Linguistic Performance of Cardiac Arrest Survivors on a Neuropsychological Screening Test

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Cardiac arrest and cardio-pulmonary-cerebral resuscitation can lead to a variety of neuropsychological sequelae. Until the advent of routine CPR procedures in the 1950s, arrest was associated with death in virtually all out-of-hospital episodes (Safar, 1988). With improved resuscitation techniques, medical practitioners shifted concerns from survival to neurological status because they became aware that the resuscitation process itself contributed to cerebral dysfunction (Negovsky, 1988). Brain regions particularly sensitive to derangement due to the arrest/resuscitation cycle of events include: the basal ganglia, hippocampus, cerebellum, occipital lobe, and "border zone" regions of the temporoparietal cortex (Parkin, Miller, & Vincent, 1987; Safar, 1988). Thus, neuropsychological deficits might be anticipated to display patterns of generalized deficits in basic processes such as attention and memory (associated with diffuse anoxic encephalopathy) along with highly specific deficits associated with one or more of the neurological zones noted above.

Researchers have noted impairments in memory, dementia-like traits, aphasia and motor speech disorders, and visuoperceptual deficits as concomitants of cardiac arrest and resuscitation (Armengol & Moes, 1986; Bigler & Alfano, 1988; Caronna & Finklestein, 1978; Cummings, Tomiyasu, Read, & Benson, 1984; Earnest, Yarnell, Merrill, & Knapp, 1980; Kotila & Kajaste, 1984; Parkin et al., 1987; Volpe & Hirst, 1983; Volpe, Holtzman, & Hirst, 1986). Conspicuously lacking in the literature is any extensive documentation of linguistic and communicative performance. Researchers disagree as to whether language impairment is even a common outcome of arrest and resuscitation. Functional and quality-of-life consequences of survival after cardiac arrest have only recently been explored (DeSilva, Lown, Murawski, Regenstein, & Reich, 1983; Bergner, Bobbitt, Carter, & Gilson, 1981; Bergner, Hallstrom, Bergner, Eisenberg, & Cobb, 1984, 1985;

Vlay & Fricchione, 1985). The cardiac arrest population remains chronically underserved from a rehabilitative perspective, despite estimates of survival-to-discharge rates of 14% to 33% (Krause, White, Aust, Nayini, & Kumar, 1988; Bergner et al., 1984; Kotila & Kajaste, 1984).

The purpose of this paper, therefore, is to describe results of administration of a pilot neuropsychological screening instrument to 39 cardiac arrest survivors. This instrument included a number of language-based items. The experimental questions addressed include:

1) Do cardiac arrest survivors differ from control subjects at 2 weeks and 6 months post arrest in total and language subtest screening performance?
2) Does language performance relate to subject variables such as age, education, cause of arrest, arrest times, duration of coma, amnesia, and/or treatment protocol?

METHODS

Subjects

Subjects were drawn from participants in the University of Pittsburgh School of Medicine's Brain Resuscitation Clinical Trial II (BRCT II, 1989) prospective study involving a randomized, double-masked investigation comparing the effects of lidoflazine with a placebo on recovery of cerebral function following cardiac arrest. The study was conducted with 516 patients in 24 hospitals in six countries. All patients were initially comatose following resuscitation; subjects were screened carefully for presence of premorbid cerebral or irreversible disease processes and use of CNS-depressant drugs, among other criteria.

Of the larger patient sample, 45 individuals received the neuropsychological screening instrument at 2 weeks, 6 months, or both intervals. The evaluation was not provided in 8 of the 24 facilities. Only the subgroup of 39 individuals receiving the examination at both 2 weeks and 6 months served as the subject sample for this report. (Note that only 170 subjects were alive at 2 weeks and only 79 were alive at 6 months.)

Demographic, baseline status, and arrest characteristics of the 516 BRCT II subject population, the 477 non-tested survivors, and the 39 persons receiving neuropsychological testing are shown in Table 1. Subjects who received neuropsychological screening were younger, had shorter arrest and CPR times, and received higher cerebral and overall performance ratings at 12 hours, 2 weeks, and 6 months than subjects who did not

receive screening. In effect, the sample tested in this study already represented the higher functioning subset of initial survivors in the BRCT II investigation.

In addition, a control sample of 20 healthy, community-dwelling volunteers matched approximately for age, sex, and education was administered the neuropsychological screening examination to gather normative data. Control subject characteristics are also summarized in Table 1. There were no significant differences between control and tested cardiac arrest subjects in age, sex, and education.

Neuropsychological Screening Instrument (NPSI)

A neuropsychological screening examination was included in the BRCT II study to detect alterations in cerebral function more subtle than those identified by standard protocol measures. In designing the examination, the following requirements were considered: brevity, ease and appropriateness of translation into different languages; ease of administration by untrained examiners; and range of neuropsychologic performance areas sampled. The resulting 48-point instrument (see Table 2) sampled aspects of orientation (person, time, place), long-term memory (early-learned factual information), procedural memory (making coffee), delayed recall (identification of three pictures shown earlier out of an array of eight pictures), verbal language expression and comprehension (picture naming, word fluency, sentence repetition, following commands, answering simple factual yes/no questions), reading comprehension (simple and complex written commands), writing (sentence length material about how the patient feels), drawing and copying (copying a cross and drawing a clock set to a specific time), and visuospatial and visuomotor perseveration and sequencing. For analysis purposes, the component items could be grouped together into three clusters: Orientation and Memory (13 points), Visuospatial Perception and Attention (9 points), and Language (26 points). The examination also probed the presence of amnesia pre- and post-cardiac arrest. Administration time with control subjects averaged 8 minutes.

PROCEDURES

All patients were enrolled in the BRCT II study within 30 minutes of restoration of adequate spontaneous circulation. Extensive patient history data were gathered, along with best estimates of primary cause of arrest, total brain insult time (TIT) and its component elements, and coma dura-

TABLE 1. DEMOGRAPHIC, BASELINE STATUS, AND CARDIAC ARREST MEASURES FOR THE 516 BRCTII STUDY SAMPLE, THE 477 SUBJECTS NOT RECEIVING THE NPSI, THE 39 SUBJECTS RECEIVING THE NPSI AT BOTH 2 WEEKS AND 6 MONTHS, AND CONTROL SUBJECTS, AS WELL AS STATISTICAL COMPARISONS OF NPSI/NON-TEST GROUP ATTRIBUTES

Attribute	*BRCT II* (*n* = 516)	*Nontested SS* (*n* = 477)	*NPSI SS* (*n* = 39)	*Control* (*n* = 20)	*t test*	*df*	*Chi²*
Age (years)							
Mean	62.8	62.8	55.2	53.9	2.6*	514	
Range	12–95	12–95	12–78	12–79			
Sex (% Male)	61.8	61.8	61.5	60.0		1	1.366
Education (years)	10.1	10.0	11.0	11.0	1.7	381	
Range	1–22	1–22	6–16	6–19			
< 12 Years (%)	62.2	60.6	50.0	50.0			
12 Years	23.6	23.5	23.7	25			
> 12 Years	13.3	16.0	26.3	25		2	2.423
Race (%)							
White	81.2	80.9	84.4	85.0			
Black	16.5	16.8	13.3	15.0			
Other	2.3	2.2	2.2			2	2.113
Primary Cause Arrest (%)							
Cardiac	67.7	67.3	74.4				
Other	32.4	32.7	25.6			1	.985
Total Arrest Time (TAT) (mean min.)	4.6	4.6	3.8		2.10*	514	

TABLE 1. (continued)

Attribute	*BRCT II* (*n* = 516)	*Nontested SS* (*n* = 477)	*NPSI SS* (*n* = 39)	*Control* (*n* = 20)	*t test*	*df*	*Chi²*
CPRT (mean min.)	24.1	24.6	17.0		1.97*	514	
Total Insult Time (TIT) (mean min.)	47.3	48.6	30.7		4.46***	514	
Location of Arrest (%)							
Out-of-Hospital	65.7	63.4	79.5				
In-Hospital	34.3	36.6	20.5			1	4.075*
Treatment Group							
Lidoflazine	50.2	50.1	53.9			1	.866
Baseline CPC							
"1"	87.4	86.9	92.3				
"2"	9.6	9.7	7.7				
"3 or 4"	3.1	3.4	0			2	.474
Baseline OPC							
"1"	58.6	57.3	74.4				
"2"	31.6	32.4	20.5				
"3 or 4"	9.8	10.4	5.1			2	11.422**

*$p < .05$, **$p < .01$, ***$p < .0001$

BRCT II—Brain Resuscitation Clinical Trial II; NPSI—Neuropsychological Screening Instrument

TABLE 2. NEUROPSYCHOLOGICAL SCREENING INSTRUMENT (NPSI) ITEMS AND CLUSTER GROUPINGS

A. Orientation (name, occupation, location, season, time of day)	5 pts
B. Picture Naming (saw, apple, shoe)	3 pts
C. Long Term Memory (capital, Adolph Hitler, date of Christmas)	3 pts
D. Procedural Memory (how do you make coffee?)	2 pts
E. Language	
1. Animal naming (word fluency)	4 pts
2. Sentence repetition	2 pts
3. Following commands (2- and 3-part)	7 pts
4. Answering questions (Yes/No Common Information)	5 pts
Reading	
5. Single command	1 pt
6. Complex commands	2 pts
7. Writing (sentence about how patient is feeling)	2 pts
F. Drawing and Copying	
1. Cross (copying)	2 pts
2. Clock (from memory, set to 10 after 11:00)	3 pts
G. Perseveration and Sequencing	
1. Fist (copy examiner motor sequence with fist)	1 pt
2. Pattern completion (exact imitation of complex visual sequences)	3 pts
H. Amnesia	
Pre-Arrest	
Post-Arrest	
I. Delayed Recall (select 3 earlier pictures out of array of 8)	3 pts
Total NPSI Points	48
Clusters	
Orientation and Memory (ACDI)	13
Language (BE)	26
Visuospation Perception/Attention (F,G)	9

tion. Severity of coma was monitored using the standard Glasgow Coma Score, the Pittsburgh Brain Stem Score, and the Glasgow Outcome Performance Categories (BRCT II, 1989), with all measures available at 12 and 24 hours, as well as at 2 weeks and 6 months (or until patient died).

Neuropsychological examination for cardiac arrest subjects was performed at 2 weeks and 6 months on those patients judged able to cooperate. (Note that it appears that some subjects were not tested because of aphasia or dysarthria, even though they might have been able to complete some portions of testing.) Responses were scored by the facility examiner but were subsequently reviewed (and rescored, if necessary) by one of the authors. Neuropsychological examinations for control subjects were administered and scored by the first author.

RESULTS

Item, cluster, and total mean NPSI scores, ranges, and standard deviations for cardiac arrest subjects at 2 weeks and 6 months and for control subjects are shown in Table 3, which also shows results of paired *t* test comparisons for 2-week and 6-month total and cluster scores, and unpaired *t* test comparisons of control and cardiac arrest subjects at both intervals. Table 4 displays the percentage of subjects missing one or more points on any given item at each testing interval and in each group.

Cardiac arrest subjects scored significantly lower on total NPSI Scores and on all cluster scores at both testing intervals (except the close-to-optimal 6-month performance on Orientation/Memory). Only the performance of experimental and control subjects on the Total NPSI scores and language components will be described in any detail here.

Language Item Performance on the NPSI

Cardiac arrest subjects showed a significant improvement in total and all cluster NPSI scores from 2-week to 6-month testing intervals (see Table 3). In addition, improvement was noted on all but the Sentence Repetition, Answering Questions, and Reading Single Commands portions of the Language Cluster. Animal Naming, Answering Questions, and Sentence Writing sections were most difficult, as judged by percentage of subjects missing one or more points (see Table 4). At 2 weeks, control subject performance exceeded cardiac arrest subject performance on the following language measures: Animal Naming, Sentence Repetition, Answering Questions, Reading Complex Commands, and Sentence Writing. At 6 months, control subjects' language performance still exceeded experimental subjects on: Animal Naming, Sentence Repetition, and Answering Questions.

Between the two testing intervals, 28 subjects improved their total scores (range of improvement from 1 to 39 points, mean change 6.6 points), and two subjects lost 2 total score points (both from scores of 47 to 45). On the Language Cluster, 21 subjects showed a positive change averaging 4.2 points, and 4 subjects lost between 1 and 2 points.

One standard deviation below control subjects' mean performance was used to establish cut-off scores for total and cluster score analysis of cardiac arrest subjects' performance. Percentages of subjects falling below both one and two standard deviation cut-off scores at both testing intervals for Total, Language, and Visuospatial/Attention Clusters are shown in Table 5. At 6 months, close to two-thirds of the cardiac arrest survivors performed one standard deviation below total, language *and* visuospatial/attention performance of control subjects, and approximately one-third

TABLE 3. TOTAL, CLUSTER, AND ITEM NPSI SCORES FOR CARDIAC ARREST SUBJECTS AT 2 WEEKS (2W) AND 6 MONTHS (6M) AND FOR CONTROL SUBJECTS, AS WELL AS *T* TEST COMPARISONS OF GROUP PERFORMANCE DIFFERENCES

NPSI Item		*2 Weeks*			*6 Months*			*Control*			*2W-6M t test* (DF = 38)	*2W-Cont t test* (DF = 57)	*6M-Cont t test* (DF = 57)
		MEAN	RANGE	SD	MEAN	RANGE	SD	MEAN	RANGE	SD			
Total Score	(48)	40.4	6–48	9.84	45.1	30–48	3.27	47.2	45–48	.83	–3.4***	–3.1**	–2.8**
Cluster Scores													
Attn/Memory	(13)	11.6	1–12	2.87	12.9	11–13	.38	13			–2.9**	–2.1*	–1.2
Language	(26)	22.6	4–26	5.14	24.7	13–26	2.14	25.8	25–26	.41	–2.1**	–2.8**	–2.3*
Visual	(9)	6.1	0–9	2.51	7.5	4–9	1.60	8.4	7–9	.68	–3.7***	–4.1****	–2.5**
Item Scores													
Orientation		4.5	0–5	1.23	5			5			–2.6**	–1.9*	NA
Long Term Mem.		2.8	0–3	.74	3.0	2–3	.22	3			–1.4	–1.4	–1.0
Proc. Memory		1.7	0–2	.65	2			2			–2.7**	–1.9	–1.1
Delayed Recall		2.7	0–3	.77	3.0	1–3	.32	3			–2.7**	–1.9*	–.7

TABLE 3. (continued)

NPSI Item	*2 Weeks*			*6 Months*			*Control*			*2W-6M t test* (DF = 38)	*2W-Cont t test* (DF = 57)	*6M-Cont t test* (DF = 57)
	MEAN	RANGE	SD	MEAN	RANGE	SD	MEAN	RANGE	SD			
Copying Cross	1.69	0–2	.61	1.87	1–2	.34	2			-2.0*	-4.2****	-2.6**
Drawing Clock	2.1	0–3	1.99	2.7	1–2	.58	3			-4.0***	-4.2****	-2.6**
Fist Imitation	.9	0–1	.34	1.0	0–1	.16	1.0	0–1	.14	-2.1*	-.9	-.5
Pattern Compl.	1.5	0–3	1.12	2.0	0–3	.99	2.5	1–3	.61	-3.0**	-3.9***	-1.0
Picture Naming	2.8	0–3	.69	3			3			-1.8*	-1.3	NA
Animal Naming	2.8	0–4	1.23	3.4	1–4	.79	3.8	3–4	.41	-3.8***	-3.3***	-2.1*
Sentence Repet.	1.8	0–2	.47	1.9	1–2	.34	2			-.9	-1.9*	-1.7*
Follow Command	6.5	2–7	1.37	7.0	4–7	.48	7			-2.0*	-1.5	-.7
Answer Questions	4.6	0–5	.94	4.7	1–5	.8	5			-.5	-1.9*	-1.7*
Reading Sing Com.	.95	0–1	.23	1.0	0–1	.16	1			-.6	-1.0	-.7
Reading Comp Com.	1.7	0–2	.74	1.9	0–2	.36	2			-2.0*	-1.9*	-1.0
Writing Sentence	1.6	0–2	.71	1.9	1–2	.31	2			-3.1**	-2.4**	-1.5

** $p < .01$
*** $p < .001$
**** $p < .0001$
* $p < .05$

TABLE 4. PERCENTAGE OF EXPERIMENTAL SUBJECTS (N = 39) AND CONTROL SUBJECTS MISSING ONE OR MORE POINTS ON EACH NPSI ITEM

Item	*Experimental*		*Control*
	2 WEEKS	6 MONTHS	
Orientation	18	0	0
Object Naming	10	0	0
Long Term Memory	10	5	0
Procedural Memory	18	0	0
Language			
Animal Naming	69	46	25
Sentence Repetition	18	13	0
Following Commands	13	3	0
Answering Questions	26	18	0
Reading			
Single Command	5	3	0
Complex Commands	16	5	0
Writing	26	10	0
Drawing and Copying			
Cross	23	13	0
Clock	56	29	0
Perseveration and Sequencing			
Fist	13	3	5
Pattern Completion	79	62	25
Delayed Recall	21	3	0

fell two standard deviations below control subjects. Thus, linguistic, perceptual and attentional deficits persisted in a sizable proportion of the sample.

Relationship of NPSI Scores to Other BRCT Study Variables

When subjects were sorted on the basis of age, education, cause of arrest, occurrence of rearrests, and type of treatment, there were no significant differences in NPSI performance (see Table 1). Duration of coma did not correlate significantly with any NPSI score at either testing interval. Arrest times were subdivided into CPR time, Total Arrest Time (TAT), and Total Insult Time (TIT, combined value of TAT plus estimates or pre- and post-arrest hypoxia). Total and language cluster NPSI scores at 2 weeks correlated with total CPR time ($r = -.35$, $df = 37$, $p < .05$ in both instances); TAT correlated with Total NPSI scores at 6 weeks ($r = -.31$, $df = 37$, $p < .05$).

Subjects who reported post-arrest amnesia at two weeks performed significantly more poorly on 2-week and 6-month Total NPSI scores (re-

TABLE 5. PERCENTAGES OF CARDIAC ARREST SUBJECTS FALLING ONE AND TWO STANDARD DEVIATIONS BELOW THE CONTROL GROUP MEAN FOR THE NPSI TOTAL, LANGUAGE CLUSTER, AND VISUOSPATIAL/ATTENTION CLUSTER

	2 Weeks		*6 Months*	
Test Component	< 1 SD	< 2 SD	< 1 SD	< 2 SD
Total Score	82%	67%	62%	39%
Language Cluster	79%	54%	64%	31%
Visuospatial/ Attention Cluster	62%	62%	33%	33%

spectively, Mann Whitney $U = 46$, $p < .05$ and $U = 41.5$, $p < .05$). Subjects who reported pre-arrest amnesia at 2 weeks scored significantly lower on 2-week total NPSI scores ($U = 49.5$, $p < .05$) and on 6-month Language Cluster items ($U = 64.5$, $p < .05$). Subjects reporting post-arrest amnesia at 6 months scored more poorly on both 2-week and 6-month Total NPSI scores ($U = 61$, $p < .05$ and $U = 66.5$, $p < .05$) and on 2-week and 6-month Language Cluster Scores ($U = 65$, $p < .05$ and $U = 64.5$, $p < .05$).

Finally, correlation coefficients were computed to examine the relationship between Total and Language Cluster NPSI scores and Cerebral Performance Category Scores (CPC) at 12 hours, 24 hours, best score in first 24 hours, 2 weeks, and 6 months. These need to be interpreted cautiously, given our sample size. CPC scores at 12 and 24 hours were not significantly related to NPSI scores. Best CPC scores within the first 24 hours were identical with CPC Scores at 6 months and were correlated with 2-week Total ($r = -.396$, $df = 35$, $p < .05$) and Language Cluster Scores ($r = -.383$, $df = 35$, $p < .05$), as well as with 6-month Total ($r = -.865$, $df = 35$, $p < .0001$) and Language Cluster Scores ($r = -.884$, $df = 35$, $p < .0001$). CPC Scores at 2 weeks were significantly correlated with 2-week Total ($r = -.645$, $df = 35$, $p < .0001$) and Language Cluster Scores ($r = -.73$, $df = 35$, $p < .0001$), and with 6-month Total ($r = -.493$, $df = 35$, $p < .01$) and Language Cluster Scores ($r = -.473$, $df = 35$, $p < .01$). Thus, the general cerebral outcome measures used in the BRCT II study correlated reasonably well with NPSI performance. However, the Cerebral Performance Scale measures markedly underestimated the number of subjects with residual deficit. At 6 months, 92% of the subjects received Cerebral Performance Scale ratings of "1" (highest possible) and 87% were rated as Normal on a functional evaluation. At that same time period, only 5.9% received Language Cluster NPSI scores within one standard deviation of control subjects performance and only 69.2% received Language Cluster Scores within two standard deviations.

DISCUSSION

Several aspects of the data presented here warrant further discussion. First, it is clear that some individuals who have suffered cardiac arrest may display deficits in specific linguistic functions (in addition to overall cognitive functions). The prevalence of these deficits has been underestimated in previous literature, and language performance has received little specific focus apart from individuals with documented (presumably moderate to severe) aphasia. The types of mild deficits identified by the NPSI easily can and do escape attention in medical evaluations. As a result, the patient may be sent home to face unexplained and frequently distressing moments of breakdown in daily communicative interactions or linguistic tasks. The resulting interference with quality of life can be further exacerbated by the absence of appropriate management programs for cardiac arrest survivors.

Second, the types of measures used in most current medical protocols for assessment of outcome (Glasgow Outcome Performance Scales) markedly underestimate the potential degree of deficit being experienced by the individual patient. The highest rating on the Cerebral Performance Category Scale is "good," and successful neurological outcome is defined as achieving this rating category. Ironically, this same rating allows for continuing minor psychologic or neurologic deficits *including* mild aphasia or cranial nerve abnormalities. It is not surprising that a considerable proportion of patients in this study continued to show below normal NPSI performance at 6 months, even though all but three of the sample received ratings of "Good" Cerebral Performance at the same time. These "outwardly normal" (Kotila & Kajaste, 1984) individuals deserve further attention.

Third, subjects continued to improve from 2 weeks to 6 months, as reflected by significant increases in NPSI scores in many areas. What is not known is the nature, extent, and time frame for further improvement. In addition, the screening format of the NPSI did not allow intensive analysis of specific language domains. Thus, the degree to which linguistic deficits are similar across subjects cannot be identified, although word fluency, sentence repetition, and answering questions appear to be particularly sensitive tasks.

Clearly, additional research is needed concerning the linguistic and broader neuropsychological deficits of patients suffering cardiac arrest. Certainly, further field testing, modification, and validation of the NPSI or similar instrument is needed if this protocol is to be used effectively in subsequent research and clinical endeavors. A comprehensive research protocol might include: a) linguistic/neuropsychological screening of all resuscitated patients at 2 weeks, 6 months, and 1 year; b) further intensive neuropsychological testing of patients failing screening at any inter-

val with a test battery that includes linguistic, functional communication, and discourse-assessment measures; c) follow-up testing for several years, accurately charting other subject variables (such as general health status and depression) to better define factors influencing prognosis; and d) longitudinal tracking of families to determine the impact of residual linguistic deficits upon quality of life. In addition, clinicians should actively begin exploring the efficacy of different treatment protocols in the management of linguistic deficit secondary to cardiac arrest and resuscitation.

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