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Development of an objective tool for the Measurement of Spatial Neglect: A Proof of Concept Study

Abstract

Objective: To determine the concurrent validity, specificity and sensitivity of a newly developed tool; New Neglect Test (NNT) with line bisection test (LBT) and semistructured scale for the functional evaluation of hemi-inattention (SSS) in stroke patients, in assessing spatial neglect.

Methods: A total of 28 patients participated in the study. Peripersonal neglect was assessed using LBT and NNT; whereas personal and extrapersonal neglects were assessed using SSS and NNT.

Results: The results of the study indicated that the new neglect test has a weak to strong correlation with SSS and LBT at assessing personal, peripersonal and extrapersonal neglect, Phi (\emptyset) correlation coefficient ranging from $r=0.05$ to $r=-0.66$. However, NNT has very low sensitivity and specificity in relation to SSS and LBT when the latter tools are considered as goal standards. Additionally, the result showed that only stage of stroke predicts the NNT's ability to detect spatial neglect in stroke patients, but not age, sex, side affected and MMSE scores.

Conclusion: NNT is valid at detecting spatial neglect especially in patients within the acute stage of stroke.

Introduction

Stroke is a focal or global neurological deficit as a result of ischaemia or hemorrhage in the brain that lasts for more than 24 hours or lead to death [1,2]. Fortunately, current advancement in patients care and prevention has reduced the number of deaths due to stroke [3]. However those that survive the stroke may have long term disabilities such as neglect [4-6]. The physical sign of neglect is that, there are failures to report respond and orient to stimuli presented on the side contralateral to the brain lesion [6]. The main cause of neglect syndrome in humans is usually large infarction of the right middle cerebral artery, but occasionally in the left [7]. Consequently many modalities in the nervous system could be affected. This made neglect to be heterogenous with many synonyms such as spatial neglect, unilateral neglect, visual neglect, visuospatial agnosia and visuospatial neglect [8].

Presence of neglect following stroke is associated with poor functional outcome and limitations in activities of daily living (ADL) [9]. The poor outcome associated with neglect could be due to the fact that, it is heterogenous and represents a wide spectrum of impairment of sensory, motor and somatosensory modalities which result in a number of tests that are used in its assessment [4,8]. However, sensitivity, specificity and psychometric properties of these tests are still poorly understood [10]. For example, tests such as line bisection and semistructured scale for hemi-inattention tests are used to measure neglect in peripersonal; and personal and extrapersonal spaces respectively, but interpretation of these tests is very subjective [11]; and they do not individually measure the whole spectrum of spatial neglect. Therefore, there is a need to develop more objective, reliable

and valid tests that consider all the spectrum of spatial neglect. The present study aimed to develop a more objective test to assess spatial neglect (personal neglect, peripersonal neglect and extrapersonal neglect). Concurrent validity of the newly developed test with semi-structural scale for the functional evaluation of hemi-inattention (used to assess personal and extrapersonal neglect) and line bisection test (used to assess peripersonal neglect) will also be investigated. The study is therefore going to answer the following research questions: 1) What is the concurrent validity of the new neglect test with line bisection test and semi-structured scale for the functional evaluation of hemi-inattention in assessing personal and extrapersonal neglect and peripersonal neglect respectively 2) What are the sensitivity and specificity of line bisection test at detecting peripersonal neglect 3) What are the sensitivity and specificity of semi-structured scale for the functional evaluation of hemi-inattention at detecting personal and extrapersonal neglect?

Methods

The design of this study is correlational study aimed at determining the concurrent validity, specificity and sensitivity of a newly developed neglect test with semi-structured scale for functional evaluation of hemi-inattention and line bisection in the assessment of spatial neglect. The study was approved by the Research Ethics Committee of Aminu Kano Teaching Hospital, Nigeria. The study population consisted of all stroke survivors attending Aminu Kano Teaching Hospital. Participants were included if they were in any stage of stroke, 18 years and above, male or female, have left or right sided hemiplegia, ischaemic or hemorrhagic stroke, have normal range of motion (ROM) both active and passive in the ipsilateral

shoulder, elbow, wrist, metacarpophalangeal and interphalangeal joints; and have no significant cognitive impairment, < 17 score on mini-mental scale examination (MMSE), and participants who gave written consents to participate in the study.

The instruments used for the collection of the study data were Socio-demographic Data Sheet designed by the authors, Mini-Mental State Examination (MMSE) [12,13], National Institute of Health Stroke Scale (NIHSS) [14,15], Semi-Structured Scale for the Functional Evaluation of Hemi-Inattention in Personal Space [16,17], Line Bisection Test and the New Neglect Test (NNT) [18,19]. The Socio-demographic Data Collection Sheet was used to record the relevant socio-demographic information such as age, sex, type of stroke, stage of stroke and side affected side. The Mini-Mental State Examination (MMSE) was used to assess the mental status of patients. MMSE comprises of 11 items which measure five cognitive domains which include orientation, registration, attention and calculation and language [12]. The scale has 30 points as its maximum score. When a patient scores ≥ 25 , it indicates that he has a normal cognition. However, any value below 25, indicates severe (≤ 9 points), moderate (10-20 points) or mild (21-24 points) cognitive impairment [13].

The NIHSS was used to objectively determine the impairment caused by a stroke including the presence of neglect. It is an 11-item test each of which scores a specific task between 0 and 4 for each item [14,15]. Scores from the individual items or subscales are usually summed up to get the total score of NIHSS. The scale's scores range from 0 to 42; 0 score means normal function, whereas a higher score indicates some degrees of impairment. When a patient scores 0, this indicates absence of stroke symptoms, scores of 1-14 indicate a minor stroke, scores between 5 and 15 indicate a moderate stroke, scores between 16 and 20 indicate moderate to severe stroke; whereas scores between 21 and 42 indicate severe stroke.

The Semi-Structured Scale for Functional Evaluation of Hemi-inattention measures neglect in personal and extra-personal spaces [16,17]. Tasks such as hair combing, and using eyeglasses and razor/make up are usually performed in the personal space; whereas, tasks such as description of a picture and a gym environment, card dealing and tea serving are usually performed in the extra-personal space. All tasks are performed while the patients are in sitting position. Task performance is rated 0, 1, 2 or 3 which mean normal, slight asymmetries, uncertainty or slowness in space explored respectively. When scores of all the subscales are summed up, the maximum score that can be obtained is 18. When a patient scores 3, this indicates presence of neglect. The scale has some good psychometric properties such as convergent validity with line bisection test ($\text{Tau}=0.60$), and letter cancellation test ($\text{Tau}=0.52$) and internal consistency ($r = 0.44-0.71$) [16].

The Line Bisection Test is used for measuring peri-personal neglect. In this test the patient is asked to sit in a comfortable chair around a table. The patient is then asked to place a mark with a pencil through the center of a series of 4 horizontal lines presented to him on an A4 size paper [18]. A deviation from the lines' centers of more than 6 mm or omissions of 2 or more lines, indicate presence of neglect. The test has a high sensitivity (76.4%) when compared with other cancellation test [19].

The New Neglect Test (NNT) was used to assess the presence of neglect in the personal space, peripersonal space and extrapersonal space. The patients were positioned in supine lying with the upper limb close to the trunk and the palm facing upward. The reference point for personal neglect is the distance between the midline and the contralateral (affected side) acromion process. The reference point for extra-personal neglect is the distance between the midline and the tip of the middle finger after maximum reach of the ipsilateral upper limb in the direction of the contralateral acromion process in the contralateral hemisphere. The reference point for the peripersonal space is the distance between the midline and an object placed at the midpoint of the extrapersonal space. The grading system for personal, peripersonal and extrapersonal neglect is as follows: mild neglect = being able to cover 2/3 to <full distance, moderate neglect = being able to cover 1/3 to <2/3 of the distance and severe neglect = being able to cover only 0 to <1/3 of the distance.

Data analysis

Table and percentages were used to describe the demographic data; while concurrent validity between the new neglect test and line bisection test in peri-personal space and semi-structured scale for the functional evaluation of hemi-inattention in personal space and extra-personal space were estimated using ϕ (phi) coefficient of correlation.

Additionally, proportions of all true positives (those who actually have neglect) out of all positives (those who were found to have neglect using semi-structured scale for the functional evaluation of hemi-inattention and line bisection test); and proportions of all true negatives (those who actually don't have neglect) out of all negatives (those who were found not to have neglect using semi-structured scale for the functional evaluation of hemi-inattention and line bisection test) were calculated to determine sensitivity and specificity of the two measures respectively.

Logistic regression was also performed to help find out the independent variables (MMSE scores, side affected, time since stroke and age of the participants) that can predict presence or absence of neglect.

Results

Twenty eight stroke patients participated in the study. See Figure 1 for the study flow chart. There were 13 males (46.4%) and 15 females (53.6%) of which 8(28.6%) were in acute stage of stroke, 7(25%) were in subacute stage and 13(46.4%) were in the chronic stage. Fifteen participants (53.6%) were having left sided affectation secondary to right hemispheric infarction while 13 participants (46.4%) were having right sided affectation secondary to left sided infarction. The mean age of participants in the study was 59 years; mean MMSE score was 24.6 and; mean NIHSS score was 11.6. Table 1 below details the characteristics of the study participants.

For personal space, NNT detected personal neglect in 3 participants (10.7%) and did not in 25 participants (89.3%) among which 2 participants (7%) have mild, 1(3.6%) has moderate and none

has severe neglect. The SSS also detected 27 participants (96.4%) with personal neglect and only 1 without it (3.6%), among which 9 (32%) have mild, 14 (50%) have moderate and none has severe neglect.

For extra-personal space, NNT detected extra-personal neglect in 10 participants (35.7%) and did not in 18 participants (64.3%) among which 3 (10.7%) have mild, 4(14.3%) have moderate and 3 (10.7%) have severe neglect. SSS also detected extra-personal neglect in 27 participants (96.4%) and did not in only 1 participant (3.6%) of which 7 (25%) have mild, 17 (60.7%) have moderate and 3 (10.7%) have severe neglect.

For peri-personal space, NNT detected neglect in 7 participants (25%) and did not in 21 participants (75%) of which 4 participants have mild neglect, 3 have severe neglect and none has moderate neglect, in contrast, LBT detected peri-personal neglect in all the 28 participants (100%).

The presence of neglect was detected in 9 participants with NNT (32.1%), but not in 19 participants (67.9%); while it was detected in 15

participants (53.6%), but not in 13 participants (46.4%) with NIHSS neglect subscale.

Relationship between NNT, SSS, LBT and NIHSS in assessing spatial neglect

The relationship between NNT, SSS, LBT and NIHSS in detecting neglect in stroke patients was determined using phi correlation coefficient, as shown in table 2. For all the patients, there was a weak positive correlation between NNT and SSS at detecting personal neglect, $r=0.05$, $n=28$, $p < 0.05$. For extra-personal neglect, there was also a weak positive correlation between NNT and SSS $r=0.28$, $n=28$, $p < 0.05$. Similarly, there was also a weak positive correlation between NNT and NIHSS neglect subscale at detecting neglect, $r=0.18$, $n=28$, $p < 0.05$. However, correlation between NNT and LBT was impossible to determine as LBT scores were constant.

In table 3, for the patients within the acute stage, correlation between NNT and SSS in detecting personal neglect shows a significant negative correlation, $r=-0.66$, $n=8$, $p < 0.05$. Correlation between NNT

Table 1: Characteristics of the Study Participants.

S/N	Age (years) stroke score	Sex	Time since	Body side affected	MMSE	NIHSS score
1	50	M	3 days	Left	29	5
2	44	F	2 years	Left	17	21
3	80	F	4 weeks	Left	24	11
4	60	F	3 years	Right	23	12
5	65	F	2 weeks	Left	27	12
6	80	M	1 year	Right	17	20
7	64	F	2 weeks	Left	17	23
8	43	M	2 years	Right	29	3
9	65	F	4 months	Right	23	7
10	48	M	2 weeks	Left	17	28
11	56	F	7 days	Left	29	3
12	70	F	3 years	Left	29	11
13	35	F	4 years	Right	29	2
14	69	F	2 years	Right	28	14
15	75	F	3 months	Left	24	17
16	75	M	15 years	Right	17	17
17	56	M	2 years	Left	29	8
18	74	M	3 years	Left	29	9
19	53	F	2 months	Right	17	22
20	54	F	6 months	Right	17	16
21	45	M	13 months	Left	28	9
22	40	M	1 year	Right	29	10
23	70	F	6 months	Right	29	12
24	52	M	2 months	Right	29	8
25	54	M	3 weeks	Left	29	11
26	74	M	5 days	Right	29	5
27	38	F	2 months	Left	29	8
28	63	M	1 year	Left	29	2

Key: MMSE (Mini-Mental State Examination) score < 17 = significant cognitive impairment, NIHSS (National Institute Health Stroke Scale) score 0 = no stroke symptom, 1-4 = minor stroke, 5-15 = moderate, 16-20 = moderate to severe, 21-42 = severe

Table 2: phi-correlation coefficient between NNT, SSS, NHISS and LBT for all patients.

	1	2	3	4	5	6	7	8
1 NNT (personal)					0.05			
2 NNT (extrapersonal)						0.28		
3 NNT (peripersonal)							-	
4 NNT (general)								0.18
5 SSS (personal)								
6 SSS (extrapersonal)								
7 LBT (peripersonal)								
8 NHISS								

r= 0.10 to 0.29-----small
r= 0.30 to 0.49-----medium
r= 0.50 to 1.0-----large

Table 3: phi-correlation coefficient between NNT, SSS, NHISS and LBT during acute stage.

	1	2	3	4	5	6	7	8
1 NNT (personal)					-0.66*			
2 NNT (extrapersonal)						-		
3 NNT (peripersonal)								
4 NNT (general)								0.56*
5 SSS (personal)					-			
6 SSS (extrapersonal)						-		
7 LBT (peripersonal)								
8 NHISS								-

*=significant correlation

and NHISS at detecting neglect shows a moderate positive correlation $r=0.56$, $n=8$, $p < 0.05$. However, correlation between NNT and SSS at detecting extra-personal neglect was impossible to determine as the values of SSS were constant.

Considering SSS as the goal standard, there were 27 participants who truly have extra-personal neglect; however, NNT detected only 10 participants out of this 27 as having neglect which accounts for 36% of the cases. Therefore, the sensitivity of NNT in detecting extra-personal neglect in acute, sub acute and chronic patients is 0.36 which is a low sensitivity. For personal neglect, NNT detected only 3 participants out of these 27 participants accounting for 11% of the cases, therefore the sensitivity of NNT at detecting personal neglect is only 0.1 which is a quiet low sensitivity. In general, sensitivity of NNT at detecting neglect for all patients is 0.32 which is a low sensitivity, as NNT detected 9 participants and SSS detected 27 participants.

For acute patients, NNT detected 6 participants with extra-personal neglect; whereas SSS detected 8 participants. The sensitivity of NNT is therefore 0.75 which is a high sensitivity. For personal neglect, the sensitivity of NNT is 0.38 which is a low sensitivity as NNT detected only 3 participants; and SSS detected 8 participants. In general, SSS detected 8 out of 8 patients while NNT detected 5 participants accounting for 63% of all cases. Therefore, the sensitivity of NNT at detecting neglect in acute stage is 0.63 which is a high sensitivity.

Taking LBT as the goal standard, in all the patients, LBT detected all 28 patients as having neglect; whereas NNT detected only 1 participant accounting for 3.5% of all cases. Therefore, sensitivity of NNT at detecting peri-personal neglect is 0.04 which is a low sensitivity. In patients within the acute stage, LBT detected all 8 participants as having peri-personal neglect; whereas NNT detected 5 participants accounting for 63% of all cases and a high sensitivity of 0.63.

For specificity, LBT scores were impossible to find out as scores they remained constant. Specificity for NNT at detecting extra-personal neglect over SSS is 0.06 which is a very low specificity as NNT detected 18 negatives; while SSS detected only 1 negative. For personal neglect SSS detected only 1 negative as not having the characteristic; whereas NNT detected 25 negatives. Therefore, the specificity of NNT at detecting personal neglect is 0.04 which is also a low specificity.

Determination of variables that can predict NNT's ability to detect presence of neglect

Direct logistic regression was performed to assess the impact of some factors on the likelihood that new neglect test would report problems with neglect. The model contained five independent variables (age, sex, time since stroke, body side affected and MMSE score). The full model containing all predictors was statistically significant, $X^2(4, N=28) = 12.29$, $p < 0.05$, indicating that the model was able to distinguish between presence and absence of neglect. The model as a whole explained between 35.5% (Cox & Snell R square) and 36.3% (Nagelkerke R squared) of the variance in neglect status and correctly classified 78.6% of cases. As shown in table 4, only stage of stroke contributed significantly to our model (the ability of new neglect test to detect spatial neglect depends on the stage of stroke). All other variable did not make any significant contribution.

The Sensitivity of the model is 88.9% (true positives), the specificity of the model is 63.2% (true negatives). Positive predictive value=53.3% (percentage of cases that the model classified as having neglect) and the negative predictive value=92.3% (percentage of cases predicted by the model observed not to have neglect).

Discussion

This study was conducted to determine the concurrent validity of a newly developed objective assessment tool (the new neglect test) for the measurement of spatial neglect in three spaces (personal, peripersonal and extrapersonal spaces) with some existing assessment tools; LBT for the measurement of peripersonal neglect and SSS for the measurement of personal and extrapersonal neglects.

The results of the study indicated that the new neglect test has weak to strong correlation with SSS and LBT at assessing personal, peripersonal and extrapersonal neglect. However, NNT has very low sensitivity and specificity in relation to SSS and LBT when the latter tools are considered as goal standards. In the study, most of the patients detected by NNT to have neglect were in the acute stage of stroke. Thus, among other variables such as age, sex, side affected and MMSE scores, the result showed that only stage of stroke predicts the NNT's ability to detect spatial neglect in stroke patients.

Table 4: Logistic Regression Predicting Likelihood of NNT to Detect Spatial Neglect in Stroke Patients.

	B	S.E	Wald	df	P	Odd Ratio	95% Lower	CI for odd ratio Upper
Age	0.88	1.10	0.65	1	0.42	2.42	0.28	20.84
Sex	-0.58	1.17	0.65	1	0.62	0.562	0.06	5.57
Stage of stroke	-2.95	1.33	4.90	1	0.27	0.52	0.00	0.71
Body side affected	-0.27	1.01	0.07	1	0.79	0.76	0.11	5.54
MMSE	-21.10	28370.57	0.00	1	0.11	0.00	0.00	
Constant	21.33	28370.57	0.00	1	0.11	2E070G		

In contrast with the present study, a previous found LBT to have lower specificity and sensitivity than cancellation test $r=0.76$ and $r=0.79$ respectively [20]. However, the difficulty in perform these tests differ from one test to another. For example, dividing a line into two equal halves as in the LBT may be more challenging than simply cancelling a star as in the cancellation test. Similarly, for the NNT, asking a patient to move his ipsilateral limb to the contralateral space could be more difficult than dividing a line into two equal halves. These findings seem to suggest that the more difficult the task in a particular test, the less sensitive and specific it may be.

In this study, NNT detected extra-personal neglect in most patients' more than personal neglect. This finding is in agreement with the study conducted by Zocollatti and colleagues which also showed the ability of SSS to detect extra-personal neglect more than personal neglect [16]. For the SSS, the findings may be attributed to the fact that the tasks such as combing and using razor in the personal neglect subscale are more difficult to perform than tasks such as picture description in the extra-personal neglect subscale. However, for NNT the findings cannot be attributed to any factor.

Also, in this study, the ability of the new neglect test to detect neglect was not predicted by the type of stroke (ischaemic or haemorrhagic), age or sex of the participants. In previous studies, similar variables including site of the lesion did not predict presence of neglect [21,22]. However, sensitivity and specificity of the new neglect test (NNT) depends upon the stage of the stroke; the earlier, the better. During the acute stage, 62.5% of patients were detected as having neglect by NNT; whereas, 100 % were detected by SSS and LBT. The value obtained using NNT was much higher than that obtained in a previous study [21]. Thus, ability to detect neglect largely depends on the tool used. Consequently, such variables need to be considered by clinicians when choosing a measure for neglect.

One of the advantages of the NNT is its ability to determine the severity of neglect (i.e. mild, moderate and severe). This is because; in the study NNT was sensitive enough to determine that none of the participants had severe neglect in personal space the same way with SSS. Additionally, both NNT and SSS determined 3 participants each as having severe extra-personal neglect. These suggest that, NNT is as important as the SSS in determining neglect. However, the NNT has a peculiarity over the SSS; it provides anatomical reference points (midline, contralateral acromion process and tip of distal phalanx of middle finger) which are used to objectively measure neglect. This has not been provided by any other studies using the previous tools

such as Zocollatti and colleagues; and Azouvi and colleagues in the literature [16,18]. Furthermore, similar methods to the present study was used in determining neglect in personal space where participants were asked to move their unaffected arms from to the contralateral space [23].

There are limitations to this study both with the methodology and the measure (NNT) itself. For the methodology, the sample size was very small, there was no assessors' blinding, and it was not a repeated measurement; assessment was done was once. For the measure, it was not able to differentiate between apraxia, anosognosia and neglect. Two, positioning of patients for measurement of spatial neglect in supine position may be difficult for the individual to perform movements compared to sitting or standing positions which could affect the findings of the study. Thus, future studies should try using sitting position.

Conclusion

NNT may be used for the measurement of spatial neglect, especially during the acute stage of stroke.

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