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Health care innovation of a Stroke assessment scale and its impact on future stroke care in the UK

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Abstract: Swansea Stroke Scale- a Validated Clinical Scale for use by multi-disciplinary staff in Acute Stroke and its value in healthcare delivery:

This workplace-based research project combines clinical stroke medicine and innovation management within a business school context to explore how a new clinimetric tool can be designed, validated, and implemented in a complex health system, and to assess its broader impact on the health service.

Background and Aims:

In the United Kingdom, there is a shortage of Stroke specialists (Iacobucci 2019). Multidisciplinary teams, including non-specialists such as healthcare support workers, physician associates, resident doctors, and registered nurses, increasingly deliver post-stroke care. Neurological decline in the acute phase could be missed because of the lack of a simple neurological examination. A collaboration between Swansea University's School of Management and healthcare partners, funded by the Welsh Government, resulted in the creation of the Swansea Stroke Scale (SSS), a

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stroke-specific tool for staff across all cohorts that is easy to apply without prior training. The SSS evaluates five constructs: Situation, Sight, Speech, Oral intake, and Movement, derived after an extensive literature review, All-Wales collaboration and proto-typing as per the steps of innovation cycle. Scores range from 5 (no deficits) to 20 (maximal deficits). This study validates the SSS against the specialist-led National Institute of Health Stroke Scale (NIHSS). The Social Return on Investment (SROI) for the SSS was evaluated after the stroke scale was validated for clinical use.

Methods:

Approved by the Research Ethics Committee, the study underwent a pilot phase in 2024, followed by the main study in 2025. The pilot recruited 20 participants, while the main study included 135 stroke survivors over 18 years old in an acute stroke unit with symptom onset <7 days. Convergent validity was evaluated using paired assessments of SSS and NIHSS on admission and day 2. Pre-admission modified Rankin score (mRS) was used for divergent validity. Parallel Form reliability and categorical reliability against the NIHSS were analysed with intraclass correlation (ICC) and kappa statistic. Two non-specialists on day 2 evaluated inter-rater agreement via independent SSS assessments. Thirty-day outcome was used for predictive validity. Innovation management principles were applied to calculate the SROI and Net Present Value (NPV).

Results:

The Pearson correlation coefficient of 0.924 ($p<0.001$, 95% CI 0.895–0.945) between SSS and NIHSS indicates strong convergent validity. Divergent validity was confirmed by a low correlation with pre-admission mRS ($r=0.18$, $p=0.037$). ICC of admission SSS with admission NIHSS is 0.92, stayed the same for 24-hour assessments, revealing an excellent parallel form reliability with the NIHSS. The ICC of 0.99 ($p<0.001$, 95% CI 0.987–0.993) between two assessors showed excellent inter-rater agreement. ROC curve AUC for mild stroke presentations is 0.97 (95% CI 0.96, 0.99; $p<0.001$), whilst that of a severe stroke is 0.99 (95% CI 0.98,1.00; $p<0.001$), showing perfect sensitivity and specificity. For moderate strokes, ROC curve AUC is 0.76 (95% CI 0.69, 0.82; $p<0.001$), with a macro-average ROC curve AUC = 0.91 (95% CI 0.89, 0.93; $p<0.001$), supporting categorical reliability between SSS and NIHSS stroke severity categories.

The SSS was statistically significant ($F=18.71$, $p<0.001$) for 30-day disposition. This innovation has a potential Social Return on Investment of £4.6 million per year with a Net Present Value of £4.2 million per year.

Conclusions:

The new stroke scale for non-specialists showed strong validity and reliability against the NIHSS used by specialists, and it has good 30-day outcome prediction with wider implications for areas deficient in stroke specialists. Upskilling non-specialist staff to address the specialist gap should improve patient care, experience, and outcomes. This could provide significant financial savings for the National Health Service.

Background and Aims:

In the United Kingdom, a persistent shortage of stroke specialists means that multidisciplinary, non-specialist staff such as healthcare support workers, physician associates, resident doctors and registered nurses increasingly deliver post-stroke care in acute units (2025). Neurological deterioration in the acute phase can be missed because simple, standardised bedside neurological assessments are not routinely available to all staff.

To address this service gap, Swansea Bay University Health Board, the School of Management at Swansea University and Welsh Government partners co-developed the Swansea Stroke Scale (SSS) as a targeted healthcare innovation. From an innovation management perspective, SSS was designed as a user-centred, low-training tool that can be integrated into routine workflows, enabling non-specialists to perform consistent stroke assessments at the bedside. The SSS evaluates five constructs – Situation, Sight, Speech, Oral intake and Movement – with scores from 5 (no deficits) to 20 (maximal deficits). This study validates SSS against the specialist-led National Institutes of Health Stroke Scale (NIHSS) (Adams, Davis et al. 1999) and explores its potential to support workforce redesign and service improvement.

The Swansea Stroke Scale is a collaboration between the United Kingdom National Health Service (NHS), Swansea University, the Welsh Government and Stroke Hub Wales Patient and Public Involvement group (PPI), to improve patient care. Clinicians of varying professional backgrounds and experience along with patients and their relatives helped in the design and production of the new stroke scale.

Research Methodology:

The research innovation follows the steps of innovation cycle to develop a simple bedside clinimetric scale by means of prospective cohort patient-facing research study. This pilot and the main study took place in an acute stroke unit and recruited 135 adults with acute stroke (20 separate cohort recruited for the pilot phase), age over 18 years and symptom onset less than 7 days, following research ethics committee approval.

Design: Single centre prospective cohort of consecutive stroke admissions to an acute stroke unit.

Population: Adults (over the age of 18) with confirmed acute stroke admitted within two weeks of their symptom onset to an acute stroke unit.

Assessments:

- NIHSS by stroke specialist (gold standard) on admission and at 24–36 hours.
- SSS by two non-specialist assessors undertaken independently (blinded to each other and to NIHSS), at the same time points.
- Premorbid mRS and mRS at 24–36 hours.

Outcomes:

- Psychometric: convergent and divergent validity, parallel form, categorical and inter-rater reliability.
- Clinical: 30-day mortality and places of disposition of the study cohort, along with total hospital length of stay (LoS).

Convergent validity was assessed by paired SSS and NIHSS assessments on Day 1 and calculation of Pearson’s product-moment correlation coefficient (Cohen 1988). Divergent validity was examined using correlation between SSS and the pre-admission modified Rankin Scale (mRS) (Wilson, Hareendran et al. 2002), which reflects pre-morbid disability rather than acute neurological status.

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Inter-rater reliability for SSS was evaluated through two independent non-specialist assessments within 24–36 hours of admission, with intraclass correlation coefficients (ICC) (Koo and Li 2016) quantifying agreement on total scores. Parallel form reliability on admission scores and at 24-36 hours by assessors 1 and 2 evaluated through ICC. Kappa statistics (Landis and Koch 1977) for SSS severity categories were planned to assess categorical agreement. Predictive validity was tested using 30-day outcome: SSS values were examined in relation to survival and disposition through inferential statistics, including tests of group differences and analysis of variance for disposition category. This analytical approach combines psychometric validation methods with clinically meaningful outcomes, aligning with innovation evaluation principles in healthcare.

Hypothesis and operationalising the methodology:

With an All-Wales collaboration and an extensive evidence review, a new stroke scale was developed and tested for validity and reliability against the existing scales such as the NIHSS and mRS. The hypothesis has been divided into different sections-

Hypothesis 1:

Validity: This is measured against the NIHSS and mRS as below. Construct validity: SSS scores have (a) strong convergent validity with NIHSS and mRS when measured at the same time points defined as Pearson value $(r) \geq 0.70$, and (b) appropriate divergent validity through a weak correlation with premorbid disability measured as preadmission mRS, $r \leq 0.2$.

Hypothesis 2:

Reliability: The SSS was examined for parallel form reliability against the total NIHSS, categorical reliability against the NIHSS stroke severity categories and inter-rater reliability when assessed by different non-specialists.

a) Parallel Forms reliability: This measures agreement and assess how interchangeable standardised SSS scores behaves with standardised NIHSS and standardised mRS scores. Intra Class Correlation (ICC) was used, a value of >0.9 signifies excellent reliability; 0.75-0.9 good reliability; 0.5-0.75 moderate reliability; <0.5 poor reliability.

b) Categorical reliability (agreement) of the SSS severity levels is analysed against the NIHSS categories, defined by kappa statistic ($\kappa \geq 0.61$). Sensitivity and specificity of SSS classification was analysed with Receiver Operating Characteristic (ROC) Curve.

c) Inter rater reliability of SSS was demonstrated by an Intra Class Correlation (ICC) ≥ 0.70, which would confirm that non-specialist staff can produce stable and consistent Swansea Stroke Scale (SSS) assessments.

Hypothesis 3:

Prognostic validity: Admission and 24–36-hour SSS scores demonstrate a comparable ability to NIHSS and mRS collected at similar time points in discriminating 30-day outcome. Specifically, (a) mortality: independent t-tests will show significant differences ($p < 0.05$) between survivors and deceased patients, mirroring the discriminative performance of NIHSS and mRS and, (b) disposition: one-way ANOVA will demonstrate that SSS scores vary significantly across the four disposition categories (whether discharged home, moved to a rehabilitation unit, discharged to a care home or death) in a pattern statistically similar to the NIHSS, with lower mean scores successfully identifying those discharged home ($p < 0.05$)

Hypothesis 4:

Clinical Utility: SSS adds bedside utility by being usable by non-specialists (no formal training required). This is demonstrated by

(a) Feasibility: high completion rate (e.g., ≥ 80%) for any of the three professional groups (resident doctor, physician associate and healthcare support worker) and

(b) Efficiency (Average time to complete (e.g., < 5 minutes) for any of the professional groups.

The aim of 80% completion was derived simply from the fact that a matched cohort of patients on SSNAP database only had NIHSS completion of 22% on day 2. SSS, which is predicted to be easier to use without formal training, should perform much better to give at least an 80% completion.

The time needed for completion is retrieved after the pilot study where all staff participants reported the time of completion of SSS to be less than 5 minutes.

An extensive literature review on the existing stroke scales helped to categorise these into pre-hospital, acute and outcome-based scales, none of which were fitting with the criteria studied in this research project. The review also identified the NIHSS and mRS as the two ‘standard of care’ stroke scales for validating the Swansea Stroke scale.

Prototyping by means of a pilot study where 20 stroke survivors were included after ethical approval helped develop the Swansea Stroke Scale described in table 1.

Table 1: Swansea Stroke Scale:

SSS (5-20 points)	1 point	2 points	3 points	4 points
Situation	Awake and able to respond	Sleepy, but easily woken up	Drowsy, not waking to voice but responds to physical stimulus	Unresponsive to recurrent vocal and physical stimulus
Sight	Looking around	Not seeing objects/people on one side	Gaze fixed to one side	Eyes closed (not opening despite vocal or physical stimulus)
Speech	Able to follow and talk normally	Able to follow and talk but slurred speech	Able to follow, unable to talk or Unable to follow, talking random words/sentences	Unable to follow and unable to talk (mute)
Oral intake	Normal diet	Amended oral diet	*NG (or **PEG) feed	No feeding options (nil by mouth, not for NG or PEG /oral feeding at risk)
Movement	No limb weakness/ moving all 4 limbs equally or mobile without aids/ support	Mild arm/leg weakness or Able to walk with aids/ support	Moderate arm/leg weakness (inability to hold one or more limbs against gravity) or Steady transfer	Severe arm/leg weakness (inability to move one or more limbs) or Hoisted/bed bound
Other significant effects of stroke (if any):				

The above scale was used in pilot study where staff participants consented to use this after routine ward rounds. A staff survey at the end revealed a

100% completion rate and am excellent clinical utility where all non-specialist staff groups completed this stroke assessment scale in less than 5 minutes.

Results:

Our baseline demographics reveal an age range from 19 to 103, with a mean age of 73. Gender split was equal, 84 % of the cohort had other co-morbidities. Predominant type of co-morbidity in our SSS cohort was hypertension (56%), followed by diabetes (28%), previous stroke (18 %) and Atrial fibrillation (16 %). Other co-morbidities and their % are documented in the table below:

Table 2: Baseline demographics of the study cohort

Gender n (%)	Female Male	67 (50%) 68 (50%)
Age on Arrival	mean (sd) min, max	73.03 (13.13) 19, 103
People with comorbidities n (%)	Yes No	114 (84%) 21 (16%)
Type of comorbidities n (%)	Vascular disease Ischaemic heart disease Peripheral vascular disease Angina Diabetes Hypertension Previous stroke Cognitive impairment/Dementia Active cancer Atrial Fibrillation	16 (12%) 11 (8%) 3 (2%) 3 (2%) 38 (28%) 76 (56%) 24 (18%) 8 (6%) 10 (7%) 22 (16%)
Type of Stroke n (%)	Ischaemic Stroke Primary Intraparenchymal Haemorrhage	119 (88%) 16 (12%)

Severity of stroke n (%)	Minor stroke (NIHSS 0-4) Moderate (NIHSS 5-15) Severe (NIHSS 16 or above)	51(38%) 66 (49%) 18 (13%)
modified Rankin score n (%) Pre-Admission	0: No symptoms at all 1: No significant disability 2: Slight disability 3: Moderate disability 4: Moderately severe disability 5: Severe disability	68 (50%) 26 (19%) 25 (19%) 11 (8%) 4 (3%) 1 (1%)

Validity and Reliability of Swansea Stroke Scale:

Table 3: Convergent Validity of SSS against the NIHSS (Hypothesis 1):

	Pearson Correlation	Sig. (2-tailed)	95% Confidence Intervals (2-tailed)	
			Lower	Upper
Admission Swansea Stroke Scale (SSS) total with Admission NIHSS total (n=135)	0.924	<.001	0.895	0.945
SSS b1 at 24-36 hours by first assessor (total) with 24-36 hours NIHSS total (n=132)	0.918	<.001	0.886	0.941
SSS b2 at 24-36 hours by second assessor (total) with 24-36 hours NIHSS total (n=132)	0.914	<.001	0.881	0.939
SSS b1 at 24-36 hours by first assessor (total) with mRS at 24-36 hours (n=132)	0.755	<.001	0.671	0.82
SSS b2 at 24-36 hours by second assessor (total) with mRS at 24-36 hours (n=132)	0.749	<.001	0.663	0.816

The SSS showed excellent convergent validity with NIHSS, with Pearson's correlation of 0.924 ($p<0.001$, 95% CI 0.895–0.945). Divergent validity was supported by a low correlation with pre-admission mRS ($r = 0.18$, $p = 0.037$), indicating that SSS reflects acute neurological deficit rather than baseline disability.

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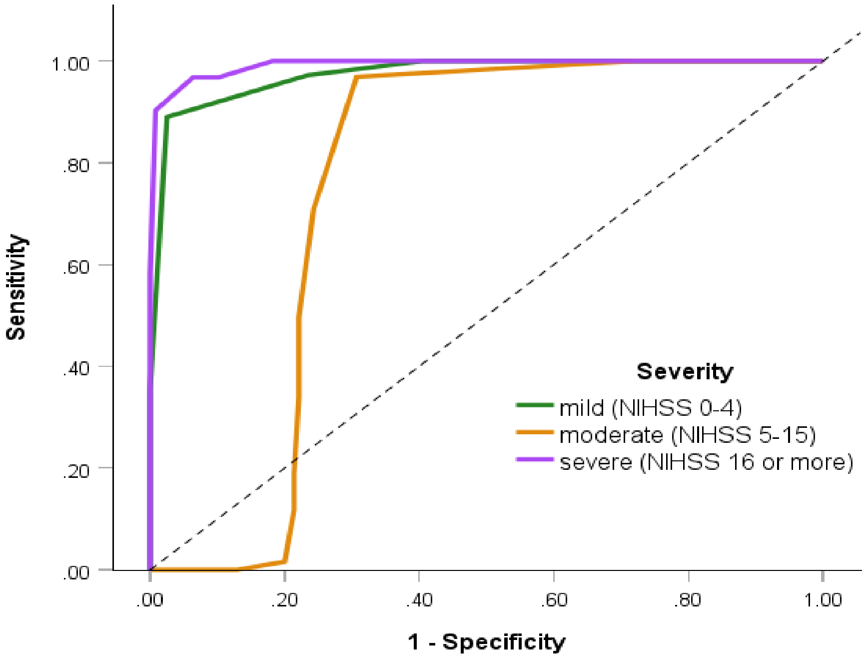
Reliability results (Hypothesis 2):

Categorical reliability (agreement) of the SSS severity levels against the NIHSS categories was demonstrated using the graph below:

Figure 1: Sensitivity and specificity of SSS classification- ROC curve:



Above graph reveals a macro-average ROC curve AUC = 0.91 (95% CI 0.89, 0.93; p<0.001). ROC curve AUC for mild stroke presentations is 0.97 (95% CI 0.96, 0.99; p<0.001), whilst that of a severe stroke is 0.99 (95% CI 0.98,1.00; p<0.001), showing perfect sensitivity and specificity. For moderate strokes, ROC curve AUC is 0.76 (95% CI 0.69, 0.82; p<0.001), which is still accurate but not as strong as the severe or mild stroke categories.

The model demonstrates excellent overall discriminative power, achieving a macro-average AUC of 0.908 (95% CI: 0.885–0.931), which indicates

high performance across the entire severity spectrum. Individual ROC analysis shows near-perfect discrimination for severe cases (AUC = 0.992) and mild cases (AUC = 0.974), though the moderate category presented a greater challenge (AUC = 0.757). Interestingly, both mild and moderate categories shared an optimal mathematical threshold of 6.5, suggesting this score serves as a "disease-presence" gate rather than a unique identifier for the middle tier. However, the confusion matrix validates the practical utility of the tiered scoring system (Mild <6; Moderate 7–11; Severe ≥12). This "New Standard" successfully isolated 85% of moderate cases with a high precision of 89.3%, effectively resolving the theoretical overlap seen in the ROC curves. While the threshold of 12 for the severe category prioritizes clinical safety by capturing 96.8% of severe patients, it does so by over-calling 15 moderate cases, highlighting a necessary trade-off between sensitivity and specificity at the higher end of the scale.
SSS showed excellent ability to discriminate between different levels of stroke severity. The high AUC values indicate that a randomly selected person from a higher severity class is very likely to have a higher score on the scale than a randomly selected person from a lower severity class.

Inter-rater reliability between two non-specialist assessors was very high, with an intraclass correlation coefficient (Koo and Li 2016) of 0.99 (p<0.001, 95% CI 0.987–0.993), demonstrating consistent scoring across staff.

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Table 4 Level of agreement of SSS and NIHSS in classifying stroke severity- Confusion matrix:

	Mild SSS <6	Moderate SSS 7-11	Severe SSS 12 or more	Total
Mild NIHSS (0-4)	97	12	0	109
Moderate NIHSS (5-15)	4	108	15	127
Severe NIHSS (16 or more)	0	1	30	31
Total	101	121	45	267

Tertiary/Explorative objectives and Results:

The tertiary objective of the study was to explore how the Swansea Stroke Scale, the National Institute of Health Stroke Scale, and the modified Rankin Score on admission and on day 2 behave in predicting patient outcomes at 30 days.

SSS was statistically significant for predicting 30-day disposition ($F = 18.71$, $p<0.001$), indicating that higher admission scores were associated with poorer short-term outcome.

Table 5- Predictability of SSS, NIHSS and mRS in those who passed away against those who survived (Hypothesis 3):

30 days outcome	Passed away (n=9)	Survived (n=126)	Mean Diff	95% CI of the Difference		p value
	mean (sd)	mean (sd)		Lower	Upper	
Admission SSS total	10.78 (3.70)	8.26 (3.06)	2.52	-0.35	5.38	0.08
24-36 hours SSS total by Assessor 1	11.89 (4.08) (4.08)	7.77[$] (2.67)	4.12	0.97	7.27	0.016*
24-36 hours SSS total by Assessor 2	11.78 (4.06)	7.72[$] (2.60)	4.05	0.92	7.19	0.017*
Admission NIHSS total	12.89 (6.86)	7.23 (6.08)	5.66	0.33	10.98	0.04*
24-36 hours NIHSS total	14.00 (7.48)	6.25[$] (5.94)	7.75	1.95	13.54	0.02*
Pre-admission modified Rankin score (mRS)	0.78 (0.67)	0.98 (1.22)	-0.2	-0.74	0.34	0.44
24-36 hours mRS	4.33 (1.32)	3.11[$] (1.44)	1.22	0.19	2.25	0.025*

[$]n=123; * Sig at 0.05 level

As revealed above, those who survived had a lower SSS score (less disability/minor stroke) compared to those who died. Analysing the mean difference and standard deviation in SSS on admission for those who survived against those who died revealed that admission SSS score was not statistically significant to predict 30-day survival. However, the mortality prediction of SSS score is much more reliable at 24-36 hours with a p value of 0.016 and 0.017 (for assessors 1 and 2 respectively).

NIHSS scores on admission and at 24 hours were noted to predict mortality with p values of 0.04 and 0.02 respectively.

Admission NIHSS outperforms admission SSS in terms of predictive validity for patients who pass away at 30 days. But we already knew that NIHSS can predict outcome, but unable to be widely used by all staff groups without appropriate training and certification. A matched cohort from the SSNAP database revealed that 24-hour completion of NIHSS is poor outside the research setting. This is exactly why the new stroke scale is being produced for ease of use by all staff.

Modified Rankin scale (mRS) pre-admission had no significant impact on those who survived and those who died signifying the fact that stroke severity on admission and at 24 hours is the predictor of mortality and not the pre-admission mRS/ level of independence. However, mRS at 24-36 hours, which reflects the disability acquired after suffering the acute stroke event, can predict mortality at 30 days with a p value of 0.025.

Table 6- Admission Swansea Stroke Scale and 30-day progress:

	Mean Difference	95% Confidence Interval		Significance/ P value
Progress at 30 days		Lower Bound	Upper Bound	
Discharged home - Moved to Rehab unit	-2.95	-4.29	-1.62	<.001
Discharged home - Died	-3.82	-6.33	-1.30	<.001
Discharged home - Acute hospital	-5.64	-8.93	-2.35	<.001
Moved to Rehab unit - Died	-0.86	-3.46	1.73	0.94
Moved to Rehab unit -Acute hospital	-2.69	-6.04	0.67	0.19
Died - Acute hospital	-1.82	-5.80	2.15	0.78

Above table reveals a significant difference in the SSS score between those discharged home (lower SSS/less severe illness) and those who were in acute hospital, or moved to rehabilitation unit and those who died, signifying the fact that admission SSS is a good at predicting the outcome at 30 days, supporting the scores' predictive validity. Those who were discharged home had a lower SSS at 24 hours than those who were in acute hospital, rehabilitation hospital and those who passed away within 30 days.

Hypothesis 4- Results of Clinical Utility:

SSS adds bedside utility by being usable by non-specialists (no formal training required). This is demonstrated by (a) Feasibility: high completion rate (eg $\geq$ 80 %) for any of the three professional groups (resident doctor, physician associate and healthcare support worker) and (b) Efficiency (Average time to complete (eg < 5 minutes) for any of the professional groups.

Professional roles of the assessors:

Table 7 Assessor 1 staff category:

Roles	Frequency	%	Valid %	Cumulative %
Resident Doctor	30	22.2	22.7	22.7
Physician Associate	100	74.1	75.8	98.5
Healthcare Support Worker	2	1.5	1.5	100
Total	132	97.8	100	

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This clinimetric scale was designed and developed for the use by any ward staff caring for a stroke survivor. The non-specialist staff included in the pilot and main phase of the study are Resident Doctors (RD), Physician Associates (PAs), Registered Nurses (RNs) and Health Care Support Workers (HCSW). Baseline assessment is undertaken by any of the four categories of staff. The person who undertook the baseline assessments repeated these at 24-36 hours on the same patient and classed as Assessor 1. This was to make sure continuity of care is prioritised as the same staff member will be able to have appropriate communication with family members and discuss progress at the daily multi-disciplinary team meetings.

Staff category of assessor 1- Most of the daily bedside care was delivered on the ward by Physician Associates (74.1 %), followed by Resident doctors (22.2%). The number of Health care support workers available to undertake the scale was limited (1.5 %) and Registered nurses were not able to undertake this as part of the research.

Assessor 2 is an independent non-specialist who does not look after he patient regularly but has been asked to apply the SSS scoring by means of bedside examination and report these findings independently to the research nurses by completing a paper case report form. Assessor 2 was blinded from assessor 1of the neurological status of the patient. This was to evaluate the inter-rater agreeability of the clinimetric scale.

Table 8: Time taken for completing the admission SSS scoring:

	N	Mean (minutes)	Std. Deviation	Std. Error	95% CI for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Resident Doctor	16	1.06	1.57	0.39	0.23	1.90	0	5
Physician Associate	117	0.62	0.99	0.09	0.44	0.81	0	4
Healthcare Support Worker	2	1.00	0.00	0.00	1.00	1.00	1	1
Total	135	0.68	1.07	0.09	0.50	0.86	0	5

Differences in SSS completion time between professional groups at admission was not statistically significant in the table above with F (2, 132) =1.278, p=0.282, η2=.019. It is certainly reassuring to find that the mean time for completion of the SSS score was less than a minute (0.68 of a minute) with 95 % CI of 0.50 to 0.86, with a maximum time of 5 minutes.

Evaluation and discussion:

For consultants and other specialists who are responsible to oversee post-stroke care, daily reviews to detect clinical change by means of conducting a full neurological examination and NIHSS is both time consuming and impractical due to staffing shortages. Besides, we have evidence from national audit that routine NIHSS is not performed in many centres to identify post-stroke decline. Analysis of our organisation's national audit report in 2025 revealed only 22 % of the total stroke admissions had their NIHSS completed routinely on day 2 in a matched cohort of patients who were not included in the study but admitted during the same time-period. This supports the lack of user friendliness of the NIHSS assessment scale. SSS, however, is not time consuming, easily applied, requires no prior training or certification and was validated to be equally good and can be applied by anyone. This provides clearer, more structured information from the bedside with available staff, supporting decision-making while enabling more efficient use of specialist time.

Table 9- Impact Framework for SSS:

Stakeholder	**Current evidence from this study**	**Future impact measures**
Patient	30-day mortality and discharge destination predicted by SSS at 24–36h.	Time to escalation, LoS*, ICU** transfers, PROM/PREM#, 3-month outcomes
Specialists	Strong convergent validity with NIHSS and good severity classification, enabling safer delegation of monitoring.	Decision quality, workload metrics, clinician satisfaction
Non-specialists	Excellent inter-rater reliability across RN$s, RD##s, PA$$s, HCSW@s at 24–36h.	Confidence, training time, frequency and appropriateness of escalation
Organisation	Potential to replace GCS£ for stroke monitoring and align with prudent healthcare and lean principles.	Safety incidents, LoS*, discharge patterns, integration into audits and electronic systems

* LoS: Length of Stay
** ICU: Intensive Care Unit
# PROM/PREM: Patient Reported Outcome Measure/Patient Reported Experience Measure
$ RN: Registered Nurses

RD: Resident Doctors
$$ PA: Physician Associate

Social return on investment (SROI) of the SSS:

The Return of Investment (ROI), a measure of a project's success, is originally derived from the private sector and focuses traditionally on financial gain (profit) with a formula as below:

“ $Return\ on\ Investment\ ROI = Net\ Profit\ /\ Investment \times 100$ ” (Fidelity 2025)

“There are 3 broad categories of ROI that intersect with the health sector: financial ROI that excludes monetised health benefits, ROI that incorporates such benefits and the broadest form of ROI known as social ROI (SROI), which includes other indirect benefits and costs from a societal perspective” (Neumann and Kim 2023).

“Social return on investment (SROI) was first developed and promoted in the non-profit sector by the Roberts Enterprise Development Fund in 1996 and concurrently in academia as a social impact assessment tool” (Corvo, Pastore et al. 2022). To calculate the SROI of the new stroke scale, the project analysed the existing costs of stroke per year and the stroke recurrence rate in population.

Social Cost Benefit Analysis (CBA) is another way of quantifying the benefits, which assesses the impact of different options on social welfare, valuing all relevant costs and benefits in monetary terms, unless it is not proportionate or

possible to do so (HM Treasury 2026).

Although both SROA and CBA analyses the monetary value of an intervention, their main difference is that SROI is more practical and can be used in small studies whilst CBA has a broader perspective. SROI focuses on the need to measure value from the bottom up, including the perspective of different stakeholders, while the Green Book appraisal is about valuing costs and benefits to the whole of UK society (Nicholls J 2012).

Cost of Stroke in the UK:

Table 5 reveals the cost of stroke care in the UK, which is predicted to increase from the 2015 value of £26 billion to £75 billion in 2035, an increase of 194% over 20 years (King, Wittenberg et al. 2020). The 2025 cost of stroke in the UK taking into consideration the health and social care, lost productivity, unpaid care, private care is noted to be 42.6 billion per year (King, Wittenberg et al. 2020).

Table 10: Projected Stroke care costs per year in the UK:
(King, Wittenberg et al. 2020)

Costs (£m)	2015	2025	2035	% change
Health care	3400	6900	10,200	200%
Social care—Public	2400	4700	9000	275%
Social care—Private	2700	5400	10,300	280%
Social care—Total	5200	10,100	19,300	270%
Unpaid care	15,600	24,400	42,200	170%
Lost productivity	1500	2300	3500	135%
Total	25,600	42,600	75,200	195%

Health Economics has calculated the per patient cost of a stroke to be £46,039 for 5 years with a fivefold variation in the magnitude of costs between patients, ranging from £19,101 to £107,336, depending on the stroke severity, age at time of stroke, healthcare costs for acute diagnostics and treatments such as thrombolysis, and social care needs once the acute stage is complete (Xu, Vestesson et al. 2018).

Table 11: Mean healthcare cost for stroke per patient (Xu et al.,2018):

	1 Year	5 Year
Mean healthcare costs per patient[a]	£13,452	£17,963
Mean social care costs per patient[b]	£8977	£28,076
Mean total health and social care costs per patient	£22,429	£46,039
Combined total cost for all patients included in SSNAP, April 2015–March 2016 (n = 84,184)	£1,736,338,300	£3,604,672,200
Mean health and social costs per patient with ischaemic stroke	£20,121	£41,432
Mean health and social costs per patient with ICH stroke	£24,297	£52,726

ICH: intracerebral hemorrhage; SSNAP: Sentinel Stroke National Audit Programme.

a Healthcare costs include: ambulance, MRI or CT scan, thrombolysis, acute stroke unit care, rehabilitation stroke unit care, general medical ward care, community rehabilitation, GP visits, secondary prevention, and ESD therapists.

Table 11 reveals the mean total health and social care cost per patient per year to be £22,429. In ischaemic stroke, this mean value is slightly less at £20,121 whilst the cost is higher in haemorrhagic strokes, which tends to be severe and more disabling (£24, 297 per patient). To calculate the SROI, the combined mean of £22,429 is used.

The per patient cost of stroke is taken into account for calculating the SROI.

Role of stroke recurrence in calculating the SROI:

Systematic review and metanalysis of multiple observational studies have reported a stroke recurrence rate ranging from 5.7% to 51.3% for ischaemic stroke, 2.5% to 5% for intracerebral haemorrhage (ICH), with hypertension, diabetes mellitus, atrial fibrillation, previous transient

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ischemic attack, and high stroke severity to be the independent risk factors for this recurrence. (Kolmos, Christoffersen et al. 2021).

“Recurrent stroke is defined as a new neurological deficit presenting after a period of clinical stability, lasting for more than 24 hours, and with attributable new ischaemic or haemorrhagic lesions verified either by CT or MRI of the brain; the consequences of these events are more extensive cerebrovascular impairments resulting in additional physical and cognitive disability, as well as significant social impact” (Kolmos, Christoffersen et al. 2021).

Hence detection of this is crucial on an acute stroke ward. If we assume 5% (taking the lower end of the range of 5.7% to 51.3 % as mentioned above), recurrence on an acute stroke unit in Swansea with 750 admission per year equates to 37.5 rounded as 38 strokes per year per organisation. Excluding Powys health board, rest of the 6 health boards In Wales have acute admitting units of around 750-1000 strokes per year. Even if we take the lower end of the range, 38 times 6 is 228 recurrent strokes that are preventable in Wales alone. If early detection and identification with the SSS could prevent at least one third of the recurrent stroke, this will equate to 76 strokes prevented per year.

The mean health and social care cost per patient is £22,429 in the first year and £46,039 in 5 years as per the health economics data by Xu et al., 2018 where the healthcare costs have included ambulance, MRI or CT scan, thrombolysis, acute stroke unit care, rehabilitation stroke unit care, general medical ward care, community rehabilitation, GP visits, secondary prevention, and ESD therapists and Social care costs included care home, home help, meals on wheels, and social service day centre visits .

76 strokes prevented per year would thereby give us a financial gain of £1.7 million in the first year and £3.5 million in five years.
Apart from the stroke reduction impact on SROI, we have a huge staff benefit due to ability to replace the missing specialist appointments with non-specialists who can provide care with a validated tool as good as the NIHSS, but not needing the training and certification that the NIHSS adopts. We already know from a recent BIASP survey of 100 hospitals in England that 70 per cent of acute stroke units are short of at least one stroke consultant, and many are short of two; 53 of 84 hospitals that responded had vacancies for a total of 96 consultants, and that the NHS relies heavily on locum doctors to fill holes in the workforce (Wootton-Cane 2026)

Organisational Structure of NHS Wales:

In Wales, acute stroke care is provided in 6 health boards, although some of these have 2-3 acute admitting hospital (Hywel Dda health board has 4 acute sites, Betsi has 3, Cwm Taff Morgannwg has 2 acute stroke units at present, rest of the health boards have one each excluding Powys, which does not have an acute admitting unit and the patients are admitted to the nearby health boards (see figure 9.3). A deficiency of at least 2 specialists per organisation in Wales equates to a minimum of 12 stroke consultant posts that are unfilled.
Health Boards in Wales are organised regionally as is shown in figure 9.3. Each health board has multiple hospitals under them, some acute and others rehabilitation hospitals. In addition, there are three NHS Trusts which operate on an all-Wales basis- Welsh Ambulance Services NHS Trust, Velindre NHS Trust and Public Health Wales (NHS Wales Shared Services Partnership (NWSSP))

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Figure 2: Health boards in Wales:

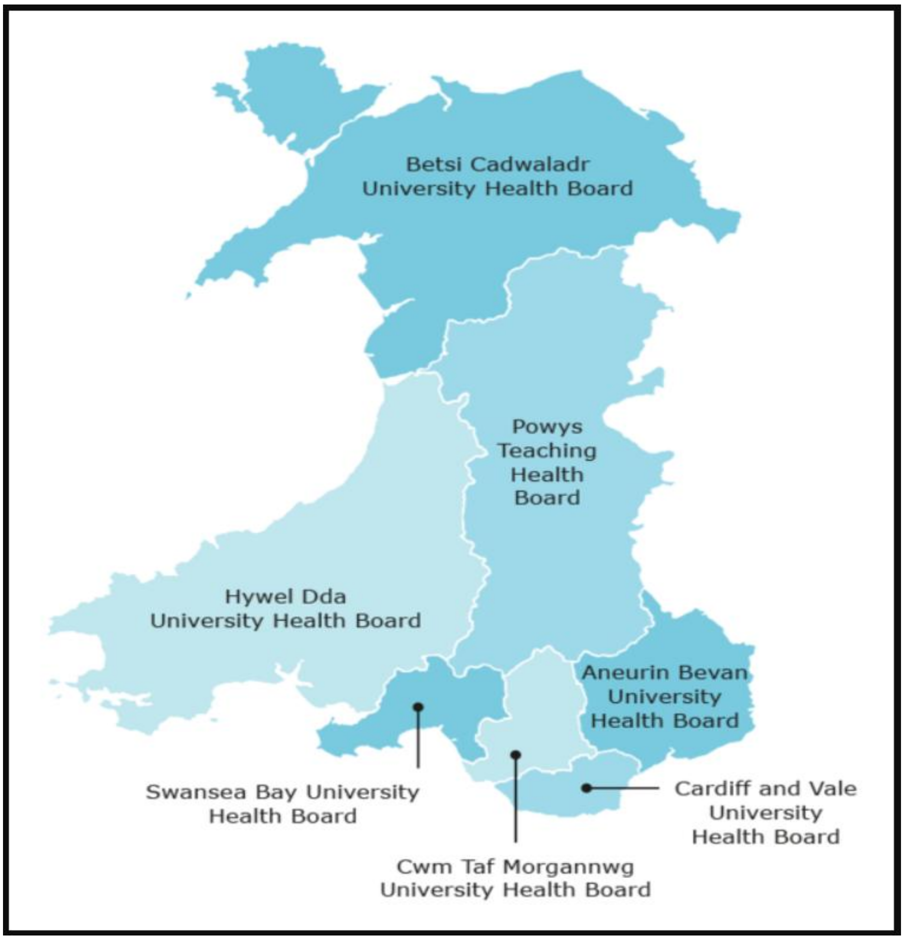

Figure above with the 7 health boards in Wales, of which only 6 are acute stroke admitting sites.

To analyse the SROI, the following table was created identifying the non-financial impact of the innovation, followed by quantifying this impact to identify the monetary value associated with the impact.

Table 12: SROI of Swansea Stroke Scale:

Non-financial Impact	Quantify Impact	Monetary value
Identify patient decline without delay	76 strokes prevented per year	Financial gain of £1.7 million in the first year and £3.5 million in five years.
Mortality reduction	10% mortality in our study cohort, which equates to avoidance of 7-8 deaths per year if we prevent 76 strokes as above	This is included in the financial gain above
Reduction in hospital length of stay (LoS)	Mean LoS of 9 to 60 days in our cohort for those discharged home	This is included in the financial gain above
Reduction in Variable pay for locum doctors	12 specialists covered with locum per year in Wales £125/hour*8 hours*260*12 working days (minimum, calculated as 5 day weeks)	Financial gain of £3.12 million per year as money unspent
Plugging the gap for specialists by non-specialists	12 non-specialists instead, calculated as band 6 PA (annual salary at top point £46,580	Expenditure of £558,960 per year
Total savings per year		£4.26 million

Net Present Value of Swansea Stroke Scale:

In healthcare innovation, Net Present Value (NPV) is a crucial metric used to evaluate the financial viability of new medical interventions, to help determine whether the expected benefits outweigh the costs (Levitan, Getz et al. 2018). NPV considers various factors such as Implementation costs (integration into current system, training, change management), Ongoing costs (maintenance, licensing, security, support), Operational efficiency (reduced duplication, shorter hospital stays, improved resource allocation) and Clinical outcomes (fewer readmissions, reduced medication errors, earlier interventions, improved treatment adherence etc) (Dando and Lebmeier 2020).

Expected Net Present value (ENPV) is used for innovations that have not reached the market yet and is widely recognised as a metric that combines the revenue, cost, and time value drivers with the associated risks of getting to market and reflects the risk-adjusted NPV. For any entrepreneurial venture, a positive net present value (rNPV) calculation on any product in development is a good indication that upon market release, the financial return will exceed the cumulative life cycle costs of research, development and validation, summarised as return on investment (ROI) (Dando and Lebmeier 2020).

The ENPV of Swansea Stroke scale will need to consider the expenditure at the start of the innovation, which includes the University costs (£7,450), Research support cost from Swansea Bay Charitable funds (£34,093), and the time taken for innovation, covered within the supporting professional activities session for research within the researcher's job plan (and hence no additional cost for the time spent on the innovation). None of the expenditures at the beginning of the study are recurrent in nature.

However, when we look at the financial savings of the innovation, this will be a recurrent benefit. Hence the ENPV of Swansea Stroke Scale over the first year is Cash inflow (£4.26 million) minus Cash outflow (£41,543) = £4,218,458 (rounded as 4.22 million). The ENPV from year 2 onwards will be higher as there won't be any cash outflow as innovation is already validated in the study.

"Despite its potential, NPV is not widely used in healthcare procurement, highlighting the need for better integration and adoption of this financial tool in the sector" (National Institute for Health and Care Excellence (NICE) 2013). It is reassuring to see how financially beneficial the Swansea Stroke Scale will be for future healthcare as revealed by its NPV.

Conclusion and Benefits:

The Swansea Stroke Scale demonstrates how structured innovation management in healthcare can generate a practical, scalable tool that addresses a clearly defined gap in stroke services. By enabling non-specialist staff to carry out reliable, standardised neurological assessments without extensive training, SSS supports workforce upskilling, more efficient deployment of scarce stroke specialists and earlier recognition of clinical deterioration. These changes have direct benefits for patient safety, experience and outcomes by reducing the risk of missed neurological decline and supporting timely escalation of care.

As evidenced in our research study, NIHSS, which is the most used stroke scale across the international stroke community, was never intended or evidenced for routine neurological review in stroke survivors outside the

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research trials (Marsh, Lawrence et al. 2016). NIHSS is not validated for use in non-specialists either, yet it remains the main scale utilised in our guidelines and pathways. This research has produced an alternative, the Swansea Stroke Scale, showing excellent validity and reliability against the NIHSS. More importantly, it has confirmed the efficiency and clinical utility in non-specialist staff proven by hypothesis 4.

In head trauma patients, GCS is used as a valid tool for mortality prediction but the GCS is not a good predictor of morbidity or outcomes and some studies have suggested modified versions incorporating age to improve its predictive function (Salottolo, Panchal et al. 2021). However, because of the non-availability of a simple tool that can be used by anyone, unfortunately GCS has been incorporated into stroke pathways for monitoring clinical decline. It has also been incorporated into the NEWS2 chart to identify post stroke complications such as pneumonia. But changes in GCS is not appropriate for monitoring a stroke patient, simply because, GCS was never developed for acute stroke.

Stroke is a disease condition that needs a specific tool comparable with the gold standard one, the NIHSS, but simplistic and user friendly. The innovation of Swansea Stroke Scale provides an opportunity for the stroke community to use this and embed it in stroke pathways. This has become the unique selling point of the SSS, which will help its future dissemination.

For organisations, embedding SSS into acute stroke pathways can improve consistency of assessment, enhance data quality for decision-making and streamline discharge planning through better prediction of 30-day disposition. At system level, this low-cost innovation has potential to deliver financial savings for the national health service by reducing avoidable complications, shortening length of stay and optimising use of specialist resources, particularly in areas with limited stroke expertise. Overall, SSS offers a validated, implementable innovation that aligns clinical, organisational and system-level benefits, and provides a replicable example of managing healthcare innovation from co-design through to evaluation and impact on future stroke care.

References:

(2025). NHS Wales National Stroke Service Standards, Stroke Implementation Network (part of the National Strategic Network for Cardiovascular Conditions).

Adams, H. P., Jr., et al. (1999). "Baseline NIH Stroke Scale score strongly predicts outcome after stroke: A report of the Trial of Org 10172 in Acute Stroke Treatment (TOAST)." Neurology **53**(1): 126–131.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.), Lawrence Erlbaum Associates.

Corvo, L., et al. (2022). "The social return on investment model: a systematic literature review." Meditari Accountancy Research **30**(7): 49–86.

Dando, J. and M. Lebmeier (2020). "A novel valuation model for medical intervention development based on progressive dynamic changes that integrates Health Technology Assessment outcomes with early-stage innovation and indication-specific clinical success rates." Journal of Innovation and Entrepreneurship **9**(1): 1.

Fidelity (2025). "How to calculate return on investment (ROI)." from https://www.fidelity.com/learning-center/smart-money/how-to-calculate-ROI.

HM Treasury (2026). The Green Book, Central Government Guidance on Appraisal and Evaluation. London, HM Treasury.

Iacobucci, G. (2019). "NHS is urged to increase number of stroke specialists by a third to tackle “serious shortfall”." BMJ **366**: l4740.

King, D., et al. (2020). "The future incidence, prevalence and costs of stroke in the UK." Age Ageing **49**(2): 277–282.

Kolmos, M., et al. (2021). "Recurrent Ischemic Stroke – A Systematic Review and Meta-Analysis." Journal of Stroke and Cerebrovascular Diseases **30**(8): 105935.

This paper was presented at the XXXVII ISPIM Innovation Conference, held in Granada, Spain on 07 June to 10 June 2026. ISBN 978-952-65771-2-8.

Koo, T. K. and M. Y. Li (2016). "A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research." J Chiropr Med **15**(2): 155–163.

Landis, J. R. and G. G. Koch (1977). "An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers." Biometrics **33**(2): 363–374.

Levitan, B., et al. (2018). "Assessing the Financial Value of Patient Engagement: A Quantitative Approach from CTTI's Patient Groups and Clinical Trials Project." Ther Innov Regul Sci **52**(2): 220–229.

Marsh, E. B., et al. (2016). "The NIH Stroke Scale Has Limited Utility in Accurate Daily Monitoring of Neurologic Status." Neurohospitalist **6**(3): 97–101.

National Institute for Health and Care Excellence (NICE) (2013). How NICE measures value for money in relation to public health interventions. London, NICE.

Neumann, P. J. and D. D. Kim (2023). "Cost-effectiveness Thresholds Used by Study Authors, 1990-2021." JAMA **329**(15): 1312–1314.

NHS Wales Shared Services Partnership (NWSSP). "Organisation Structure of NHS Wales." from https://nwssp.nhs.wales/a-wp/governance-e-manual/knowing-who-does-what-why/organisation-structure-of-nhs-wales/.

Nicholls J, L. E., Neitzert E, Goodspeed T. A (2012). A Guide to Social Return on Investment. London, The Cabinet Office.

Salottolo, K., et al. (2021). "Incorporating age improves the Glasgow Coma Scale score for predicting mortality from traumatic brain injury." Trauma Surgery & Acute Care Open **6**(1): e000641.

Wilson, J. T. L., et al. (2002). "Improving the Assessment of Outcomes in Stroke." Stroke **33**(9): 2243–2246.

Wootton-Cane, N. (2026). Thousands left dead or disabled due to shortage of stroke specialists, medics warn. The Guardian. UK.

Xu, X.-M., et al. (2018). "The economic burden of stroke care in England, Wales and Northern Ireland: Using a national stroke register to estimate and report patient-level stroke.