carotis interna ($n = 17$) and in 6 patients the posterior circulation region. The median time of discharge after the aSAH was 14 days, inter-quartile range, 8 to 24 days. The same neuropsychiatrist (JES) examined all patients on all occasions. An independent study (19) has shown that the patients were representative of the Swedish aneurysm population from 1989–90.

Statistical methods

In this study, long-term changes in social outcome, assessed by the S-GOS, were evaluated by pairwise comparisons of individual changes in outcome between the contiguous follow-up occasions at 0, 3, 6, 12, 24 and 60 months after discharge. The procedure for a comprehensive evaluation of group and individual changes in ordered categorical outcome responses between two occasions is described briefly. The practical use of the method is demonstrated by the evaluation of change in outcome between discharge from hospital and at 3 months of follow-up.

The patterns of change in ordered categorical outcome between pairs of contiguous occasions were displayed in contingency tables, where the main diagonal of unchanged categorical levels is oriented from the lower-left to the upper-right corner. The distributions of observations on the ordered categories on the two occasions, also called marginal distributions, provide information about the presence of systematic change in ordered categorical data over time. When the marginal distributions differ, there is an indication of a systematic change in outcome between the two occasions in common for the study group. This group change was graphically shown by plotting the cumulative proportions of the two distributions, together with the point (0, 0), yielding a type of ROC (relative operating characteristic) curve (17, 18, 20). Fig. 1 illustrates different shapes of ROC curves, and Appendix 1 shows the empirical formulae of the two measures of systematic change in ordered categories. Fig. 1a represents a case when there is a systematic shift in position of the classifications on the scale towards higher categories on the second occasion. The difference between the probability of the classifications being shifted towards higher categories, and the probability of the classifications being shifted towards lower categories, on the second occasion defines a measure called relative position (RP).

Fig. 1b represents a case when there is a systematic shift in concentration of the classifications on the scale towards central categories on the second occasion. The difference between the probability of the marginal distribution on the second occasion being concentrated relative to the first and vice versa defines the measure of relative concentration (RC). Possible values of probabilities range between 0 and 1. The measures of RP and RC are defined by a difference between two probabilities (Appendix 1) so possible values range from −1 to 1.

The marginal distributions provide information about the systematic change in common for the group, and the pattern of pure systematic change in pairs of observations is entirely defined by these marginals and can be constructed by pairing off the two sets of marginal frequencies.

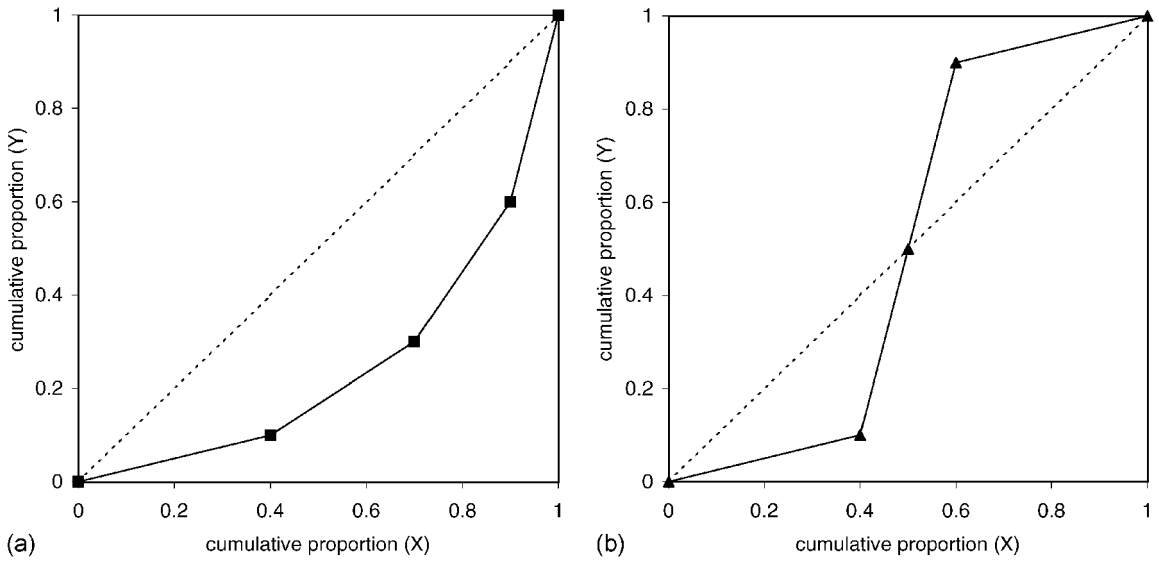


Fig. 1. Relative operating characteristic (ROC) curves of systematic changes in classification between occasion X and Y. (a) A systematic change in position of a 4-point scale from the set of marginal frequencies $\{x_i$: 8,6,4,2$\}$ to {2,4,6,8}, RP = 0.50. (b) A systematic change in concentration of a 4-point scale from the set of marginal frequencies $\{x_i$: 8,2,2,8$\}$ to {2,8,8,2}, RC = 0.62.

This so-called rank-transformable pattern of change (RTPC) describes the pattern of systematic change in the contingency table. In the RTPC, all individuals have kept their ordering relative to the others in the group between the two occasions, although they may have changed categorical levels (17, 18, 20). The observed pattern of change is compared with the RTPC defined by the marginal distributions of the contingency table. Dispersed observations from the RTPC are a sign of additional individual changes unexplained by the common pattern of group change. The two categorical assessments of each individual are transformed to a pair of rank values, which is a common non-parametric approach. In the augmented ranking approach by Svensson (17) the ranks are tied on the pairs of observations, which provide the evaluation of systematic group change separately from the evaluation of individual changes. When the two rank values of an individual differ, there is a sign of individual dispersion of change from the common systematic group change. The measure of individual dispersion, RV, was calculated according to the expression in Appendix 2. The higher the value, the more heterogeneous are the individual changes. Possible values of RV range between 0 and 1, where RV = 0 means lack of individual dispersion from the RTPC, which has RV = 0. The level of homogeneity of individual changes relative to the common group change, r_a, was calculated (21).

Approximate 95% confidence intervals (CI) for the measures were calculated by means of the bootstrap technique (22). The sign test for analysis of change in paired assessments, adjusted for continuity, was used (15). In order to obtain an overall significance level of at least 5% in the analyses of step-wise changes by the use of the sign test, each *p*-value was adjusted by means of the Bonferroni-Holm sequential procedure (23).

RESULTS

Overall outcome

The distributions of the 63 individuals on the eight outcome levels at all the follow-up occasions are shown in Fig. 2. Note that no patient was in a "vegetative state" in this study. An overall recovery at the group level during the first year after discharge was seen. At discharge 41% of the 63 individuals were rated "severe disability, low (C) or high (D)", and 6 months after discharge the proportion had decreased to 14%, when death was included.

The individual outcome assessments showed that 28 patients (44%) had non-decreasing outcome levels during the 60 months, and an additional 17 (27%) patients had non-decreasing outcome level during the first 12 months of the study.

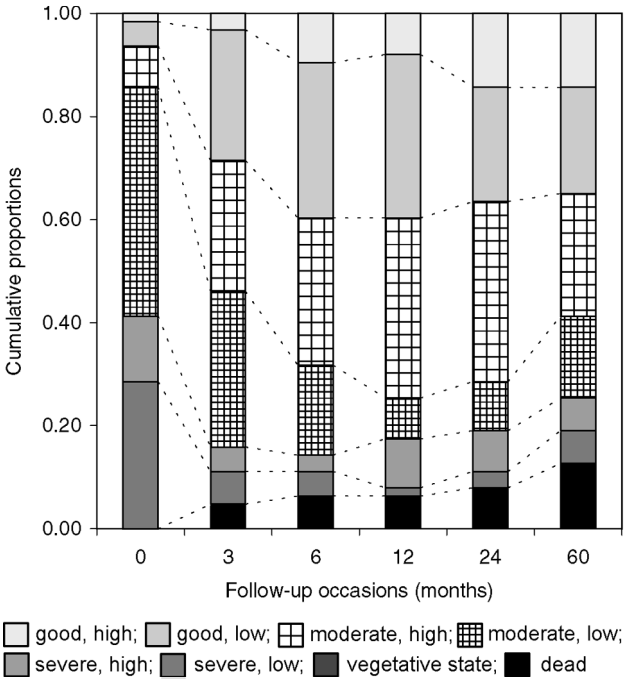


Fig. 2. The occasion-specific distributions of the level of social outcome in 63 patients measured by the Swedish version of the eight-point Glasgow Outcome Scale (S-GOS).

The observed pattern of change in S-GOS

After 3 months (Y) \ At discharge (X)	A	B	C	D	E	F	G	H	y_i	$C(y)_i$
Good recovery, high (H)						1		1	2	1.0
Good recovery, low (G)			2	3	6	3	2		16	0.97
Moderate disability, high (F)			3	2	9	1	1		16	0.71
Moderate disability, low (E)			4	2	13				19	0.46
Severe disability, high (D)			2	1					3	0.16
Severe disability, low (C)			4						4	0.11
Vegetative state (B)									0	0.05
Death (A)			3						3	0.05
Total (x_i)	0	0	18	8	28	5	3	1	63	
$C(x)_i$	0	0	0.29	0.41	0.86	0.94	0.98	1.0		

Fig. 3. The pattern of change in social outcome assessed by the Swedish version of Glasgow Outcome Scale (S-GOS) for 63 individuals between discharge and the 3-month follow-up occasion; cell frequencies (x_i, y_j), marginal frequencies (x_i) and (y_i) and the cumulative marginal frequencies $C(x)_i$ and $C(y)_i$.

Change in outcome in first 3 months after discharge

Fig. 3 shows the pattern of change in outcome for the 63 patients between discharge (denoted X) and the 3-month follow-up occasion (denoted Y). Unchanged status was seen among 22 patients (35%) and 59% improved their social outcome, ($p < 0.0001$).

The different marginal distributions, {x_i: 0,0,18,8,28,5,3,1} and {y_i: 3,0,4,3,19,16,16,2} (Fig. 3) indicate a systematic change in outcome in common for the group. The two sets of cumulative relative frequencies, (Fig. 3) define the ROC curve (Fig. 4a). The shape of the curve shows that there is mainly a systematic change in position of the outcome classifications towards improvement in social outcome. The level of change in position (RP) was therefore calculated according to Appendix 1. From the frequencies and cumulative frequencies of the marginal distributions, p_{xy} is calculated:

$$p_{xy} = \frac{1}{63^2}[4 \times 0 + 3 \times 18 + 19 \times 26 + 16 \times 54 + 16 \times 59 + 2 \times 62] = 0.6248$$

Correspondingly, $p_{yx} = 0.1842$ and $RP = p_{xy} - p_{yx} = 0.44$ (95% CI(RP) from 0.31 to 0.57). This means that there is a 44% larger chance of a higher S-GOS level than of a lower level on the 3-month follow-up occasion as compared with the level at discharge.

Fig. 4b shows the RTPC, which was constructed by pairing off the two sets of marginal distributions in Fig. 3. This means that the 18 observations on level C at discharge are paired off with the first 18 marginal observations on the follow-up occasion. Hence there will be three pairs in the cell (C, A), fours pairs (C, C) and three pairs (C, D), and the remaining eight observations are paired with eight of the 19 individuals on level E, (see Fig. 4b). According to the RTPC, the group of patients rated "severe disability, high (D)" and "moderate disability, high (F)" will have an expected increase in outcome 3 months after discharge, as the non-zero cells are located above the main diagonal. The expected patterns of change for patients with baseline status "severe disability, low (C)" and "moderate disability, low (E)" range over three categories (Fig. 4b).

The observed pattern of change in outcome (Fig. 3) was dispersed from the expected pattern of group change (the RTPC) (Fig. 4b). This indicates that some individuals have changed in outcome more or less than the expected group change. Five individuals, who were "severely disabled, low or high", were assessed "good recovery, low (G)" on the 3-month follow-up occasion, while the expected change for the group was to "moderate disability, low (E)". This means that the augmented ranks allocated to these individuals according to their joint positions on the cells differ (see Fig. 4c). Note that the pair of rank values for the five (2 + 3) individuals, mentioned above, have the greatest mean rank differences of 29 and 24 respectively, and these individuals contribute more than half of the heterogeneity in recovery measured by the RV. From the cell frequencies (x_{ij}) (Fig. 3) and the augmented mean ranks (Fig. 4c), the sum square of the rank differences is calculated, according to Appendix 2, as:

$$\sum_{i=1}^{8}\sum_{j=1}^{8} x_{ij}\Delta\overline{R}_{ij}^2 = 4(11.5 - 12.5)^2 + 3 \times (15 - 31)^2 + 2 \times (17.5 - 46.5)^2 + 9^2 + 2 \times 5^2 + 2 \times 11^2 + 3 \times 24^2 + 13 \times 10^2 + 9 \times 5^2 + 6 \times 2^2 + 1 \times 11^2 + 3 \times 1^2 + 1 \times 3^2 + 1 \times 15^2 + 2 \times 1^2 = 6464$$

Then, $RV = 6 \times 6464/63^3 = 0.1551$, which indicates heterogeneity in individual changes during this period (95% CI, 0.04 to 0.28). The corresponding measure of closeness to the expected pattern of group change, r_a, was 0.84.

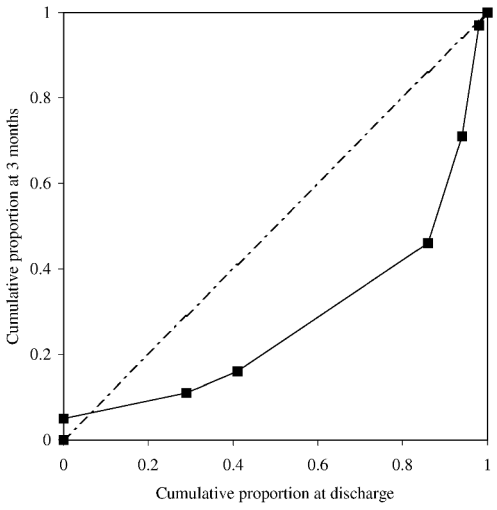
The stepwise comparisons of follow-up occasions

The stepwise comparisons of the change in outcome between the consecutive follow-up occasions are shown in the contingency tables of Fig. 5. The corresponding expected patterns of group changes are indicated by double line in the tables. The measures of group and individual changes are given in Table II.

After the first 3 months, the individual changes were mainly consistent with the expected pattern of change for the group. The heterogeneity in change was mainly present for individuals classified as "moderate disability" (Fig. 5). The high value of r_a and the low value of RV (Table II) confirmed this homogeneity in recovery.

The series of ROC curves (Fig. 6) show the progress of systematic changes over time. There was also an overall significant increase towards a higher level of social outcome assessed by the S-GOS from 3 to 6 months after discharge for the group, as the RP was 0.16 (95% CI, 0.07 to 0.25, $p = 0.012$) (Fig. 6). Hence, there is a 16% larger chance of being classified to a higher level of S-GOS than to a lower level on the 6-month-follow-up occasion as compared with the level 3 months after

(a)



(b)

The RTPC

After 3 months \ At discharge	A	B	C	D	E	F	G	H	Total
Good recovery, high (H)							1	1	2
Good recovery, low (G)					9	5	2		16
Moderate disability, high (F)					16				16
Moderate disability, low (E)			8	8	3				19
Severe disability, high (D)			3						3
Severe disability, low (C)			4						4
Vegetative state (B)									0
Death (A)			3						3
Total	0	0	18	8	28	5	3	1	63

(c)

	A	B	C	D	E	F	G	H
H						59 62		63 63
G			17.5 46.5	25 49	51.5 53.5	57 58	61.5 60.5	
F			15 21	22.5 23.5	44 39	55 44	60 45	
E			11.5 12.5	20.5 15.5	33 23			
D			8.5 8.5	19 10				
C			5.5 5.5					
B								
A			2 2					

Fig. 4. (a) The relative operating characteristic (ROC) curve of systematic change in social outcome measured by the Swedish version of Glasgow Outcome Scale (S-GOS) between discharge and on the 3-month follow-up occasion ($n = 63$). (b). The rank-transformable pattern of change (RTPC) defined by the marginal distributions in Fig. 3. (c) The pair of augmented mean ranks for the S-GOS levels according to the assessments at discharge ($\overline{R}_{ij}^{(X)}$) and on the 3-month follow-up occasion ($\overline{R}_{ij}^{(Y)}$) shown in Fig. 3. Each cell shows $\overline{R}_{ij}^{(X)}$ above and $\overline{R}_{ij}^{(Y)}$ below.

discharge. After 6 months a slight improvement in outcome was seen for moderately disabled individuals only (95% CI for RP, −0.07 to 0.10). The small and negative values of RP on the two latest occasions in Table II indicate that no further improvement on group level was seen one year after discharge (95% CI for RP, −0.10 to 0.07 and −0.17 to 0.004, respectively).

The conclusion from this comprehensive analysis is that the endpoint of recovery for the aSAH group was 6 months after discharge. At the individual level the pattern of recovery was very heterogeneous during the first 3 months after discharge but became homogeneous and consistent to the pattern of group change thereafter.

DISCUSSION

The statistical approach

The present study focused on the evaluation of change in ordinal assessments. This presents a methodological problem, as ordinal data have no other arithmetic properties than the ordered structure and therefore change in outcome cannot be defined by calculating differences (12, 13). Traditionally, categorical distributions are presented as bar charts (Fig. 2) and the median and quartile values are commonly given. The statistical evaluations are often based on marginal models, which means that only the group changes are considered. Most marginal models are semi-parametric and place distributional restrictions on the data (24–26).

The statistical method used in this paper takes account of the non-metric properties of ordinal data (rank-invariance), and the fact that there are paired (dependent) data and provides a method for evaluating change, irrespective of the number of response categories on the scale. The method presented is suitable, and recommendable, for paired ordinal data and is valid for all types of outcome values; for discrete scales as well as for analogue scales (as from VAS). It is also applicable for multi-item scales, both on item level and on a global level defined by the median score or another rule of global scaling. The method allows for zero cell frequencies and for small data sets as it is developed for paired ordinal data with no other assumptions on the data.

The present approach makes it possible to separate the pattern of change into two components, one of which concerns the pattern of group changes and the other the individual changes that are not explained by the expected group change. In clinical practice it is important to identify the two different types of patterns of change, as they have different impacts on the planning of further treatment or interventions. Large individual changes, evident from RV, indicate heterogeneity in the group and the need for individualized treatment or intervention.

The sign test for comparison of paired proportions showed that there was a significant change in social outcome between discharge and after 3 months of follow-up and also between 3 and 6 months of follow-up. However, the use of a single test did not use the information gained from the comprehensive follow-up study efficiently. In this study the pattern of change in

The observed pattern of change in S-GOS

After 6 months / **After 3 months**

After 6 months	A	B	C	D	E	F	G	H	Total
Good recovery, high (H)						1	3	2	6
Good recovery, low (G)					2	7	10		19
Moderate disability, high (F)					9	6	3		18
Moderate disability, low (E)				1	8	2			11
Severe disability, high (D)				2					2
Severe disability, low (C)			3						3
Vegetative state (B)									0
Death (A)	3		1						4
Total	3	0	4	3	19	16	16	2	63

The observed pattern of change in S-GOS

After 12 months / **After 6 months**

After 12 months	A	B	C	D	E	F	G	H	Total
Good recovery, high (H)							1	4	5
Good recovery, low (G)						4	15	1	20
Moderate disability, high (F)					6	13	3		22
Moderate disability, low (E)				1	3	1			5
Severe disability, high (D)			2	1	2			1	6
Severe disability, low (C)			1						1
Vegetative state (B)									
Death (A)	4								4
Total	4	0	3	2	11	18	19	6	63

The observed pattern of change in S-GOS

After 24 months / **After 12 months**

After 24 months	A	B	C	D	E	F	G	H	Total
Good recovery, high (H)							5	4	9
Good recovery, low (G)						3	11		14
Moderate disability, high (F)				1	2	14	4	1	22
Moderate disability, low (E)				1	2	3			6
Severe disability, high (D)				2	1	2			5
Severe disability, low (C)			1	1					2
Vegetative state (B)									0
Death (A)	4			1					5
Total	4	0	1	6	5	22	20	5	63

The observed pattern of change in S-GOS

After 60 months / **After 24 months**

After 60 months	A	B	C	D	E	F	G	H	Total
Good recovery, high (H)							4	5	9
Good recovery, low (G)						4	5	4	13
Moderate disability, high (F)					2	11	3		16
Moderate disability, low (E)					2	6	1		9
Severe disability, high (D)				3		1			4
Severe disability, low (C)			1	2	1				4
Vegetative state (B)									0
Death (A)	5		1		1		1		8
Total	5	0	2	5	6	22	14	9	63

Fig. 5. The patterns of change in the Swedish Glasgow Outcome scale (S-GOS) levels for the 63 patients in the pairwise comparisons between consecutive follow-up occasions 3, 6, 12, 24 and 60 months after discharge. The cells of corresponding rank-transformable patterns (RTPC) are delineated by double lines in the table.

outcome between discharge and at 3-month follow-up occasion revealed both a considerable improvement in social outcome in common for the group and an additional large amount of individual variability in change. The significant change in outcome between 3 and 6 months of follow-up, on the other hand, could be explained by a change in outcome in common for the group.

Endpoint for evaluation of outcome after aSAH

To our knowledge, this is the first prospective study of outcome covering more than the first 2 years after aSAH. The same observer performed the assessments of social outcome using the S-GOS. The main result was the identification of a definite endpoint for evaluation at 12 months, at most, after discharge from hospital, even when significant changes occurred during the first 6 months. The main change between 6 and 12 months occurred among individuals with "moderate disability, low".

Teasdale et al. (27) suggest that a suitable end-point for evaluation of recovery after stroke is 3 months. Explanations for the difference in endpoints between the evaluation of patients

Table II. *Measures of systematic group changes and individual changes in the step-wise comparisons of the Swedish eight-point form of Glasgow Outcome Scale (S-GOS) assessments in the 5-year follow-up study (n = 63)*

Measures of change in S-GOS levels	Discharge vs. 3 months	3 months vs. 6 months	6 months vs. 12 months	12 months vs. 24 months	24 months vs. 60 months
Systematic, order-preserved change for the group					
—in position, RP	0.44	0.16	0.019	−0.017	−0.084
SE(RP)	(0.06)	(0.05)	(0.044)	(0.042)	(0.044)
—in concentration, RC	−0.20	−0.092	0.039	−0.087	−0.10
SE(RC)	(0.14)	(0.065)	(0.040)	(0.055)	(0.06)
Individual changes, RV	0.16	0.026	0.057	0.017	0.047
SE(RV)	(0.06)	(0.013)	(0.053)	(0.010)	(0.030)
Homogeneity to the group change r_a	0.84	0.97	0.94	0.98	0.95

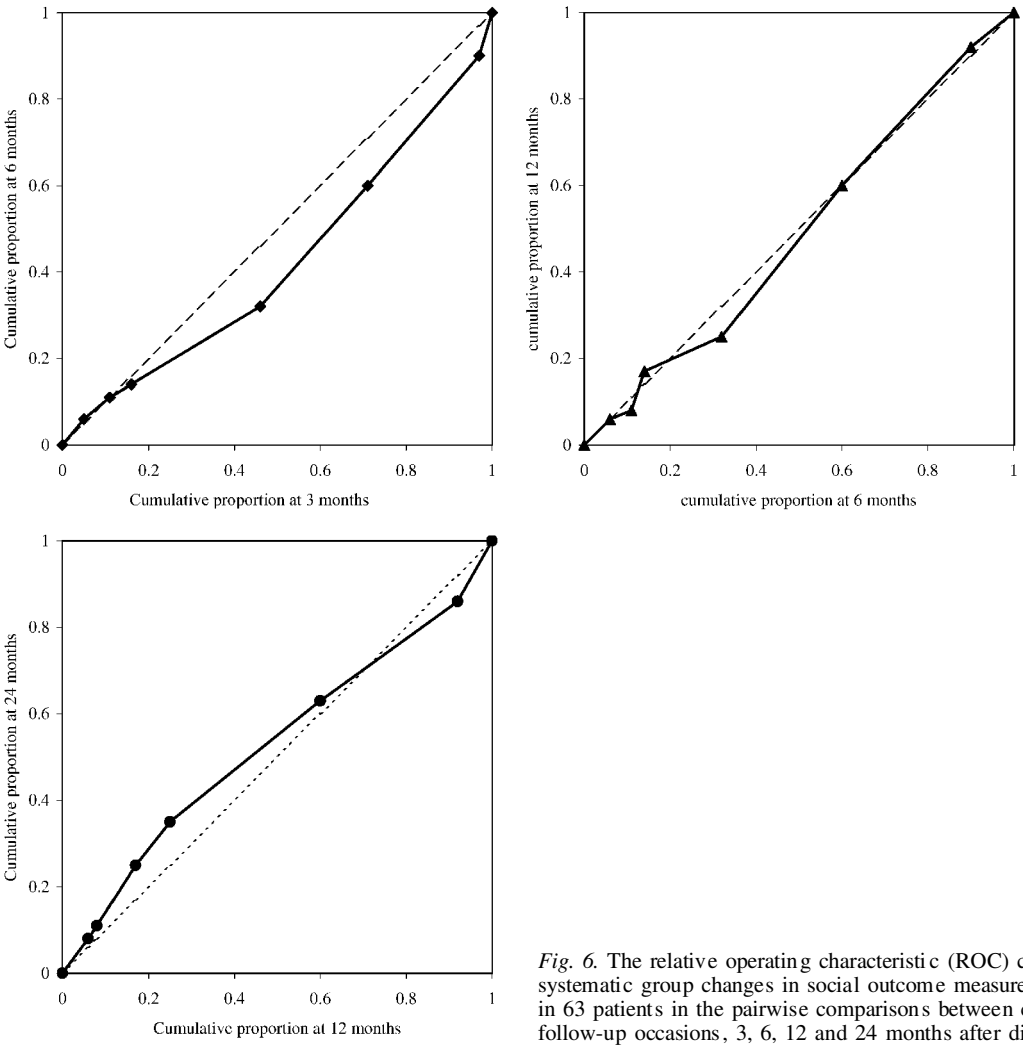


Fig. 6. The relative operating characteristic (ROC) curves of systematic group changes in social outcome measured by S-GOS in 63 patients in the pairwise comparisons between consecutive follow-up occasions, 3, 6, 12 and 24 months after discharge.

with stroke and aSAH might be that the latter group of patients had rather few gross neurological deficits and were followed for a longer period of time. The evaluation of outcome is commonly focused on patients with "severe disability". In this study, seven (11%) patients were classified "severe disability, low and high" on the 12-month follow-up occasion. Additionally, five individuals were classified as "moderately disabled, low", which means that they could not return full time to their previous social activities. Most of them received a permanent disability pension and were dependent on help for their instrumental daily life activities. For patients with aSAH, therefore, the cut-off between a poor and good outcome should be based on the outcome level "moderate disability, low" rather than on "severe disability, high". According to this definition of poor outcome, the final evaluation of outcome after aSAH should be at 12 months, in order to give patients a chance to return to their previous social activities, such as work, at least on a part-time basis. This study also indicated a sign of deterioration in social outcome at the group level two years after discharge. This late deterioration after aSAH has not been reported previously and should be investigated further.

The outcome assessments

The Swedish version of the Glasgow Outcome Scale (S-GOS) is based on the extended GOS version published by Maas et al. (6). The most important difference between the S-GOS and the GOS seems to be the delineation of severe disability from moderate recovery. In the S-GOS the need for supervision of the patients is defined as 24 hours, while in the version of Wilson et al. (28) this need must exceed 8 hours.

For the assessment of social functioning after traumatic head injuries (THI), resumption of previous work capacity is a very important item for the definition of "good recovery", but this might be less valid for an aSAH population, which is 20 years older and has the opposite gender distribution compared with a population of THI. One problem, common to the two populations, is the pre-morbid presence of disabilities of other types, such as antisocial behaviour and alcoholic dependence among patients with THI, while cardiovascular disease and orthopaedic problems are common among aSAH patients. It is therefore very important to estimate a baseline level before the aSAH and to disregard the effects of any new disease during follow-up. In the

present study all clinical available information was used for the global assessment, as recommended by Jennett et al. (3).

Responsiveness of the eight-point GOS

The five-point GOS has been recommended for use in head trauma research as well as for reporting of studies of aSAH (4). Bond & Brooks (9) concluded in their review of studies on recovery from severe head trauma that 90% of the patients reached their final outcome, measured by the five-point GOS, after 6 months. The five-point GOS has been criticized (3) but its lack of responsiveness has not been identified in the literature.

The present study showed that a suitable endpoint for assessment of recovery of patients operated on for an acute aSAH was between 6 and 12 months, dependent on the patient's status at discharge.

The S-GOS showed a high level of responsiveness in the comparisons. In particular, the two levels of "severe disability" and "moderate disability" showed different patterns of recovery, which was not evident when the five-point version of the scale was used. The observations at these levels produce steps in the rank-transformable patterns and in the ROC curves. The advantage in responsiveness of the eight-point version over the five-point scale is easily seen by constructing 5×5 contingency tables on the basis of the tables in Fig. 5. The patterns of changes were homogeneous; the RV values ranged between 0.004 and 0.09, and there were negligible individual changes apart from the group change. A significant systematic group change between discharge and the 3-month follow-up occasion was seen (RP, 0.35; 95% CI, 0.23 to 0.47). The RP value indicates that there is a 35% higher chance of being classified in a higher S-GOS level than in a lower level 3 months after discharge as compared with the level at discharge. No other changes were evident from using the five-point assessments. The RP values for the follow-up occasions were 0.10, −0.02, −0.04 and −0.06, respectively.

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REFERENCES

1. McDowell I, Newell C. Measuring health. A guide to rating scales and questionnaires. 2nd edition. Oxford: Oxford University Press; 1996.
2. Jennett B, Bond M. Assessment of outcome after severe brain damage. A practical scale. Lancet 1975; i: 480–484.
3. Jennett B, Snoek J, Bond MR, Brooks N. Disability after severe head injury: observations on the use of the Glasgow Outcome Scale. J Neurol Neurosurg Psychiatry 1981; 44: 285–293.
4. Drake CG. Report of World Federation of Neurosurgical Societies Committee on a universal subarachnoid haemorrhage grading scale. J Neurosurg 1988; 68: 985–986.
5. van Gijn J, Bromberg JEC, Lindsay KW, Hasan D, Vermeulen M. Definition of initial grading, specific events, and overall outcome in patients with aneurysmal subarachnoid hemorrhage stroke. 1994; 25: 1623–1627.
6. Maas AIR, Braakman R, Schouten HJA, Minderhoud JM, van Zomeren AH. Agreement between physicians on assessment of outcome following severe head injury. J Neurosurg 1983; 58: 321–325.
7. Guyatt GH, Deyo RA, Charlson M, Levine MN, Mitchell A. Responsiveness and validity in health status measurement: a clarification. J Clin Epidemiol 1989; 42: 403–408.
8. Bond MR. The stages of recovery from severe head injury with special reference to late outcome. Intern Rehabil Med 1979; 1: 155–159.
9. Bond MR, Brooks DN. Understanding the process of recovery as a basis for the investigation of the rehabilitation of the brain injured. Scand J Rehabil Med 1976; 8: 127–133.
10. Stevens SS. On the theory of scales of measurement. Science 1946; 103: 677–680.
11. Merbitz C, Morris J, Grip JC. Ordinal scales and foundations of misinference. Arch Phys Med Rehab 1989; 70: 308–312.
12. Hand DJ. Statistics and the theory of measurement. JR Statist Soc SerA 1996; 159: 445–492.
13. Feinstein AR, Josephy BR, Wells CK. Scientific and clinical problems in indexes of functional disability. Ann Intern Med 1986; 105: 413–420.
14. Svensson E. Guidelines to statistical evaluation of data from rating scales and questionnaires. J Rehabil Med 2001; 33: 47–48.
15. Altman DG. Practical statistics for medical research. London: Chapman & Hall; 1991.
16. Feinstein AR. Beyond statistics: What is really important in medicine? Cleve Clin J Med 1997; 64: 127–128.
17. Svensson E. Analysis of systematic and random differences between paired ordinal categorical data (dissertation). Stockholm: Almqvist & Wiksell International; 1993.
18. Svensson E. Ordinal invariant measures for individual and group changes in ordered categorical data. Stat Med 1998; 17: 2923–2936.
19. Säveland H, Hillman J, Brandt L, Edner G, Jacobsson K-E, Algers G. Overall outcome in subarachnoid haemorrhage. J Neurosurg 1992; 76: 729–734.
20. Sonn U, Svensson E. Measures of individual and group changes in ordered categorical data: application to the ADL Staircase. Scand J Rehabil Med 1997; 29: 233–242.
21. Svensson E. A coefficient of agreement adjusted for bias in paired ordered categorical data. Biometrical J 1997; 39: 643–657.
22. Efron B, Tibshirani RJ. An introduction to the bootstrap. London: Chapman & Hall; 1993.
23. Holm S. A simple sequentially rejective multiple test procedure. Scand J Stat 1979; 6: 65–70.
24. Ware JH, Lipsitz S, Speizer FE. Issues in the analysis of repeated categorical outcomes. 1988; 7: 95–107.
25. Agresti A. A survey of models for repeated ordered categorical response data. Stat Med 1989; 8: 1209–1224.
26. Cox C. Location-scale cumulative odds models for ordinal data. A generalized non-linear approach. Stat Med 1995; 14: 1191–1203.
27. Teasdale GM, Pettigrew LE, Wilson JT, Murray G, Jennett B. Analyzing outcome of treatment of severe head injury: a review and update on advancing the use of the Glasgow Outcome Scale. J Neurotrauma 1998; 15: 587–597.
28. Wilson JT, Pettigrew LE, Teasdale GM. Structured interviews for the Glasgow Outcome Scale and the extended Glasgow Outcome Scale: guidelines for their use. J Neurotrauma 1998; 15: 573–585.

APPENDIX 1. Empirical expressions for calculating the measures of group change; the relative position (RP) and the relative concentration (RC)

Notations:

m: the number of ordered scale categories

n: the number of individuals

x_i and y_i: the ith category frequencies of marginal distributions X and Y

$C(X)_i$ and $C(Y)_i$: the ith category cumulative frequencies

The probability of Y being classified toward higher categories than X, $P(X < Y)$ is estimated by

$$p_{xy} = \frac{1}{n^2}\sum_{i=1}^{m}[y_i \cdot C(X)_{i-1}]$$

The probability of X being classified toward higher categories than Y,$P(Y < X)$ is estimated by

$$p_{yx} = \frac{1}{n^2}\sum_{i=1}^{m}[x_i \cdot C(Y)_{i-1}]$$

The measure of systematic change in position is $RP = p_{xy} - p_{yx}$.

The probability of Y being concentrated between the marginal distribution of X, $P(X_1 < Y_k < X_o)$ is estimated by

$$p_{xyx} = \frac{1}{n^3}\sum_{i=1}^{m}\{y_i \cdot C(X)_{i-1}[n - C(X)_i]\}$$

The probability of X being concentrated between the marginal distribution of Y, $P(Y_1 < X_k < Y_o)$, is estimated by

$$p_{yxy} = \frac{1}{n^3}\sum_{i=1}^{m}\{x_i \cdot C(Y)_{i-1}[n - C(Y)_i]\}.$$

The measure of systematic change in concentration is

$$RC = \frac{1}{M}(p_{xyx} - p_{yxy})$$

M is the minimum value of $(p_{xy} - p_{xy}^2)$ and $(p_{yx} - p_{yx}^2)$ provided $0 < (p_{xy}$ and $p_{yx}) < 1$.

APPENDIX 2. The augmented ranking approach and the measure of individual changes (RV) and homogeneity (r_a)

Notations:

n is the number of individuals

x_{ij} is the (i, j)th cell frequency, where $i, j = 1, \ldots, m$

$\overline{R}_{ij}^{(X)}$ and $\overline{R}_{ij}^{(Y)}$, the mean ranks of the observations in the (i, j)th cell of the $m \times m$ contingency table, according to the judgements on occasion X and Y.

The augmented ranking procedure means that the mean ranks for observations in the (i,j):th cell differ from the means ranks for observations in the $(i, j+1)$th cell, $(\overline{R}_{ij}^{(X)} < \overline{R}_{i,j+1}^{(X)})$, and from the $(i+1, j)$th cell, $(\overline{R}_{ij}^{(Y)} < \overline{R}_{i+1,j}^{(Y)})$ for i and $j = 1, \ldots, m$.

$\Delta\overline{R}_{ij}^2$ is the square of the augmented mean rank difference of the observations in the (ij)th cell.

The relative rank variance,

$$RV = \frac{6}{n^3}\sum_{i=1}^{m}\sum_{j=1}^{m}x_{ij}\Delta\overline{R}_{ij}^2$$

The correlation of the augmented mean ranks, r_a $(0 \leq r_a \leq 1)$, defines the level of homogeneity of individual changes relative to the common group change. The higher the value $(r_a \leq 1)$, the more homogeneous are the changes in the group. For untied observations

$$r_a = 1 - \frac{n^3}{n^3 - n}RV.$$