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The Glasgow Outcome Scale: 40 years of application and refinement

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Abstract

The Glasgow Outcome Scale (GOS) was first published in 1975 by Brian Jennett and Michael Bond, and, with over 4,000 citations to the original paper, is the most highly cited outcome measure in studies of brain injury and the second most-cited paper in clinical neurosurgery. The original GOS and the subsequently developed extended GOS (GOSE) are recommended by several national bodies as the outcome measure for major trauma and for head injury. The enduring appeal of the GOS is linked to its simplicity, short administration time, reliability and validity, stability, flexibility of administration (face-to-face, over the telephone and by post), cost-free availability and ease of access. These benefits apply to other derivatives of the scale, including the Glasgow Outcome at Discharge Scale (GODS) and the GOS paediatric revision. The GOS was devised to provide an overview of outcome and to have a focus on social recovery. Since the initial development of the GOS, there has been an increasing focus on the multidimensional nature of outcome after head injury. This Review charts the development of the GOS, its refinement and usage over the past 40 years, and considers its current and future roles in developing an understanding of brain injury.

Key points

- The Glasgow Outcome Scale (GOS) in its original and extended form assesses disability and social participation and is the most highly cited outcome measure in studies on brain injury

- The GOS is widely used as a primary outcome measure, and is recommended by several national bodies, including the NIH in the USA, and the Department of Health in the UK

- The GOS can be administered in various ways: face-to-face or telephone interview, mail, and in inpatient settings using a modified version; this flexibility leads to high rates of follow-up

- The GOS is freely available, simple to use and requires little training, it has been validated, is reliable, and adult and paediatric versions are available
- The GOS is the most popular clinician-reported outcome assessment for randomized clinical trials in acute head injury, and has been used in >90% of the most methodologically robust trials
- Extensive use of the GOS over 40 years has led to interest in the development of composite measures that include the GOS to improve the assessment of brain injury outcome The early 1970s saw the emergence of an interest in quality of life after head injury, driven in part by concerns that improved medical care was reducing mortality in people with severe head injury, leaving some with long-term physical and mental difficulties and reduced social participation. Publication of the Glasgow Coma Scale in 1974 provided a reliable and practical means of assessing the level of consciousness and an early index of the severity of injury[1]. 1 year later, Bryan Jennett and Michael Bond published a complementary scale, the Glasgow Outcome Scale (GOS), designed to assess outcomes of brain injury[2]. The GOS was intentionally designed to provide an overview of outcome after brain injury, with a focus on social recovery. Since the initial description of the GOS, emphasis has been increasingly placed on the multi-dimensional nature of outcomes after head injury, which often comprise complex combinations of changes in emotional control, cognitive function and physical ability that, together with pre-injury factors and the post-injury environment, are associated with heterogeneity in outcome and with a change in outcome late after injury in a considerable proportion of patients[3–5].

The original article that described the GOS[2] is the most highly cited outcome measure in studies of brain injury, with 4,308citations (Web of Science Core Collection 06.06.2016), and is the second most cited paper in clinical neurosurgery[6]. The later description of the extended GOS (GOSE)[7] is in the top 25 cited papers on traumatic brain injury (TBI)[8]. The GOS in its original or extended form is recommended as the outcome measure to be used for major trauma and for head injury by, among others, the National Institute of Neurological Disorders and Stroke, the NIH National Institute of Child Health and Human Development TBI Clinical Trials Network and the Department of Health in England[9–11]. In the USA, the GOS is the core measure used for outcome research in TBI in the Common Data Elements project[12]. The GOS has also been used by a range of diagnostic groups, although the focus has largely been head injury. This Review explains the background to the development of the GOS, its uses, impact and future potential, and how its application has evolved to meet the aspirations of the original authors 40 years after the original publication.

[H1] Background of the Glasgow Outcome Scale

During the early 1970s, outcome assessment after acute brain injury became increasingly focussed on quality of survival rather than the simple fact of survival. Death rates were still as high as 50%[13–15], but improvements in intensive care, such as artificial ventilation, were believed to be reducing early mortality. This change led on one hand to claims of 'miraculous' recoveries, but on the other hand raised concerns about increasing numbers of highly dependent survivors[16]. The prospect of long-lasting disorders of consciousness caused unease, leading to the publication of the seminal paper on the persistent vegetative state by Jennett and Plum[17] in 1972. Reservations were also voiced about the subjectivity of claims that patients had made a 'good recovery'. Furthermore, the fact that many patients with head injuries were young led to concern about the prospect of survival in the community for many years with an undefined level of recovery and about the use of interventions that might improve survival but leave patients with permanent, severe disability and poor quality of life. An anonymous letter published in the Lancet in 1973 expresses this[18]:

…uncertainties about prognosis after severe head injury have lately been reviewed by Jennett. He maintains that claims about remarkable recoveries after severe head injury often prove to be falsely founded, closer examination of the circumstances commonly revealing either that the initial state was not as serious as had been thought, or that the degree of recovery is not as good as was recorded. In regard to recovery he makes some astringent

comments about the terms used (worthwhile, useful, practical), and he calls for a more objective scale. But that is easier said than done, because what matters is the overall social consequence of the combination of physical and mental sequelae.

In order to assess the evidence for these views and to understand the pattern of events after brain injury, a system was needed that could bring together the factors that are important in outcome and express the summation of their effects on a structured scale. At the time, outcomes after brain injury were categorized with gross, descriptive and often poorly defined terms: examples of such categorizations include 'dead, vegetative existence or recovery'[19], 'dead, permanently unconscious/demented or recovered'[14], or 'persisting coma, persisting dementia or mental restitution'[13]. Although crude, these categorizations did reflect a realization that outcomes needed to be considered in terms of social function and reintegration into the community.

An original driver for the development of a robust outcome scale was the realization that multicentre studies of outcomes after coma were needed to address the issue of balancing reductions in mortality rate with survival and quality of life[7]. The GOS was, therefore, designed and published in this context. The original scale consisted of five categories, each of which was described; the three most positive categories related to social function and return to work[2] (Table 1). The scale was designed to assess disability outcomes in the community, with a broad concept of disability that included social participation and was later defined as "handicap" in the WHO 1980 classification[20,21].

[H1] Evolution and application of the Glasgow Outcome Scales

[H2] Early development

Soon after its publication, the GOS was used in two ground-breaking prospective international multicentre studies of head injury[15] and nontraumatic coma[22]. In a 1978 article that identified head injury as a notable public health problem and emphasized the need for a greater understanding of outcome predictors, use of the GOS was recommended to neurosurgical centres worldwide to determine the effectiveness of neurosurgical interventions[23]. The GOS was welcomed and used in several other studies in the 1970s and early 1980s[24,25], and was the main outcome measure in the US National Traumatic Coma Databank[26] study.

In 1981, Jennett and colleagues[7] expanded the five-point GOS into an eight-point scale — later to become known as the GOSE —by dividing each of the Moderate, Severe Disability and Good Recovery categories into two: “better” and “worse”. They also performed some initial validation of the GOSE by comparing outcomes obtained from it with the duration of post-traumatic amnesia, outcome ratings given by an experienced clinician, and the results of cognitive assessment. Further early work assessed the validity of GOS outcomes in relation to cognitive function more systematically[27]. The GOS ratings were associated with cognitive test scores, but the GOSE ratings were not associated in the same way, although the sample was subdivided for analysis and as a result was small and might have been underpowered.

[H2] The structured format and its administration

Studies that assessed the reliability of the GOS and GOSE found the five-point version to be superior, but also identified considerable inter-rater variation in rankings for both versions of the scale, and systematic differences according to the background and experience of the assessor[27–29]. In 1998, a structured format was developed for use with the original five-point GOS and the eight-point GOSE[30]. New guidelines were developed, which more explicitly stated the rationale for assignment of individuals to each category. Importantly, the structured format also provided a means of taking into account pre-injury disability by making explicit that the GOS should reflect change from before the head injury. Also emphasized in this format is the need to use the best available source of information, which can be a person who is close to the patient given that the patient themselves might not have insight into their difficulties, and guidelines are included for dealing with additional factors, such as multiple injuries and epilepsy. Use of this structured format improves inter-rater reliability for the GOS (kappa = 0.89) and GOSE (kappa = 0.85)[30]. A comparison of the structured format of the GOS and GOSE with cognitive tests revealed medium to strong correlations between rankings on the GOS and GOSE and scores on cognitive tests at 3–6 months after injury[31,32]. Strong correlations were also seen with self-report measures of mental well-being, including the Beck Depression Inventory, the Short Form Health Survey-36 (SF-36) and General Health Questionnaire 28[31].

Flexibility in methods of administration for assessments offers benefits such as improving follow-up rates. The structured format of the GOS and GOSE has been used to validate telephone and postal administration. High levels of agreement were seen between telephone and face-to face administration (test-retest GOS kappa= 0.92 and GOSE 0.92; inter-rater GOS kappa= 0.85 and GOSE 0.84)[33]. Postal versions of the GOS and the GOSE, which

could be completed by the person with head injury or by a proxy, also had very high test–retest reliability (kappa= 0.94 GOS and 0.98 GOSE)[34].

[H2] The Glasgow Outcome at Discharge Scale

The GOS was designed to assess independence in the community, but in some studies, the GOS and GOSE have been used in an inpatient setting. These scales are not validated for use in this context, but their use demonstrates a demand for an inpatient scale that enables comparisons with later GOS and GOSE outcomes in the community in longitudinal studies. An inpatient scale also has the potential to facilitate clinical decisions about discharging patients, especially when patients are being discharged from a non-specialist ward. The Glasgow Outcome at Discharge Scale (GODS) was published in 2013[35]. This scale was developed from the GOSE and uses the same outcome categories, but the criteria for categorization are modified for the inpatient setting. Use of the GODS has shown that it can predict disability on the GOSE at 3 weeks after discharge with a sensitivity of 89% and specificity of 75%, and inter-rate reliability seems to be high (kappa = 0.98)[35].

[H2] Children's versions

The original GOS is frequently used to examine outcomes in children[36–38], although data on the validity of the GOS in this context are limited. The brevity of the GOS and its ease of administration are considered to be advantages over other scales[39], but the literature generally points towards benefits from using a modified version of the GOSE for children.

In 1992, the GOS was modified specifically to assess outcomes in children in the intensive care unit, and a category of 'Mild Disability' (somewhat similar to the GOSE Lower Good Recovery category) was added to the original five-point scale[40]. Subsequently derived from the modified scale was the Paediatric Overall Performance Category and the Paediatric Cognitive Performance Category Scales. These scales are intended to be administered at hospital admission (baseline) and at discharge, enabling the changes in score to be compared with the length of stay in intensive care and the mortality. Inter-rater reliability of these scales seems to be high (intraclass correlation coefficient = 0.88–0.92). However, the validity of the scales for predicting outcomes after discharge from hospital remains unclear[41].

In 2012, the GOSE Pediatric Revision (GOSE-Peds) was developed to take into account developmental stages[42]. The GOSE-Peds uses the same eight categories as the GOSE and involves a structured interview that is adapted from that for the GOSE to allow for developmental differences. The validity of the GOSE-Peds was assessed by comparing rankings with those from the GOS and scores on standardized functional scales for children,

including the Vineland Adaptive Behaviour Scale (VABS), parental report and tests of general intellect and learning. The study included 159 patients aged 1 month to 17 years, and revealed a strong association between rankings on the GOSE-Peds and those from the GOS at 3 months (Spearman r = 0.87) and 6 months (Spearman r= 0.82) after injury. A similarly strong association was seen with the VABS (Spearman r = –0.62 at 3 months and –0.74 at 6 months). Rankings on the GOSE-Peds tended to be more a strongly associated with other outcome measures than were rankings on the GOS[42]. Further work is required to confirm which scale is best in children (including comparisons of paediatric scales with the GOSE), and a tendency remains to use the GOSE or GOS in paediatric studies.

[H2] Application and typical findings

Outcomes determined with the GOS or GOSE at 3–12 months after severe head injury have a bimodal distribution: typically, >70% of patients have extreme outcomes of Good Recovery or Dead[43]. In those who survive at 1 year, approximately half of patients who had mild, moderate and severe head injuries are categorized as disabled by the GOS at 1 year, 5–7 years and 10–12 years after injury[4,44,45]. Follow-up rates in studies that use the GOSs are high, an observation that holds true for large-scale clinical trials[46], long term community follow-up studies, and unselected series that include patients with mild head injuries (which often have a relatively low retention at follow-up) [4,44,45]. The GOSs also tend to be associated with higher follow-up rates than are other assessments, such as cognitive testing[4,47], an observation that, at least in part, probably reflects their ease of administration and the range of validated methods of administration (face-to-face, telephone or post) as a community measure (GOS and GOSE) and, more recently, as an inpatient measure (GODS).

The numbers that are sometimes attached to outcomes of the GOS, GOSE or GODS are rankings and must not be seen as arithmetic ‘scores’. As categorical, ordinal information, the scales require non-parametric approaches to statistical analyses.

[H1] Criticisms

[H2] Sensitivity and reliability

Despite widespread use of the GOS and GOSE, they have been criticized, often in relation to their use in clinical trials of acute care. Most studies in which neuroprotective therapies are tested have used the GOS as a primary outcome measure, and the possibility that the sensitivity of the GOS is insufficient to detect changes has been raised as an explanation for uniformly negative findings[42]. The sensitivity of an outcome scale such as the GOS is,

however, directly related to the change that is considered clinically relevant, and not to its ability to detect effects on an impairment that are just noticeable but have no impact on function.

Another criticism of the GOS that has been raised relates to its reliability. For example, Lu *et al*.[48,49] have raised concerns about the inter-rater reliability of the GOS and GOSE, and the fact that misclassifications would reduce the power to detect a significant effect in clinical trials. These critics have suggested that early estimates of the inter-rater reliability of the GOS were optimistic and note that significant inter-rater variability for the GOSE was reported when it was used by untrained investigators[50]. Inter-rater agreement has been improved by the development of an alternative two-step system for rating with the GOSE, which initially focuses on allocation to a GOS category and then involves limited questioning to further determine the appropriate GOSE category[49]. Further improvements were seen if raters received feedback on each case during their review. This approach complicates the assessment process, and a requirement for reviewer feedback might make it impractical. The study did not consider the impact of pre-study rater training, which could be self-administered via the Internet and incorporate a test of competency.

[H2] Dichotomization of outcomes

Despite early criticism of the GOS for "over-compressing" survival outcome[7], a convention developed for dichotomising the five-point GOS scale into 'unfavourable' (Dead, Vegetative or Severe Disability) or 'favourable' (Moderate Disability or Good Recovery) outcomes. This dichotomy reflects the view that independent function, rather than survival with disability that leaves patients dependent, is the desired outcome because head injury is most common among young adults. However, several aspects of this dichotomization have been questioned.

One drawback of the dichotomy is that it does not take into consideration the patient's perception of life satisfaction, which is crucial and cannot simply be equated with independent function[51]: studies have shown that self-reported quality of life can be good in the face of severe disability[52–54] and that the factors most strongly associated with disability outcomes are emotional rather than physical[4,55].

Dichotomizing outcomes in this way also limits comparison of outcomes between clinical trials. A state-of-the-science overview published in 2016 identified >180 randomized controlled trials published since 1980 in which interventions for managing acute head injury

were compared[56], and the GOS or GOSE was the clinician-reported index of outcome in more than two thirds of these trials.[56] Twenty-six of these RCTs, were defined as methodologically robust and the GOS/GOSE was used in 23. The analysis in many of these studies was based on outcome dichotomization, and the criterion for efficacy was a shift from unfavourable outcomes to favourable outcomes. Few studies have reported significant benefits of active interventions, and the failure to find an effect in any kind of acute brain damage despite so many studies has raised questions about aspects of trial methodology, including the limitations of simple dichotomization. The division between Severe Disability and Moderate Disability came to be seen as arbitrary, and a dichotomy at this point fails to acknowledge a change from Moderate Disability to Good Recovery Importantly, concerns were raised about whether dichotomization might be statistically inefficient, as it underuses the information available about shifts in the pattern of finding over the full, ordered spectrum of outcomes[9]. These disadvantages have led to the investigation of two new approaches to the analysis of the GOS in the past decade: the sliding dichotomy and the proportional odds methods. Both methods make use of statistical analyses for use with ordinal scales such as the GOSs. Ordinal data is presented in order of magnitude, but the size of the difference between points on the scale may not be the same; for example vegetative state is worse than severe disability which is worse than moderate disability and so on.

In the sliding dichotomy analysis, outcomes are still split into two categories, but a favourable outcome is defined as one that is better than expected when the prognosis of patients at entry into the study is taken into account. This involves dividing the study population into subgroups according to the early severity of their injury. This is done by taking into account factors such as clinical and imaging findings and patient age[57]. The point of dichotomization is adjusted according to the subgroup. For example, among patients with a good prognosis, only Good Recovery is considered to be a favourable outcome; for patients with an intermediate prognosis, a favourable outcome is Moderate Disability or better.

Proportional odds analysis has the potential to be even more informative. It exploits the full range of the GOS ratings to produce a single estimate of a treatment effect. All possible configurations of dichotomized outcomes are assessed, based on the assumption that the odds ratio of a favourable outcome relative to an unfavourable outcome will be similar regardless of where the scale is dichotomized. The analysis yields a pooled estimate, or common odds ratio that indicates change in outcome across the entire range of GOS ratings after treatment. It is possible to control statistically for the influence of factors that contribute

to variability in the impact of among the study population, allowing more inclusive entry criteria and, consequently, faster recruitment of participants.

The potential benefits of ordinal statistical methods, such as sliding dichotomy and proportional odds analysis, were initially explored with the Rankin Scale for stroke[58] before being applied to the GOS in spontaneous intracranial haemorrhage[59] and head injury[60]. The theoretical statistical advantages of these new approaches were confirmed in simulation studies[61] that showed substantial gains in efficiency that could allow sample sizes to be reduced by up to 50% without loss of statistical power. Powerful validation of the approach came from a retrospective study that used data from a large trial of corticosteroid treatment in head injury[62]. Dichotomous analysis of the GOS at 6 months after injury showed a non-significant adverse effect of the treatment (OR 1.09, 95% CI 0.98–1.21, *P* = 0.096). Analysis with the proportional odds logistic regression model, however, produced a highly significant effect (estimated common OR 1.15, 95% CI 1.06–1.25, *P* = 0.0007). Similar results were obtained with sliding dichotomy. If using either ordinal analysis, a 2–2.5-fold gain in information density was achieved. Use of the GOSE can give a modest increase in efficiency over use of the GOS, corresponding to a further reduction in the required sample size of 3–5%[63].

To date, prospective application of ordinal analyses has been crucial in only a few instances. However, the International Stroke Trial of thrombolysis in stroke is one example in which such analysis was important. The pre-specified primary dichotomized analysis indicated no significant treatment benefit, but the pre-specified ordinal analysis revealed a highly significant benefit. Meta-analysis of all trials of tissue plasminogen activator strongly suggests that the result of the ordinal analysis is valid[64]. The use of ordinal methods is increasing: these methods were used in 60% of stroke trials published between 2007 and 2014, but are specified in the protocols of 15 of 16 current trials[65]. In head injury research the use of ordinal methods in analysis is one of four key recommendations made by the International Mission on Prognosis and Clinical Trial Design in TBI (IMPACT) group after several years of extensive research into trial methodology[66] .

The extra information gained by using the sliding dichotomy or proportional odds methods does not seem to differ consistently, and other factors influence which of these methods is chosen. The sliding dichotomy is more clinically appealing because the underlying concept of assessing how often a patient achieves an outcome that is better than was predicted, is easy to communicate and comprehend. The proportional odds is theoretically more efficient but is also more complex and its results are not so readily translated into clinical terms. [In

either case, these developments in methodology increase the value of information obtained from the GOS and GOSE, and are likely to extend the role of these scales in clinical research.

[H2] Ceiling effects

Some have argued that GOS and GOSE ratings have a low ceiling that does not adequately represent the range of impairment within Good Recovery categories[43]. For this reason, interest has grown in developing composite batteries that combine the GOSE with, for example, cognitive tests so as to increase sensitivity and the ability to detect subtle changes in outcome[10]. Composite endpoints have been used in several large-scale clinical trials in TBI, including studies of the impact of magnesium sulphate[67] and intracranial pressure monitoring on functional recovery following TBI[68]. Despite use of a range of outcome measures, these trials still failed to demonstrate benefits of intervention. A simulation in which the GOSE alone was compared with a composite measure that included the GOSE and three neuropsychological tests showed that, after adjusting for baseline prognosis, the two approaches had similar power to detect an effect[69]. The authors of this study concluded that cognitive testing only adds an advantage if the intervention has a larger effect on cognition than on global outcome. This finding has generated interest in developing sensitive cognitive endpoints that might be used as primary endpoints in place of the GOS and GOSE, but clinical studies have provided no evidence that composite endpoints are superior to the GOSE alone. Furthermore, attempts to combine measures in this way need to take into account the fact that cognitive impairment may not be associated with changes in daily function.

[H1] Relationships with other outcome measures

The main alternative to the GOS or GOSE as an index of general outcome is the Disability Rating Scale (DRS), which focuses on neurological symptoms and restrictions in activities of daily living. The DRS is a 30-point scale that uses eight questions and tends to under-represent social participation. The DRS was originally developed to track reductions in disability during rehabilitation[70]. Some reports have suggested that the DRS is more sensitive to change in inpatients than is the GOS, but the absence of a validated or objective comparator makes this conclusion difficult to justify[71]. Furthermore, assessment of the GOS in inpatient settings is inappropriate, and similar studies in future should use the GODS[35]. On the other hand, several aspects of the DRS have been criticized. Its use requires more training than is needed for the GOS or GOSE, and severe disability and vegetative

outcomes overlap[43,72]. The sensitivity of the DRS has also been questioned; for example, comparison of the DRS and GOS in the community has shown that the GOS is more sensitive to treatment effects of a hypothermia intervention[72].

Other scales tend to be used in rehabilitation settings, require rater training, and take longer to complete than the GOS, but can provide fine-grained assessments. For example, the Functional Independence Measure (FIM) comprises 18 questions, each of which is answered on a scale of 0–8. Use of the Functional Assessment Measure (FAM) as an adjuvant adds a further 12 questions. However, the FIM is thought to be of limited use in detecting changes after patients are discharged from rehabilitation, and it lacks sensitivity to psychosocial disability[73].

The DRS, FIM and FAM are not strictly ordinal, as they subcategorize abilities that do not have an inherent rank order; for example, a score for a feeding subcategory cannot be ranked below a higher score in communication[9]. Furthermore, errors in can reduce the power to detect an effect, and the potential for such misclassification increases as the number of items being scored increases[72]. This effect demonstrates the trade-off in using a measure, such as the GODS or GOSE, that is reliable, quick to administer and requires little training, or other measures that provide more-detailed information about actual and potential disability and can indicate specific needs for intervention and rehabilitation , but are more time consuming, less reliable, require more lengthy training and are more difficult to interpret, especially when using grouped data.

The GOSE is associated with psychological factors, such as self-esteem, stress, depression, anxiety and locus of control. Late after injury, psychological factors are more strongly associated with outcome than are injury-related physical factors[4,35]. Sequential and serial assessment of patients with the GOSE has, therefore, facilitated attempts to understand the relationships between emotional function, disability and change in disability over time. Results of these longitudinal studies indicate that some outcomes remain unchanged, but others are dynamic and can improve or deteriorate even ten years or more after injury[4,35,45,74,75].

Assessment of health-related quality of life (QoL) has become increasingly important in neurological disease. The GOSs have been described as indices of quality of life, although are perhaps more precisely assessments of life function, which is just one component of QoL. Emotional distress continues to be associated with poor functional outcome many years after injury[74], and GOS measures correlate closely with emotional distress and QoL as measured with generic QoL assessments, such as the SF-36, and with the Quality of Life

After Brain Injury (QOLIBRI) measure, which is specific for patients with head injury.[35,56] The strength of the association between these measures indicates excellent validity of the clinician rating scales in relation to patient-reported outcomes. The direction of any causal relationship between subjective wellbeing and global function remains to be clarified, and is an important issue for understanding how patients can adjust to the effects of head injury.

[H1] International developments

Much of the work to develop the GOSs was conducted in Glasgow, UK, but the measures have been used widely and in multicentre international randomized controlled trials. Important insights have been gained from their worldwide use.

[H2] Australia

The GOS and GOSE have been used extensively in Australian studies that assessed early interventions[76–80] and examined the effects of genetic status[75,81], psychiatric disorders[82,83], demographics, injury severity and rehabilitation[74,84-88] on outcome. The Victorian State Trauma Registry also involves use of the GOSE to assess outcome in general trauma victims, including those with TBI[89].

The optimal method of analysing GOSE results remains a subject of debate in Australia. In many studies, the scale has been dichotomized, leading to reduced sensitivity. The point of dichotomization has varied: in some studies of medical interventions, a GOSE ranking of 5–8 has indicated a good outcome[76-78,80], whereas in some studies of rehabilitation , rankings of 7–8 were good outcomes[74,75]. Not all of these dichotomizations are necessarily sensible: classifying Moderate Disability as a favourable outcome when the individual has been unable to return to pre-injury work and social activities, for example, is arguably inappropriate. The use of proportional odds analysis or a sliding dichotomy to describe GOS and GOSE outcomes in relation to the baseline risk for the individual could address this issue[73]. However, such methods seem to have been used very little in Australia to date. **[**

The possibility that the GOS has low sensitivity to emotional and psychosocial effects[88] has been addressed in Australia with the development of The Sydney Psychosocial Reintegration Scale. This scale is a 12-item clinician rating scale designed to measure psychosocial functioning in people with head injury in the domains of Occupational Activity, Interpersonal Relationships and Independent Living Skills[90]. Having undergone a rigorous development process, this scale has been used, predominantly in Australian studies to date,

to document outcome across separate domains form both the patient and close other perspective, and to identify predictors of outcome. It has also shown sensitivity to change in response to treatment[91]. Although it takes longer than the GOSE to administer, these features render the SPRS complementary to the GOSE in certain contexts[92].

[H2] The USA

In the USA, the GOS has been used extensively in single-centre and multicentre observational studies of severe TBI, including the National Coma Data Bank and NIH-funded clinical trials[93,94]. An undisputed advantage of the GOS and GOSE for trials in severe head injury is its capability to grade outcome in patients who are noncommunicative, or when standard performance-based outcome measures are not feasible through the use of clinical observation and/or input from a collateral source such as a carer or relative. Trends in current head injury research and clinical practice in the USA support the use of the GOS and its extensions, such as GOSE, GODS and GOSE-Peds, for use with children. For example, the GOSE-Peds has been used in clinical trials of hypothermia in children[42].

Versions of the GOS have been included in Common Data Element resources developed, on the basis of recommendations by study groups, by the NIH and other US Federal agencies, for assessing global outcome after TBI and outcomes in specific domains, including cognition, behaviour and social participation[12]. Version 2 of the CDE specified the most appropriate outcome measures according to severity of TBI, age of the patient and phase of recovery[95]. The National Institute of Neurological Disorders and Stroke (NINDS) designated the GOSE as a ‘core’ CDE measure of global outcome of adult TBI, including outcomes of acute hospitalization, rehabilitation after moderate to severe head injury, mild TBI, and as an outcome measure in epidemiology studies. The GOSE-Peds was recommended as a ‘basic’ measure of global outcome of acute hospitalization and rehabilitation in children with moderate to severe TBI, as a ‘supplemental’ outcome measure for concussion and mild TBI, and as an outcome in epidemiology studies. The GOS was designated as a ‘supplemental’ measure for all severities and phases of recovery from adult head injury, implying that GOSE should be preferred. This Federal impetus towards standardization of outcome measures facilitates comparison between studies, and US investigators are now mandated to submit their data on TBI to a Federal registry, which will eventually facilitate meta-analysis of aggregated data sets.

The GOSE was the primary measure of global outcome in the Transforming Research and Clinical Knowledge in TBI (TRACK-TBI) pilot[96] in the USA. The project involved patients with acute injuries across the spectrum of severity and produced seminal studies on the

prediction of outcome after mild TBI. Despite uncertainty about the sensitivity of the GOSE to the effects of mild TBI, Good Recovery vs Moderate to Severe Disability at 3 months was related to MRI predictors which were obtained approximately two weeks post-injury [97].

A major area of research and clinical practice in the USA is concussion in athletes, and the GOSs could have a role in this context. Given the intense interest in late effects of concussion, such as chronic traumatic encephalopathy, the GOS or GOSE might be useful in conjunction with other measures for grading the long-term effects of repetitive head impacts in prospective studies.

Also in the USA, increasing recognition that the assessment of outcomes should include the patient's perspective has led to NIH-supported development of self-report measures such as the Neuro-QOL, which has item banks to assess everyday functioning, social participation, emotional status, satisfaction with life, and applied cognition. Brief and extended self-report measures that are derived from the item banks have produced promising data that indicate their reliability and validity, and have been designated as CDEs. These self-report measures could complement the GOSE in future research[96].

[H1] Current status, future uses and improvements

Nichol and colleagues[73] list five features of the ideal outcome scale for head injury: it should be logistically simple to administer (that is, take a short time to administer, be valid with different methods of administration and have clearly defined scoring); reliable; valid; stable (that is, sensitive and responsive with no ceiling effects); and free to administer. As discussed above, the GOSs meet all of these criteria, and are widely recommended as the main outcome measure in studies of head injury[9–11]. An important and often overlooked advantage of the GOSs are their (validated) flexibility of administration as a community measure (GOS/GOSE) and as an inpatient measure (GODS), in addition to their ease of administration. As discussed, these features are associated with high follow-up rates in longitudinal studies[4,44]. Inevitably, however, choices need to be made, and the advantages of brevity, modest requirement for assessor training and high reliability of the GOSs must be weighed against the limitations and benefits of more comprehensive and fine-grained assessments.

These considerations have stimulated efforts to combine the GOS and GOSE with other instruments to create multidimensional endpoints[10]. As discussed, interest is growing in developing measures that combine the global outcome of GOSE with outcomes from tests of

cognitive impairment and quality of life[98,99]. Future studies that compare global outcomes with such composite approaches could be informative. Important to keep in mind when looking for subtle effects with such measures, however, is that the GOSs assess change in function that results from brain injury, whereas performance on cognitive tests is strongly affected by sociodemographic factors, such as age, education and deprivation, and by motivation to perform the tests[100]. Nevertheless, work in this area together with a better understanding of the impact of factors, such as rehabilitation and the community environment, in the post-acute stage could improve covariate adjustment in clinical trials, and therefore the overall sensitivity of endpoints to brain injury.

Currently, the GOSE should be used in preference to the GOS for two reasons. First, data collected for the GOSE can be collapsed to provide GOS ratings if necessary, but the reverse is not true. Second, the GOSE has greater sensitivity[32,62]. The potential of the GODS to aid clinical decision-making and planning at the time of discharge, particularly from general wards, is an avenue for further research[35].

[H1] Conclusions

The GOS in its original and extended forms is the most highly cited outcome scale in studies of brain injury, and 40 years after its original publication, it continues to be widely recommended as the primary outcome measure in intervention trials. The GOSs are simple to use, valid and reliable, are freely available and include adult and paediatric versions. Their flexibility of administration facilitates high follow-up rates. The GOSE should be used in the community in preference to the original to improve sensitivity, and the GODS can be used in inpatient settings[32,35,51]. The GOS is also the most popular clinician-reported outcome assessment for randomized controlled trials in acute head injury, and its extensive use over the past four decades has fostered interest in the development of composite assessments that use the GOSE in conjunction with other validated measures to enhance the assessment of outcome after brain injury. Our understanding of outcome after head injury will continue to develop, and the GOSs look set to continue to play an important role.

Note: The GOS, GOSE and GODS together with guidance for use and training materials are available without cost at the following websites: https://commondataelements.ninds.nih.gov/TBI.aspx#tab=Data_Standards

http://www.gla.ac.uk/media/media_253224_en.pdf

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Table 1: Original proposed descriptions of GOS categories by Jennett and Bond[2]

GOS Category	**Proposed description of category**
Death	Ascribable to a particular incident and due to original brain damage. Potentially sub-categorize deaths according to whether they occur before or after regaining consciousness to distinguish initial recovery from brain damage
Persistent Vegetative State	Unresponsive and speechless for weeks or

	months after acute brain damage. Sleep wake cycles return after 2–3 weeks
Severe Disability (conscious but disabled)	Dependent on daily support because of physical and/or mental causes
Moderate Disability (disabled but independent)	Independent in ‘daily life’ (for example, can use public transport and work in a sheltered environment). Able to maintain self-care and ‘activities of daily living’. Considerable family disruption possible
Good Recovery	Resumption of normal life, although there may be minor neurological and psychological deficits. Return to work could lead to false impressions in either direction (for example, socioeconomic factors in work availability, attitude of past employers; included here are leisure interests and family relationships