



Review Article

# Social Network Structure and Function are Associated with Blood Pressure Reduction in Stroke Survivors

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## Abstract

**Introduction:** Hypertension and risk of stroke recurrence remains prevalent among stroke survivors. Social networks are crucial for health promotion, behavioral change, and health outcomes. Evidence suggests integrating them into interventions can enhance vascular risk reduction, yet the relationship between a stroke survivor's social network and secondary prevention efforts is understudied. **Objective:** To assess the association between social network structure and function and Systolic Blood Pressure (SBP) reduction at one-year post stroke. **Methods:** We analyzed a cohort of 552 stroke/transient ischemic attack survivors from the DESERVE trial, a skills-based, culturally tailored discharge educational intervention. Participants were enrolled from four New York City medical centers during hospitalization or emergency department visits between August 2012 and May 2016. The primary outcome was SBP change from baseline (pre-discharge) to 12-months post-discharge. We regressed SBP reduction on social network characteristics adjusting for covariates. **Results:** We found that family/friend networks and networks with higher educational experiences were associated with greater SBP reduction. In fully adjusted models, having a family/friend network compared to a family-only network ( $\beta=8.29$ ;  $p=0.01$ ) was significantly associated with a larger SBP reduction, as was having 3-5 alters (persons with whom the patient discusses important matters) with at least 3 having completed a HS education compared to no alters ( $\beta=12.37$ ;  $p=0.03$ ). **Conclusions:** Social networks play an important role in SBP reduction among patients post stroke. Larger family/friend networks are beneficial for blood pressure reduction, suggesting their importance in designing future primary and secondary prevention interventions.

**Clinical Trial Registration:** Clinical Trial Registration-URL: <http://www.clinicaltrials.gov>. Unique identifier: NCT01836354.

**Abbreviations:** SBP: Systolic Blood Pressure

**Keywords:** Social networks, hypertension, high blood pressure, stroke, prevention, secondary prevention.

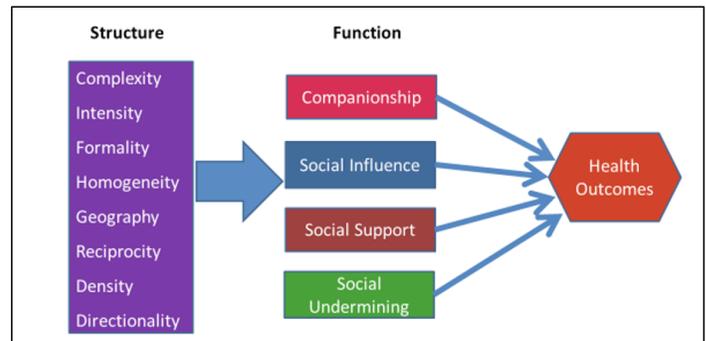
**Introduction**

Stroke recurrence and associated adverse vascular outcomes are a serious but potentially modifiable health burden among stroke survivors. For those who have experienced a first stroke, risk of recurrence is alarmingly high-up to 30% within five years [1] yet evidence indicates this risk is largely modifiable [2]. Approximately 25% of the 800,000 stroke events that occur annually are recurrent events. To reduce stroke recurrence and other adverse vascular outcomes, epidemiological and clinical trial data support the effectiveness of improving health behaviors such as increasing physical activity, adopting/maintaining a healthy diet, and smoking cessation [3–5] as well as reducing key vascular risk factors including hypertension [6–8]. Despite the benefit of blood pressure control to reduce stroke risk, hypertension remains highly prevalent among stroke survivors with estimates around 70% among recent ischemic stroke survivors [2]. Strategies to reduce hypertension among stroke survivors have been suboptimal and have not focused on factors that support successful risk reduction, including self-efficacy and emotional support, accessible information and resources, as well as proper reinforcement strategies for optimal long-term risk factor management. Part of the challenge with secondary stroke is that patients and caregivers have to work concurrently on recovery, on coping with the psychosocial impact of a devastating event, and on secondary stroke prevention. A multitude of tasks are involved in managing those aspects of post-stroke care, including daily physical activity regimens, medication adherence, preparation of healthy meals, coping with depression, understanding and acting on new health information, and navigating changes in family dynamics.

Leveraging social networks may offer an effective and sustainable mechanism to enhance risk reduction. With more than three decades of evidence, it is well understood that social networks influence health behaviors [9,10] and numerous studies have demonstrated that family structure can profoundly influence health outcomes [11–13]. A 2014 American Heart Association/American Stroke Association (AHA/ASA) review of 32 stroke-related studies found that family caregiver and dyad interventions improve physical functioning and health-related quality of life among stroke survivors and also reduce depression and improve preparedness among caregivers [14]. In the Northern Manhattan Stroke Study (NOMAS), we demonstrated that lack of social support (having fewer than three network members who visit the home) is an independent risk factor for stroke recurrence and cardiovascular events post stroke [15]. Other studies suggest that different types of social networks (friends vs. family) may differentially impact health behaviors (physical activity vs. stroke preparedness); living arrangements may be associated with vascular risk factors including hypertension; and these effects vary by gender and race-ethnicity [15–19]. There is growing evidence that integrating a patient’s social network into behavioral interventions

improves the effectiveness and sustainability of vascular risk reduction strategies [14,15,20]. Our previous studies of behavioral interventions have demonstrated that the stroke event constitutes a “teachable moment,” whereby family involvement and concern about risk reduction play a critical role in motivating behavioral change [21,22].

Much of the social support work to date in stroke recovery, as evidenced by the AHA/ASA recommendations, has focused on the relationship between patient and caregiver. However, Berkman’s theory of social networks extends the network beyond the caregiver and suggests differential health-related roles for members of a larger network [9,10,23]. Members of networks might engage in companionship [24] social influence, social support, and social undermining, all of which can shape health outcomes (Figure 1). The mechanisms by which social networks influence stroke outcomes may include reinforcing behaviors, bolstering self-efficacy, or reducing stress through physiological mechanisms [25]. All of these mechanisms potentially impact the utilization of prevention behaviors. However, despite literature strongly suggesting the importance of networks as part of the prevention paradigm, little is known about the relationship between the stroke survivor’s social network and secondary prevention efforts. Using secondary data from the Discharge Educational Strategies for Reduction of Vascular Events (DESERVE) intervention, we assessed the association between social network structure and function and Systolic Blood Pressure (SBP) reduction at one-year post stroke.



**Figure 1:** Structural and functional characteristics of social networks that influence health outcomes (Adapted 25).

Adapted from Israel, B. *Social Networks and Social Support. Health Behavior.* 2010. Relevant examples of companionship include engaging in group exercise routines or attending doctor’s appointments. Relevant examples of social influence include sharing risk knowledge or spreading healthy behaviors. Relevant examples of social support include medication reminders or emotional support. Relevant examples of social undermining include discouraging smoking habits.

**Methods**

Data for this analysis is derived from DESERVE, a two-arm randomized controlled trial conducted between August 2012 and

May 2016 in New York City. The methods of DESERVE have been published in detail elsewhere [26,27] Briefly, 552 mild/moderate stroke/Transient Ischemic Attack (TIA) survivors were prospectively enrolled and randomized from four major medical centers in New York City (*i.e.*, Langone Medical Center, Icahn School of Medicine at Mount Sinai, Columbia University Medical Center, and Bellevue Hospital Center). DESERVE assessed a skills-based, culturally tailored intervention designed to improve patient-physician communication, medication adherence, and accurate stroke risk perception through an interactive educational session, a patient-paced workbook, patient narrative videos, and intervention follow-up at 72 hours, one month, and three months. Usual care consisted of language appropriate information on risk reduction post stroke. Individuals missing blood pressure measurements at 12 months were excluded from this analysis. The study was approved by the IRBs of the participating medical centers and was registered at ClinicalTrials.gov (NCT01836354).

As part of the DESERVE baseline enrollment, participants were asked to identify up to five persons (“alters”) with whom they discuss important matters, including health. Based on data collected about the nature of these relationships, we classified network characteristics into two groups: structural and functional (Table 1). We defined structural characteristics as being related to the composition of the network (who are the people in the network and what are their relationships to each other). Structural characteristics were defined by the alters who make up the network and included

number of alters, alter(s) living in the same household, a family-only vs. family and friend network, and education. Education level of each alter was defined as high (completed high school) or low (did not complete high school). Functional characteristics described the nature and type of interactions that define the relationship and included actions related to companionship, social influence, social support, and social undermining. Our functional network variables included the frequency of contact with each alter, likelihood of discussing health concerns, and reported relationship closeness.

We chose variables and cut points previously identified in the literature to describe the most beneficial scenarios within social networks (Table 1). We operationalized network characteristics as a combination of the number of alters named and the number of alters who met the most beneficial scenario for each characteristic. We grouped patients into those reporting 0, 1-2, or 3-5 alters. To analyze potential associations with alters’ educational level (a structural characteristic) and functional characteristics, we further subdivided patients reporting only 1-2 alters into one of two categories for each characteristic: those patients with at least 1 alter meeting the most beneficial scenario and those patients with no alters meeting the most beneficial scenario. Similarly, we subdivided patients who reported 3-5 alters into those who reported at least 3 respondents meeting the most beneficial scenario and those who did not. Since less than 3% of the sample reported having 1-2 alters with none meeting the most beneficial scenarios, we combined the 1-2 alters group as one category in our models.

Network Characteristics	Alter variables	Variable cutpoint	Variable Categories
Structural	Number of alters	—	0
			01-Feb
			03-May
	Relationship to ego	—	Family only network
			Family and friend network
	Living arrangements	—	Same household as ego
			Different household from ego
	Education	More than high school (HS)	1-2 alters, none with >HS education
			1-2 alters, ≥ 1 with >HS education
			3-5 alters, none with >HS education
3-5 alters, ≥ 3 have >HS education			

Functional	Frequency of alter talking to ego	At least several times per week <sup>15</sup>	1-2 alters, talks to no one at least several times per week
			1-2 alters, talks to $\geq 1$ at least several days per week
			3-5 alters, talks to $<3$ at least several days per week
			3-5 alters, talks to $\geq 3$ several days per week
	Closeness of ego's relationship with alter	Extremely/very close	1-2 alters, extremely/very close to no one
			1-2 alters, extremely/very close to $\geq 1$
			3-5 alters, extremely/very close $<3$
			3-5 alters, extremely/very close to $\geq 3$
	Likelihood of ego discussing health matters with alter	Very likely	1-2 alters, very likely to discuss health matters with no one
			1-2 alters, very likely to discuss health matters with $\geq 1$
			3-5 alters, very likely to discuss health matters with $<3$
			3-5 alters, very likely to discuss health matters with $\geq 3$
<p><b>*Note:</b> We employed the workable definition of social isolation as “knowing fewer than 3 people well enough to visit with in their homes” (Boden-Albala, B et al., 2005).</p>			

**Table 1:** Network variables collected on alters.

Our primary outcome was SBP change from baseline (pre-discharge) to 12-months post-discharge. At each data collection time point, Blood Pressure (BP) was measured up to three times by trained coordinators or research assistants using a BP Tru automatic sphygmomanometer, as described previously [26]. Baseline BP measurements were taken at least 48-hours post stroke. At 12-month follow-up, 27.3% of BP measurements were collected in person by the study team, 66.8% came from either clinic visits where our study staff met the patient or abstracted chart records, and 5.9% were self-reported by the participant. The distribution of source of follow-up BP measurement did not differ significantly between groups. The average of the second and third BP readings was utilized as the measure for BP or the average of the first two readings if the third was missing or just the first reading if no other measurements were collected.

Covariates included participant age, race-ethnicity, gender, NIH Stroke Scale (NIHSS) at admission, education (completed high school or more education versus less than high school completion), and prior stroke history. Marital status served as a historically relevant indicator of social support. DESERVE trial arm was handled as a covariate. We collected the Center for Epidemiologic Studies Depression (CES-D) Scale to assess full depression (CES-D score  $\geq 16$ ) at 12 months following stroke, however, we were not able to use it in the dataset due to missingness at 12 months. Antihypertensive medication adherence was assessed using the self-reported 8-item Morisky Medication Adherence Scale (MMAS-8), which has been validated against blood pressure levels and shown to be valid in a sample of primarily low-income, minority patients with hypertension [28]. The scale consisted of 8 dichotomous (yes/no, with no coded as 1, indicating higher

adherence) or Likert items (normalized to range between 0 and 1, with higher values indicating higher adherence). Examples of items were, “Do you ever forget to take your high blood pressure medication?” and “When you feel like your blood pressure is under control, do you ever stop taking your medicine?” 13 Recoded items were summed and ranged from 0 to 8. The summed score was dichotomized into high adherence (score of 8) and low or medium adherence (scores of 0 to 7).

### Statistical analysis

Frequencies, percentages, means, and standard deviations were used to describe the distribution of our variables of interest, as appropriate. Mean SBP change across categories of social network structure and function characteristics were assessed using ANOVA. Differences in measures of social networks across additional covariates were assessed using chi-square tests. Linear regression models were used to quantify the association of SBP change with structural and functional social network variables first unadjusted, then adjusting for trial arm, age, gender, race-ethnicity, NIHSS, education, marital status, and prior stroke, and finally additionally adjusting for medication adherence. Structural and functional social network variables were stratified to explore heterogeneity by race-ethnicity. Analyses were conducted using SAS v9.4. Hypothesis tests were conducted at the two-sided 0.05 level.

## Results

### Ego characteristics

There were 407 participants enrolled in DESERVE with baseline and 12-month blood pressure measurements. Participants had a

mean age of 64.2 ( $\pm$  14.6) years and were 48.4% male. The racial and ethnic distribution was nearly equivalent with 33.4% Hispanic, 31.7% non-Hispanic black, 28.5% non-Hispanic white, and 6.4% other race-ethnicity. Approximately one-quarter had less than a high school education, 21.0% had completed high school or equivalent, and 53.1% reported having at least some college education. Slightly less than half (47.6%) were married or living with a partner; 35.3% were divorced, separated, or widowed; and 17.1% were single/never married. Marital status was more common in those under 66 years of age, and men were more likely to be married. Approximately one-third of the sample had a prior stroke or TIA. Only 3% had high medication adherence, and among those not missing elements in the depression score, almost one-third had depression. The overall mean SBP reduction at 12-month follow-up was 6.7 ( $\pm$  23.8) mmHg (Table 2).

	N	%
<b>Age, mean (SD)<sup>†</sup></b>	64.2	-14.58
<b>Gender</b>		
Male	197	48.4
Female	209	51.35
<b>Race ethnicity</b>		
Hispanic	135	33.42
Non-Hispanic black	128	31.68
Non-Hispanic white	115	28.47
Other	26	6.44
<b>Education</b>		
Less than high school	104	25.94
High school or GED	84	20.95
More than high school	213	53.12
<b>Marital status</b>		
Married, living with partner	189	47.61
Divorced, separated, widowed	140	35.26
Single never married	68	17.13
<b>Prior stroke or TIA at baseline</b>		
No	273	67.08
Yes	134	32.92
NIHSS, median (IQR)	2	(0 – 5)
<b>Medication Adherence (Morisky)</b>		
High adherence	11	3.11
Medium/Low adherence	343	96.89
<b>Depression (CESD-20)</b>		
No	171	68.67
Yes	78	31.33
<b>Trial arm</b>		
Intervention	207	50.86
Usual care	200	49.14
<b>BP reduction at 12-month follow-up, mean (SD)</b>	6.7	-23.78
Intervention	8.19	-25
Usual care	5.16	-22.4

Age was missing for 1 subject; 3 missing race/ethnicity; 6 missing education; 10 missing marital status; 32 missing NIHSS; 53 missing medication adherences; 158 missing depression.  
GED=General Educational Development/high school equivalency; TIA=Transient Ischemic Attack; NIHSS=National Institutes of Health Stroke Scale; BP=Blood Pressure

**Table 2:** Demographic and clinical characteristics of the DESERVE cohort of stroke/transient ischemic attack survivors (N=407), New York City, 2012-2016.

### Network characteristics

In terms of structural network characteristics (Table 3), 8% of participants identified no alters, 35% one alter, 24% two alters, 13% three alters, 9% four alters, and 11% five alters. Of those with at least one alter, 62% reported having an alter in the same household and 72% reported having a family-only network.

Of the 241 participants reporting 1-2 alters, 96% reported talking to at least 1 alter several days per week, 96% reported they were extremely or very close to at least 1 alter, 95% reported they were very likely to discuss health matters with at least 1 alter, and 68% reported having at least 1 alter with more than a high school education. Of the 133 participants reporting 3-5 alters, 71% reported talking to at least 3 alters several days per week, 80% reported they were extremely or very close to at least 3 alters, 76% reported they were very likely to discuss health matters with at least 3 alters, and 50% reported having at least 3 respondents with more than a high school education.

The mean SBP reduction between baseline and the one-year follow-up was greater across family and friend networks [mean reduction of SBP 11.32 mmHg] vs. family-only [mean reduction of SBP 5.73mmHg] ( $p=0.05$ ). Compared to no weekly contact with any alter, speaking with 1-2 or 3-5 alters at least several times a week resulted in significant SBP reduction ( $p=0.03$ ). We report a dose-response relationship between number of alters having more

than a high school education and greater mean SBP reduction ( $p=0.05$ ). Indeed, having 3-5 alters with at least 3 alters having greater than high school education was associated with a mean SBP reduction of 13.63 mmHg. Mean SBP reduction between baseline and the one-year follow-up did not differ significantly by number of alters identified ( $p=0.24$ ), whether or not the alter lived in the same household ( $p=0.89$ ), relationship closeness ( $p=0.32$ ), or likelihood of discussing health concerns ( $p=0.28$ ) (Table 3).

### Results of fully adjusted network model

In the fully adjusted model (Model 2, Table 3), having a family and friend network compared to a family-only network ( $p=0.01$ ) was significantly associated with a mean SBP reduction. Compared to reporting no alters, having 3-5 alters who speak with the ego at least three days per week resulted in a significant reduction of SBP (mean SBP reduction of 13.5 mmHg,  $p=0.03$ ). Participants reporting 3-5 alters, of which 3 or more had completed high school, were associated with a significantly larger reduction in SBP compared to participants reporting 1-2 alters, of which none had completed high school (mean difference 12.4mmHg,  $p=0.03$ ). Additional tests showed that the trial arm assignment did not modify the effect of any network characteristic (data not shown). These results were all consistent with the additional adjustment for medication adherence which was done separately due to additional missingness of the instrument.

Number of alters identified	Bivariable - mean BP reduction					Model 1		Model 2		Model 3	
	N	%	mean BP reduction (mmHg)	SD	p-value	B	p-value	B	p-value	B	p-value
0	33	8.11	0.45	16.17	0.24						
1	142	34.89	7.63	21.23							
2	99	24.32	4.63	23.64							
3	52	12.78	9.46	24.39							
4	35	8.6	3.66	30.96							
5	46	11.3	12	28.33							
<b>Number of alters identified categorized</b>											
None	33	8.11	0.45	16.17	0.19	reference		reference		reference	
1-2 alters	241	59.21	6.39	22.25		5.94	0.18	5.82	0.25	7.65	0.15
3-5 alters	133	32.68	8.81	27.59		8.36	0.07	8.15	0.13	7.75	0.16
<b>Alter in same household*</b>											
Yes	232	62.03	7.12	25.04	0.89	-0.35	0.89	-3.17	0.29	-4.78	0.15
No	142	37.97	7.47	23.06		reference		reference		reference	
<b>Family only network*</b>											
Yes	272	72.73	5.73	24.87	<b>0.05</b>	-5.6	0.05	-8.29	0.01	-9.15	0.01
No	102	27.27	11.32	22.2		reference		reference		reference	
<b>Frequency of talking to alter</b>											
No alters	33	8.11	0.45	16.17	<b>0.03</b>	reference		reference		reference	
1-2 alters, talks to no one at least several days per week	9	2.21	21.67	20.51							
1-2 alters, talks to at least one several days per week	232	57	5.8	22.14		5.94 <sup>a</sup>	0.17 <sup>a</sup>	5.93 <sup>a</sup>	0.24 <sup>a</sup>	8.37 <sup>a</sup>	0.11 <sup>a</sup>
3-5 alters, talks to less than 3 at least several days per week	38	9.34	14.95	26.23		14.49	<b>0.01</b>	13.52	<b>0.03</b>	15.66	<b>0.02</b>
3-5 alters, talks to at least 3 several days per week	95	23.34	6.36	27.87		5.9	0.21	6.14	0.26	5.63	0.31

Number of alters identified	Bivariable - mean BP reduction					Model 1		Model 2		Model 3	
	N	%	mean BP reduction (mmHg)	B	p-value	B	p-value	B	p-value	B	p-value
<b>Closeness of relationship with alter</b>											
No alters	33	8.11	0.45	16.17	0.32	reference		reference		reference	
1-2 alters, extremely/very close to no one	10	2.46	13	27.05							
1-2 alters, extremely/very close to at least one	231	56.76	6.11	22.04		5.94 <sup>b</sup>	0.18 <sup>b</sup>	5.81 <sup>b</sup>	0.25 <sup>b</sup>	7.65 <sup>b</sup>	0.15 <sup>b</sup>
3-5 alters, extremely/very close to less than 3	27	6.63	11.81	31.34		11.36	0.06	10.74	0.11	11.22	0.1
3-5 alters, extremely/very close to at least 3	106	26.04	8.05	26.66		7.59	0.11	7.45	0.17	6.75	0.23
<b>Likelihood of discussing health concerns with alter</b>											
No alters	33	8.11	0.45	16.17	0.28	reference		reference		reference	
1-2 alters, very likely to discuss health matters with no one	11	2.7	14.18	23.44							
1-2 alters, very likely to discuss health matters with at least one	230	65.51	6.02	22.18		5.94 <sup>c</sup>	0.18 <sup>c</sup>	5.88 <sup>c</sup>	0.24 <sup>c</sup>	7.77 <sup>c</sup>	0.14 <sup>c</sup>
3-5 alters, very likely to discuss health matters with less than 3	32	7.86	11.44	33.2		10.98	0.06	11.03	0.09	11.37	0.09
3-5 alters, very likely to discuss health matters with at least 3	101	24.82	7.98	25.69		7.53	0.11	7.3	0.18	6.6	0.24
<b>Education</b>											
No alters	33	8.11	0.45	16.17	0.05	reference		reference		reference	
1-2 alters, no alters with more than a HS education	78	19.16	5.08	23.27		4.62	0.34	5.52	0.33	8.8	0.14
1-2 alters, at least one alters with more than a HS education	163	40.05	7.02	21.79		6.57	0.14	6.4	0.22	7.49	0.17
3-5 alters, less than 3 alters with more than a HS education	66	16.22	3.92	25.48		3.47	0.49	3.98	0.49	2.18	0.71
3-5 alters, at least 3 alters with more than a HS education	67	16.46	13.63	28.9		13.17	<b>0.01</b>	12.37	<b>0.03</b>	13.11	<b>0.03</b>

\*Living in same household and family only network were missing for the 33 subjects that identified no alters  
 Note: Model 1: unadjusted; Model 2: adjusted for age, gender, race-ethnicity, education, marital status, prior stroke, NIHSS, and trial arm; Model 3: Model 2 + medication adherence  
 a. For multivariable regression, this response represents 1-2 alters (with no stratification of frequency of communication).  
 b. For multivariable regression, this response represents 1-2 alters (with no stratification of closeness).  
 c. For multivariable regression, this response represents 1-2 alters (with no stratification of likelihood of discussing health concerns).

**Table 3:** Distribution of social network structural and functional characteristics in the DESERVE cohort of stroke/transient ischemic attack survivors (N=407), New York City, 2012-2016.

Black participants were more likely to have 3-5 alters identified compared to Hispanic or White participants (p=0.006) (Table 4). Whites were least likely to report no alters compared to other races; Hispanics had the highest proportion of family-only networks (p=0.017). Blacks reported a higher frequency of talking to three or more alters regularly. Education of alters was significantly different across ethnic groups (p<0.001). Whites had the highest proportion of alters with more than a high school education, and Hispanics had the lowest. Higher education of alters was associated with a significant decrease in blood pressure.

Race/Ethnicity	White	Black	Hispanic	p-value
<b># of alters identified</b>	N (%)	N (%)	N (%)	
No alters	3 (3%)	15 (12%)	13 (10%)	
1-2 alters	76 (66%)	61 (48%)	85 (63%)	
3-5 alters	36 (31%)	52 (41%)	37 (27%)	<b>0.006</b>
<b>Alter in same household*</b>				
Yes	81 (72%)	55 (49%)	74 (61%)	
No alters	31 (28%)	58 (51%)	48 (39%)	<b>0.001</b>
<b>Family-only network*</b>				
Yes	79 (71%)	76 (67%)	101 (83%)	
No	33 (29%)	37 (33%)	21 (17%)	<b>0.017</b>
<b>Frequency of talking to alter</b>				
No alters (reference)	3 (3%)	15 (12%)	13 (10%)	
1-2 alters	76 (66%)	61 (48%)	85 (63%)	
3-5 alters, talks to < 3 regularly	16 (14%)	15 (12%)	6 (4%)	
3-5 alters, talks to ≥3 regularly	20 (17%)	37 (29%)	31 (23%)	<b>0.002</b>
<b>Closeness of relationship</b>				
No alters (ref)	3 (3%)	15 (12%)	13 (10%)	
1-2 alters	76 (66%)	61 (48%)	85 (63%)	
3-5 alters, close to <3	8 (7%)	13 (10%)	6 (4%)	
3-5 alters, close to ≥3	28 (24%)	39 (30%)	31 (23%)	<b>0.017</b>
<b>Likelihood of discussing health concerns</b>				
No alters (reference)	3 (3%)	15 (12%)	13 (10%)	
1-2 alters	76 (66%)	61 (48%)	85 (63%)	
3-5 alters, discuss health matters with < 3	12 (10%)	12 (9%)	7 (5%)	
3-5 alters, discuss health matters with ≥3	24 (21%)	40 (31%)	30 (22%)	<b>0.012</b>
<b>Education</b>				
No alters (reference)	3 (3%)	15 (12%)	13 (10%)	
1-2 alters, no alters with > HS education	9 (8%)	16 (13%)	46 (34%)	

1-2 alters, at least one alters >HS education	67 (58%)	45 (35%)	39 (29%)	
3-5 alters, < 3 alters with >HS education	8 (7%)	29 (23%)	26 (19%)	
3-5 alters, >= 3 alters with >HS education	28 (24%)	23 (18%)	11 (8%)	<b>&lt;0.001</b>
*missing for the 31 subjects who did not identify any alters				

**Table 4:** Social network structural and functional characteristics stratified by race/ethnicity in the DESERVE cohort of stroke/transient ischemic attack survivors (N=407), New York City, 2012-2016.

## Discussion

In framing mean SBP reduction with the context of social networks, we found that, on average, SBP decreased by a greater degree over 12-months post-stroke in participants with larger social networks compared to participants with more limited social networks. Specifically, we found greater SBP reduction for patients with networks that included both family and friends rather than family only. While these results contribute to the literature suggesting that social support decreases blood pressure, our work also provides specific information about what kind of network structures are most associated with positive risk reduction after stroke. Most previous research implementing blood pressure reduction strategies has focused on patients and their self-management of blood pressure. In aging populations at higher risk for stroke, we often think of the primary caregiver in terms of network, but more consideration should be given to the role that the larger circle of both family and friends plays in supporting the health of this population. Evidence suggests that different network members may be helpful in supporting different kinds of health behaviors. We have previously reported that acute stroke preparedness (*i.e.*, early arrival at the emergency department following onset of stroke symptoms) is optimized by close geography, intimacy, and social cohesion [22] and is best supported by the marital/partnership dyad social network. Willey et al suggest that health behaviors such as exercise may best be supported by friend networks [17]. The type of behaviors associated with blood pressure reduction are not as much intimate behaviors as they are risk reduction behaviors associated with long-term lifestyle factors (e.g., lowering salt intake and engaging in physical activity) which may be better supported by larger network groups. Nuanced within these network findings, we report that having 3-5 alters and engaging with them was significantly associated with a reduction in blood pressure compared to reporting no alters. However, the data suggest that frequent engagement with at least three of them is not needed in order to reduce blood pressure. Additionally, our finding of an 8mmHg reduction in blood pressure associated with the family-friend network, compared to the family-only network, suggests that the composition of the patient’s support network matters.

In addition to the important role of family and friend networks in the reduction of blood pressure, our data reiterate the role of education in blood pressure reduction. Indeed, any network in which at least one alter had attained some college education demonstrated positive risk reduction, and networks with higher educational attainment had larger blood pressure reduction. One explanation

for this aligns with the health behavioral pathway 25 in that within a network one individual with higher educational attainment may have better health literacy, being able to interpret medical information and coordinate actions needed, including assigning tasks to other network members or checking on medication interactions. Indeed, the largest blood pressure reduction was found in family-friend social networks with higher educational levels. The relationship between education, social networks, and reduction in SBP is complicated. Some have suggested that networks and education work together to influence reduction of blood pressure. However, while we report that Hispanics had the greatest proportion of alters with less than a high school education, previous results from the DESERVE randomized control trial found that among Hispanic individuals, the intervention produced a 9.9mmHg reduction in systolic blood pressure compared with usual care, which was statistically significant [26]. The disparity in baseline alter education may help to partially explain why this subgroup benefitted most from a skills-focused educational intervention, as the intervention utilized in DESERVE was able to bridge this knowledge gap with a larger effect compared to patients with social networks with higher education level. This finding is consistent with existing literature on education [29-31] and represents a possible target for social network-based interventions, as health and lifestyle education for the network may be more efficacious than individually-targeted strategies in improving stroke prevention both for the individual with stroke and his or her alters.

Limitations include egocentric versus sociocentric network collection so all information about alters are self-reported by the patient. However, an egocentric approach was most feasible and appropriate, and design may have had limited effect on some network measures [32]. The definitions of structural and functional, while based on Berkman’s theoretical model, may need further refinement and only approximate relational characteristics of the networks. The sample size limits power to detect differences by race-ethnicity which is a critical factor in understanding important relationship differences between race-ethnicity and network characteristics. Further, the analysis in Table 3 which drilled down to relationships between structural and function variables may be biased because of an imbalanced dataset for these variables. There may be a selection bias in those that have the 12 month blood pressure reading completed whereby those with a blood pressure reading had close to 8 times greater odds of having at least 1 alter compared to those without alters. It may be that those with poorer social networks were harder to follow up, had worse outcomes,

or less of an improvement in blood pressure reduction. Finally, the study population may be limited by the inclusion/exclusion criteria associated with the randomized controlled trial design of the parent data set although our broad eligibility criteria suggest the impact of the trial design on generalizability to be minimal.

Future interventions designed to involve social networks may help reduce vascular risk and enhance secondary prevention efforts. Importantly, these interventions are likely sustainable outside of medical settings. Stroke is a complex disease-the patient has various needs, and a larger social network might provide diversity of support and be better equipped to provide for those needs. Part of the difficulty with stroke and prevention of secondary stroke is that patients and caregivers have to work concurrently on recovery, on coping with the psycho-social impact of a devastating event, and on secondary stroke prevention. A multitude of tasks are involved in managing those aspects of post-stroke care, including daily physical activity regimens, medication adherence, preparation of healthy meals, coping with depression, understanding and acting on new health information, and changes in family dynamics. While these factors add to the complexity of designing interventions, they also underscore the concept that family/friend networks may play a critical and sustainable role in primary and secondary stroke prevention. Perhaps a systematic approach in which the family/friend networks assume individual roles and are responsible and educated on various components of care would benefit the patient.

## Conclusion

Social networks may play an important role in blood pressure reduction among patients post stroke. Our finding that larger, family/friend networks are particularly beneficial for blood pressure reduction is an important consideration for the design of future primary and secondary prevention interventions.

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