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Symptom clusters and network analysis in acute-phase patients after minimally invasive surgery for hypertensive intracerebral hemorrhage: a cross-sectional study

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Abstract

Objective

To explore symptom clusters and identify core and bridge symptoms via network analysis in acute-phase patients after minimally invasive surgery for hypertensive intracerebral hemorrhage, informing precision symptom management.

Methods

A convenience sample of 261 acute-phase patients after minimally invasive surgery for hypertensive intracerebral hemorrhage was recruited from a tertiary hospital. Symptoms were assessed using the Stroke Symptom Experience Scale. Principal component analysis with varimax rotation extracted symptom clusters. A network was constructed using R, and centrality indices identified key nodes.

Results

Three distinct symptom clusters were extracted: a somatic-motor disturbance cluster, an emotion-related cluster, and a cognitive impairment cluster. “Decreased self-care ability” ranked highest in strength, closeness, and betweenness, indicating it was the core symptom within the network. “Distress over being unable to do desired activities” exhibited cross-loading across factors and emerged as the key bridge symptom connecting the somatic-motor and emotion-related clusters.

Conclusion

Postoperative symptoms cluster predominantly around somatic-motor dysfunction. Clinically, restoring self-care ability should be prioritized, with targeted interventions at bridge symptoms to optimize the symptom network and facilitate early rehabilitation.

1. Introduction

Hypertensive intracerebral hemorrhage (HICH) is one of the most critical and life-threatening conditions encountered in neurosurgery. Characterized by sudden onset, rapid progression, and exceedingly high mortality and disability rates, HICH profoundly impairs patient prognosis and quality of life[1]. In China, the annual incidence of spontaneous intracerebral hemorrhage ranges from 150 to 300 per 100,000 population, of which 70%–80% are attributed to hypertension[2]. The 30-day case fatality rate following HICH is reported to be 35%~52%, and only approximately 20% of survivors regain independence in activities of daily living[3]. The mass effect exerted by the hematoma, compounded by secondary brain injury, constitutes the core pathophysiological mechanism underlying neurological deficits and poor

outcomes [4]; consequently, timely evacuation of the intracranial hematoma is paramount in clinical management.

In recent years, with the rapid advancement of minimally invasive neurosurgical techniques, minimally invasive hematoma evacuation has become widely adopted for the treatment of HICH[5]. Compared with conventional craniotomy, minimally invasive approaches offer several advantages, including higher hematoma clearance rates, less intraoperative blood loss, shorter operative duration, reduced intensive care unit length of stay, and lower incidence of postoperative complications[6]. The clinical efficacy of various minimally invasive modalities, such as neuroendoscope-assisted hematoma evacuation and stereotactic puncture and drainage, has been substantiated by a growing body of evidence[5, 7, 8]. Surgical intervention, however, represents merely the initial step in the patient's rehabilitation journey. The architecture of the symptom network during the acute phase following minimally invasive surgery for HICH differs substantially from that observed after conventional craniotomy. On the one hand, this acute phase coincides with the peak period of cerebral edema and the acute stress response to surgical trauma. Local tissue injury triggers neuroinflammation, accompanied by increased blood–brain barrier permeability and intracranial pressure dysregulation, which collectively give rise to a constellation of acute manifestations, including motor deficits, sensory loss, headache, nausea, and agitation [9]. In contrast, craniotomy, by virtue of bone-flap decompression, provides a greater buffering capacity for intracranial pressure, and symptom peaks tend to be delayed or more gradual. On the other hand, minimally invasive surgery avoids extensive scalp incisions and cranial bone removal, allowing patients to regain consciousness significantly earlier than those undergoing craniotomy. Although this earlier awakening facilitates timely neurological assessment, it also renders patients more acutely aware of their altered physical state. Consequently, negative emotions that would otherwise be masked by sedation or impaired consciousness emerge prematurely into a clear sensorium, establishing a dense positive feedback loop with somatic symptoms: early perceived motor dysfunction exacerbates psychological distress, which in turn activates the sympathetic-adrenomedullary system and the hypothalamic-pituitary-adrenal axis, precipitating blood pressure fluctuations and elevated intracranial pressure, thereby intensifying headache and neurological deterioration. In craniotomy patients, by contrast, delayed consciousness recovery postpones the onset of psychological distress, and the symptom network is predominantly shaped by organic cerebral edema. The temporal convergence of early somatic stress and premature psychological engagement endows the acute-phase symptom network following minimally invasive surgery with greater connectivity density and stronger mutual reinforcement effects, leading to a more pronounced and fluctuating symptom burden than that associated with other treatment modalities. This imposes heightened demands on the timeliness and precision of early nursing interventions and ultimately exerts a substantial adverse impact on neurological recovery and quality of life.

Patients in the acute phase after minimally invasive surgery for HICH frequently experience a confluence of symptoms, including physical dysfunction, pain, and agitation. Nevertheless, conventional symptom management strategies have traditionally focused on the assessment and treatment of individual

symptoms in isolation. This linear, single-symptom paradigm overlooks the potential synergistic amplification and causal cascading effects among concurrent symptoms, rendering interventions ill-suited to the complex and dynamic symptom experience of these patients. Clinical practice guidelines issued by the American Stroke Association (ASA) and the European Stroke Organisation (ESO) underscore the importance of symptom assessment, control, and management for achieving rehabilitation goals in stroke survivors[10]. However, the current guideline framework remains predominantly organized around single-symptom dimensions and does not adequately address the challenges posed by multi-symptom interactions. In response to this gap, the concept of "symptom clusters" has been introduced into symptom management research. A symptom cluster is defined as a group of two or more concurrent and interrelated symptoms that are stable and co-occur[11]. This paradigm shifts the focus from isolated symptoms to clustered symptom patterns, thereby enhancing the efficiency of symptom management. Nonetheless, it remains anchored at the level of static clustering and is incapable of elucidating the dynamic, directed interactions among symptoms or their relative weights within the network, limiting its utility in guiding precise, targeted interventions during the acute phase.

Network analysis, as an emerging methodological approach, offers a novel lens for symptom science research[12]. This approach conceptualizes symptoms as nodes within an interconnected complex network and computes centrality indices to identify symptoms that play pivotal roles in the network, while bridge strength is used to detect symptoms that connect different symptom clusters[13]. This framework addresses a critical shortcoming of traditional symptom cluster research—namely, the inability to identify precise intervention targets—and provides a methodological basis for patient-centered precision symptom management[14]. To date, network analysis has made some inroads in stroke research, with several studies having explored the symptom network structure of acute-phase stroke patients[10]. However, although these studies have included a proportion of patients with hemorrhagic stroke, none have conducted subgroup analyses specifically targeting the acute-phase population after minimally invasive surgery for HICH. The pathophysiological mechanisms, surgical stress responses, and postoperative recovery trajectories associated with HICH differ markedly from those of mixed-stroke populations, which are predominantly composed of ischemic stroke patients. Patients after minimally invasive surgery contend with a complex symptom experience in which physical dysfunction, surgical stress, and peak cerebral edema symptoms are intricately intertwined; consequently, the composition of symptom clusters, network architecture, and core symptoms in this unique population may exhibit distinct characteristics. Therefore, it is imperative to conduct a symptom cluster and network analysis specifically in this population to identify core symptoms and bridge symptoms, thereby informing the development of precise postoperative symptom management strategies.

In summary, this study aims to explore the composition of symptom clusters among patients in the acute phase after minimally invasive surgery for HICH, to construct a symptom network through network analysis, and to identify core symptoms and bridge symptoms within the network. The findings are

expected to provide an evidence-based foundation for clinicians and nurses to develop precise symptom management strategies, ultimately improving postoperative rehabilitation outcomes and quality of life in this population.

2. Methods

2.1 Study Participants

This study employed a cross-sectional design. A convenience sampling method was used to recruit patients who met the predefined inclusion and exclusion criteria from the Affiliated Hospital of Qingdao University, during the acute phase following minimally invasive surgery for HICH. The inclusion criteria were as follows: (1) diagnosis of spontaneous HICH confirmed by a clinician based on clinical manifestations consistent with the Chinese Guidelines for the Diagnosis and Treatment of Intracerebral Hemorrhage (2019) [15], in conjunction with cranial computed tomography findings; (2) age ≥ 18 years; (3) underwent minimally invasive surgery for hematoma evacuation; (4) in the acute postoperative phase, defined as within seven days after surgery; and (5) conscious, with no cognitive or communication impairments. The exclusion criteria were: (1) pre-existing limb disability or motor impairment prior to the current stroke event; and (2) concomitant severe major organ disease. The sample size was determined in accordance with established guidelines for network analysis[16]. In a symptom network with N nodes, the number of parameters to be estimated is the sum of N threshold parameters and N×(N − 1)/2 pairwise association parameters, yielding a total of [N + N×(N − 1)/2] parameters. To ensure the stability of the symptom network, symptoms with an incidence rate of less than 25% were excluded from the network analysis. The assessment instrument used in this study comprised 23 symptoms, of which 19 met this incidence threshold in the pre-survey. Consequently, the network model required the estimation of 19 threshold parameters and 190 total parameters. Accounting for a 10% invalid response rate, the minimum required sample size was calculated to be 209 patients. A total of 294 questionnaires were distributed, and 261 valid responses were collected, yielding a valid response rate of 88.78%. This study was approved by the Ethics Committee of Affiliated Hospital of Qingdao University (Ethics approval number:QYFY WZLL 30228). All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to data collection.

2.2 Instruments

2.2.1 Demographic and Clinical Characteristics Questionnaire

A self-designed demographic and clinical characteristics questionnaire was used to collect sociodemographic information and disease-related clinical data. The questionnaire encompassed the following variables: sex, age, marital status, occupation, place of residence, educational level, average

monthly household income per capita, mode of medical payment, smoking history, alcohol consumption history, hematoma location, hematoma volume, surgical modality, and severity of hypertension.

2.2.2 Stroke Symptom Experience Scale

The Stroke Symptom Experience Scale (SSES), developed by Shi et al.[17], was employed to assess symptom occurrence and symptom burden in stroke patients. The scale comprises 23 items and encompasses three dimensions: symptom frequency, severity, and distress. Each item is rated on a Likert-type scale, with the frequency dimension scored from 1 to 4 (higher scores indicating greater frequency), the severity dimension scored from 1 to 4 (higher scores indicating greater severity), and the distress dimension scored from 0 to 4 (higher scores indicating greater distress). The mean score across the three dimensions for each symptom represents the symptom burden of that particular symptom, while the average of the 23 symptom burden scores constitutes the total symptom burden, with higher scores reflecting a greater overall symptom burden. The scale demonstrated a content validity index of 0.947 and a Cronbach's α coefficient of 0.810 in the original validation study. In the present study, the Cronbach's α coefficient of the scale was 0.950, indicating excellent internal consistency reliability.

2.3 Data Collection

Questionnaire surveys were administered to hospitalized patients who had undergone minimally invasive surgery for HICH in the Department of Neurosurgery of a tertiary hospital in Affiliated Hospital of Qingdao University. Data collection was conducted during the acute postoperative phase. Prior to the survey, the study purpose and procedures were fully explained to each patient and their family members, and written informed consent was obtained from all participants. All questionnaires were administered through one-on-one, face-to-face interviews by trained investigators to ensure standardized data collection. For patients who were unable to complete the questionnaire independently due to their medical condition, responses were provided by their primary caregivers on their behalf. Upon completion, each questionnaire was reviewed immediately on site; any omissions or ambiguities were addressed and corrected promptly with the respondent. Questionnaires with a missing data rate exceeding 10% were excluded from the analysis. To ensure data accuracy, all data were entered independently by two researchers and subsequently cross-checked for consistency. Any discrepancies were resolved through verification against the original questionnaires.

2.4 Statistical Analysis

2.4.1 Descriptive Statistics and Symptom Cluster Extraction

All statistical analyses were performed using SPSS version 27.0. Categorical variables were presented as frequencies and percentages. Continuous variables following a normal distribution were described as mean ± standard deviation, while those with a non-normal distribution were summarized as medians with interquartile ranges. To ensure the clinical relevance of the extracted symptom clusters, only

symptoms with an incidence rate of 25% or higher were retained for symptom cluster extraction[18]. Principal component analysis with varimax rotation was employed to extract symptom clusters, with the following criteria: eigenvalues ≥ 1.0, a minimum of two symptoms per cluster, and factor loadings ≥ 0.4 for each symptom within its respective cluster[19]. In cases where a symptom exhibited cross-loadings ≥ 0.4 on multiple factors, it was assigned to the factor on which it demonstrated the highest loading[19].

2.4.2 Symptom Network Construction

Symptom network analysis was performed using R version 4.5.2.The symptom network was constructed based on Spearman's rank correlation coefficients, and the network structure was optimized using the Least Absolute Shrinkage and Selection Operator (LASSO) regularization technique via the Extended Bayesian Information Criterion (EBICglasso) implemented in the qgraph package. Visualization of the network was also conducted using the qgraph package, wherein nodes represented individual symptoms and edges represented regularized partial correlations. The thickness of each edge was proportional to the strength of the association, with thicker edges indicating stronger partial correlations[20].

2.4.3 Centrality Indices

Centrality indices were employed to quantify the relative importance of each symptom within the overall network. The primary centrality measures included strength, closeness, betweenness, and expected influence[21]. Strength centrality, the most commonly used index, was calculated as the sum of the absolute edge weights connecting a given symptom to all directly connected symptoms. A higher strength value indicates a more central position of the symptom within the network. Closeness centrality reflects the inverse of the average shortest path distance from a given symptom to all other symptoms in the network. A higher closeness value suggests that the symptom can influence the entire network more rapidly through shorter pathways. Betweenness centrality quantifies the extent to which a symptom serves as a bridge in connecting other symptom pairs. A higher betweenness value indicates that the symptom functions as a key mediating node in the transmission of effects across symptom clusters. Expected influence is calculated by summing the absolute values of both positive and negative edge weights separately before taking the total, providing a more robust estimate of a node's potential influence. A higher expected influence value suggests that an increase in this symptom is likely to co-occur with exacerbations of a wide range of other symptoms. By integrating these centrality indices, the structural characteristics of the symptom network can be comprehensively evaluated. Accordingly, this study employed the combined analysis of all four indices to identify core symptoms, thereby providing a theoretical basis for the identification of precise intervention targets.

2.4.4 Network Stability

Network accuracy and stability were assessed using the bootnet package in R. Non-parametric bootstrapping with 1,000 resamples was performed to estimate 95% confidence intervals (CIs) for each edge weight[22]. Wider CIs indicated greater uncertainty in the edge estimates, warranting cautious interpretation. Additionally, case-dropping bootstrap with 1,000 resamples was used to compute the

correlation stability coefficients for the centrality indices. A coefficient greater than 0.50 was considered indicative of good stability, while values between 0.25 and 0.50 were deemed acceptable[23].

3. Results

3.1 Sociodemographic Characteristics of Participants

A total of 261 participants were enrolled in this study. The sociodemographic and clinical characteristics of the participants are summarized in Table 1.

Table 1
Sociodemographic characteristics of participants(n = 261)

Variable	Category	Frequency (n)	Percentage(%)
Sex	Male	156	59.77
	Female	105	40.23
Age (years)	< 60	117	44.83
	≥ 60	144	55.17
Marital status	Married	235	90.04
	Unmarried / Divorced / Widowed	26	9.96
Residence	Urban	146	55.94
	Rural	115	44.06
Educational level	Primary school or below	99	37.93
	Junior high school	111	42.53
	High school / Junior college	46	17.62
	Bachelor's degree or above	5	1.92
Occupation	Employed	139	53.26
	Retired	60	22.99
	Unemployed / Other	62	23.75
Monthly household income per capita (CNY)	<3000	74	28.35
	3000 ~ 5000	137	52.49
	>5000	50	19.16
Mode of medical payment	Medical insurance	254	97.32
	Self-pay	7	2.68
Smoking	Yes	76	29.12
	No	185	70.88
Alcohol consumption	Yes	101	38.70
	No	160	61.30
Surgical modality	Neuroendoscope-assisted hematoma evacuation	231	88.51

Variable	Category	Frequency (n)	Percentage(%)
	Stereotactic puncture and drainage	30	11.49
Severity of hypertension	Grade I	23	8.81
	Grade □	37	14.18
	Grade □	201	77.01
Hematoma location	Basal ganglia	144	55.17
	Thalamus	16	6.13
	Cerebral lobe	84	32.18
	Cerebellum	17	6.51
Hematoma volume (mL)	<30	96	36.78
	30□	143	54.79
	>50	22	8.43

3.2 Symptoms Experienced by Participants

Table 2 presents the incidence rates and severity levels of the 23 symptoms assessed among patients in the acute phase following minimally invasive surgery for HICH. The incidence rates ranged from 3.83% to 95.79% across the 23 symptoms. The three most frequently reported symptoms were fatigue (95.79%), distress over being unable to do desired activities (91.57%), and depressed mood (88.51%). The severity scores ranged from 0 to 4.00, with the three most severe symptoms being limited physical activity [4.00 (1.00, 4.00)], decreased self-care ability [4.00 (0, 4.00)], and limb weakness [3.00 (1.00, 4.00)].

Table 2
Incidence and severity of symptoms in patients during the acute phase after minimally invasive surgery for hypertensive intracerebral hemorrhage (N = 261)

Symptom	Frequency (n, %)	Severity [M (P_{25}, P_{75})]
Limited physical activity	216(82.76)	4.00(1.00,4.00)
Limb weakness	217(83.14)	3.00(1.00,4.00)
Limb pain	10(3.83)	0(0,0)
Shoulder pain	12(4.60)	0(0,0)
Upper limb flexion contracture	153(58.62)	2.00(0,2.00)
Foot drop	29(11.11)	0(0,0)
Foot inversion	25(9.58)	0(0,0)
Incoordination of limb movements	212(81.23)	2.00(1.00,2.00)
Inability to maintain balance	213(81.61)	3.00(1.00,3.00)
Decreased limb sensation	165(63.22)	1.00(0,1.00)
Memory decline	148(56.70)	1.00(0,1.00)
Decreased attention	150(57.47)	1.00(0,1.00)
Slowed reaction	152(58.24)	1.00(0,1.00)
Slurred speech	188(72.03)	2.00(0,4.00)
Choking during eating	155(59.39)	1.00(0,2.00)
Easily agitated	220(84.29)	1.00(1.00,1.00)
Depressed mood	231(88.51)	1.00(1.00,1.00)
Disappointment about the future	195(74.71)	1.00(0,1.00)
Loss of interest in surroundings	195(74.71)	1.00(0,1.00)
Distress over being unable to do desired activities	239(91.57)	2.00(1.00,2.00)
Lack of initiative	185(70.88)	1.00(0,1.00)
Fatigue	250(95.79)	2.00(1.00,3.00)
Decreased self-care ability	191(73.18)	4.00(0,4.00)

3.3 Symptom Cluster Extraction in Acute-Phase Patients After Minimally Invasive Surgery for HICH

Principal component analysis with varimax rotation was performed on symptom items with an incidence rate > 25% to extract symptom clusters. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.915, and Bartlett's test of sphericity yielded a P-value < 0.001, indicating that the data were suitable for factor analysis. Based on the criterion of eigenvalues ≥ 1.0, three symptom clusters were extracted. The three clusters were subsequently named according to the characteristics of symptom items with factor loadings ≥ 0.4 within each factor, in conjunction with naming conventions commonly adopted in stroke-related symptom cluster research (Table 3). Factor 1 comprised 11 symptoms and was designated the somatic-motor disturbance cluster, including limited physical activity, limb weakness, decreased self-care ability, inability to maintain balance, upper limb flexion contracture, choking during eating, fatigue, incoordination of limb movements, distress over being unable to do desired activities, decreased limb sensation, and slurred speech. Factor 2 comprised 5 symptoms and was designated the emotion-related cluster, including depressed mood, easy agitation, disappointment about the future, loss of interest in surroundings, and lack of initiative. Factor 3 comprised 3 symptoms and was designated the cognitive impairment cluster, including memory decline, slowed reaction, and decreased attention.

Table 3
Exploratory factor analysis of symptom clusters in patients during the acute phase after minimally invasive surgery for HICH (N = 261)

Symptom	Factor1	Factor2	Factor3
	Somatic-motor disturbance cluster	**Emotion-related cluster**	**Cognitive impairment cluster**
Limited physical activity	**0.925**	0.236	0.129
Limb weakness	**0.902**	0.229	0.161
Decreased self-care ability	**0.902**	0.289	0.220
Inability to maintain balance	**0.873**	0.257	0.213
Upper limb flexion contracture	**0.865**	0.099	0.064
Choking during eating	**0.790**	−0.003	0.255
Fatigue	**0.780**	0.311	0.348
Incoordination of limb movements	**0.766**	0.281	0.165
Distress over being unable to do desired activities	**0.655**	0.581	0.186
Decreased limb sensation	**0.584**	0.464	0.083
Slurred speech	**0.547**	0.227	0.387
Depressed mood	0.032	**0.878**	0.192
Easily agitated	0.165	**0.860**	0.206
Disappointment about the future	0.316	**0.787**	0.240
Loss of interest in surroundings	0.403	**0.714**	0.304
Lack of initiative	0.439	**0.684**	0.379
Memory decline	0.242	0.205	**0.900**
Slowed reaction	0.203	0.311	**0.890**
Decreased attention	0.217	0.337	**0.884**

Note: Factor loadings ≥ 0.4 are presented in **bold**.

3.4 Network Structure and Centrality Indices

- In the symptom network of patients during the acute phase after minimally invasive surgery for HICH, complex interconnections were observed among the symptoms. The thickness and length of the edges between nodes in the network visually reflect the strength of pairwise symptom associations. Specifically, strong co-occurrence trends were identified between limited physical activity (S1) and limb weakness (S2) ; between incoordination of limb movements (S8) and inability to maintain balance (S9) ; among memory decline (S11), decreased attention (S12), and slowed reaction (S13) ; as well as between slurred speech (S14) and choking during eating (S15). Additionally, easy agitation (S16) and depressed mood (S17) exhibited a marked concomitant relationship. Furthermore, disappointment about the future (S18), loss of interest in surroundings (S19), and lack of initiative (S21) demonstrated a high degree of clustering, being closely interconnected with one another (Fig. 1).

Note

S1, limited physical activity; S2, limb weakness; S5, upper limb flexion contracture; S8, incoordination of limb movements; S9, inability to maintain balance; S10, decreased limb sensation; S11, memory decline; S12, decreased attention; S13, slowed reaction; S14, slurred speech; S15, choking during eating; S16, easily agitated; S17, depressed mood; S18, disappointment about the future; S19, loss of interest in surroundings; S20, distress over being unable to do desired activities; S21, lack of initiative; S22, fatigue; S23, decreased self-care ability.

Figure 1 Symptom network of patients during the acute phase after minimally invasive surgery for HICH

As presented in Fig. 2, the three symptoms with the highest strength centrality were decreased self-care ability (r=1.5238), limited physical activity (r= 1.3416), and decreased attention (r=1.2826). The three symptoms with the highest closeness centrality were decreased self-care ability (r_c=0.0054), distress over being unable to do desired activities (r_c=0.0050), and lack of initiative (r_c=0.0047). The three symptoms with the highest betweenness centrality were decreased self-care ability (r_b=108), lack of initiative (r_b=76), and distress over being unable to do desired activities (r_b=64). The three symptoms with the highest expected influence were decreased self-care ability (r_e=1.4098), decreased attention (r_e=1.2826), and limited physical activity (r_e=1.2373). Taken together, these findings indicate that decreased self-care ability emerged as the core symptom in the symptom network of patients during the acute phase after minimally invasive surgery for HICH.

3.5 Network Stability Testing

As shown in Fig. 3, the grey-shaded areas represent the 95% bootstrap confidence intervals (CIs) for each edge weight. The results demonstrated that these CIs were relatively narrow, and the average edge weight across the entire network was 0.161, indicating that the network estimates had high precision and that the associations between nodes were robust.

Figure 4 presents the CS coefficients for each centrality index. The CS coefficients for strength, expected influence, closeness, and betweenness were 0.52, 0.67, 0.44, and 0.21, respectively. According to the criteria recommended by Epskamp et al. [16] (CS > 0.25 acceptable; CS > 0.50 good), strength, expected influence, and closeness all reached acceptable levels, with strength and expected influence demonstrating good stability. Although the betweenness centrality did not reach the recommended threshold, indicating relatively insufficient stability. Overall, the stability of the centrality indices in this study was within an acceptable range.

4. Discussion

This study systematically examined the symptom clusters and symptom network structure in patients during the acute phase after minimally invasive surgery for HICH, and further identified the core symptom and bridge symptoms within the network. Our findings provide empirical evidence to support the development of individualized and precise symptom management strategies for clinical practitioners, and contribute to advancing patient-centered symptom management practices in this specific population.

4.1 Symptom Clusters in Patients During the Acute Phase After Minimally Invasive Surgery for HICH

This study employed exploratory factor analysis to identify three symptom clusters in patients during the acute phase following minimally invasive surgery for hypertensive intracerebral hemorrhage: a physical motor dysfunction cluster, an emotion-related cluster, and a cognitive impairment cluster. In terms of structural characteristics, the findings of this study both corroborate and diverge from previous literature. Regarding the core dimensional composition, our results are highly consistent with those of existing studies. Huang et al.[24] extracted five symptom clusters-physical activity impairment, emotional disturbance, cognitive-language dysfunction, somatic pain, and foot dysfunction—in a study of 432 convalescent stroke patients. Similarly, Zhou et al.[10] identified four clusters:emotion-related, coordination-balance impairment, cognitive impairment, and dysarthria-choking during swallowing—in a cohort of 505 acute-phase stroke patients. Collectively, these studies confirm that physical motor dysfunction, emotional disturbance, and cognitive impairment represent relatively stable, universal dimensions of the symptom experience in stroke patients, irrespective of disease stage or treatment modality.

However, the number of symptom clusters extracted in our study is smaller than that reported in prior investigations, a discrepancy that may be attributable to the specificity of our study population. Previous research has predominantly sampled ischemic or mixed-type stroke patients receiving conservative medical management[24, 25], whereas our study focused on patients in the acute postoperative phase of minimally invasive surgery for hypertensive intracerebral hemorrhage—a period coinciding with the peak of cerebral edema and the acute stress response to surgical trauma. Factors such as surgical injury,

residual anesthetic effects, and postoperative immobilization may lead to a more concentrated and pronounced manifestation of somatic symptoms, thereby causing multiple physical-related symptoms to statistically coalesce into a single physical motor dysfunction cluster[26, 27]. These findings suggest that the symptom network in acute postoperative patients is more condensed than that in non-surgical patients, with somatic symptoms exerting a more dominant effect. This implies that early postoperative symptom management should prioritize accurate assessment and timely intervention for physical dysfunction. Accordingly, in clinical nursing practice, functional rehabilitation training should be seamlessly integrated with psychosocial support, with close attention paid to patients' psychological distress arising from functional limitations during the early recovery phase. By bolstering patients' rehabilitation confidence and providing family emotional support, the overall symptom burden can be effectively reduced.

4.2 Decreased Self-Care Ability as the Core Symptom in the Acute Phase After Minimally Invasive Surgery for HICH

Our results demonstrated that decreased self-care ability ranked first in strength (r=1.524), closeness (r_c=0.005), and betweenness (r_b=108), and also ranked first in expected influence (r=1.410), indicating that this symptom serves as a central hub connecting somatic, emotional, and cognitive symptom clusters. This finding is consistent with previous research[28], and further suggests that the core position of decreased self-care ability in the symptom network of acute-phase patients after minimally invasive surgery may be attributable to the early recovery of consciousness conferred by the minimally invasive surgical approach.

Patients undergoing minimally invasive surgery for HICH regain consciousness significantly earlier than those undergoing conventional craniotomy[29], yet they awaken during the peak period of cerebral edema, when physical function remains at its nadir. This clinical scenario results in a situation where patients possess full awareness at the very moment when their physical capacity is most severely compromised. The stark contrast between their pre-morbid normal functioning and the abrupt postoperative disability exerts an unmitigated blow to their self-efficacy, a psychological impact that is largely unique to this surgical context. In contrast, craniotomy patients benefit from the intracranial pressure buffering effect conferred by bone-flap decompression[30], and their consciousness recovery is delayed due to prolonged sedation, which postpones their awareness of functional loss and suppresses psychological responses through anesthetic effects. Patients receiving conservative treatment, on the other hand, lack the acute inflammatory trigger induced by surgical trauma, experience a relatively gradual evolution of cerebral edema, and maintain a stable level of consciousness, allowing sufficient time for progressive psychological adaptation. In comparison, patients after minimally invasive surgery face a temporal overlap between early consciousness recovery and maximal neurological impairment, creating a distinctive psychological adaptation disorder characterized by intact self-awareness coupled with severely restricted executive function. This condition rapidly triggers negative emotions through the psychological pathway of "distress over being unable to do desired activities," which mutually reinforces

with physical dysfunction to form a dense symptom network centered on decreased self-care ability. The connectivity density and mutual reinforcement effects within this network are considerably stronger than those observed in craniotomy or conservatively treated patients.

The above analysis suggests that decreased self-care ability as the core symptom stems primarily from the temporal coincidence of the timing of consciousness recovery and the peak of functional deficit, rather than being determined solely by the extent of organic injury. Accordingly, postoperative acute-phase nursing should target the improvement of decreased self-care ability as the central focus and implement a hierarchical, integrated management strategy. At the physical level, rehabilitation should proceed progressively, including proper positioning of the affected limbs, passive range-of-motion exercises, and postural transition training, while balancing activity and rest to prevent overexertion. At the cognitive level, orientation training and attention-activation exercises should be integrated, and rehabilitation instructions should be delivered through step-by-step decomposition and repeated demonstration to enhance patients' comprehension and execution of rehabilitation tasks. At the emotional level, the unique psychological stressor of "functional deprivation in a fully conscious state" should be acknowledged and addressed through empathetic communication and graded goal-setting to rebuild patients' sense of self-efficacy. Through coordinated interventions targeting the physical, cognitive, and emotional domains, the symptom-maintaining network centered on decreased self-care ability can be effectively disrupted, thereby facilitating early recovery of patients' independence in self-care.

4.3 Distress Over Being Unable to Do Desired Activities as a Bridge Symptom in the Acute Phase After Minimally Invasive Surgery for HICH

Our findings revealed that "distress over being unable to do desired activities" plays a pivotal bridging role in connecting the somatic-motor disturbance cluster and the emotion-related cluster. In the exploratory factor analysis, this symptom exhibited factor loadings of 0.655 on the somatic-motor disturbance factor and 0.581 on the emotion-related factor, demonstrating a prototypical cross-cluster loading pattern. This suggests that it is neither a pure perception of physical limitation nor an isolated emotional stress response, but rather a mediating node possessing dual attributes. The network centrality analysis further corroborated this hypothesis, as this symptom ranked among the highest in both closeness (r_c=0.005) and betweenness (r_b=64), indicating its prominent hub role in information transmission and inter-cluster connectivity, and positioning it as a critical pathway for cascading symptom transmission.

From the perspective of psychopathological transmission mechanisms, this symptom essentially constitutes the core psychological mediating pathway through which somatic dysfunction transitions into emotional disturbance. In patients during the acute phase after minimally invasive surgery for HICH, the abrupt decline in limb mobility and self-care ability creates a profound discrepancy between objective functional deficits and subjective rehabilitation expectations when basic physiological needs—such as eating and toileting—cannot be independently met. This discrepancy precipitates sustained

frustrative psychological stress, manifested as "distress." As a psychological state that is both situation-dependent and reactive, this symptom is statistically anchored to the somatic dimension in terms of factor structure, yet functionally it directly engages the emotional regulation system. When such distress persists due to delayed functional recovery, it progressively generalizes and solidifies, through cognitive fixation and repeated reinforcement of negative automatic thoughts, into pervasive negative emotional states such as depressed mood and disappointment about the future, thereby completing a cross-dimensional, stepwise transmission from physical limitation to emotional disturbance.

It is noteworthy that although "lack of initiative" also exhibited some degree of nodal mediating effect in the network, it is essentially a secondary, extended manifestation at the emotion-cognition dimension. The decline in behavioral drive underlying this symptom can be traced back to the persistent frustrative experience and depletion of self-efficacy carried by the distress symptom, placing the latter at a more upstream and initiating position in the transmission chain.

The above mechanisms suggest that, in clinical nursing interventions during the postoperative acute phase, "distress over being unable to do desired activities" can serve as a targeted intervention node for breaking the vicious cycle among symptom clusters and precisely interrupting the cascade amplification of symptoms. Specifically, nurses should employ cognitive assessment to identify patients' unrealistic expectations and negative attributional biases arising from functional limitations, and through staged goal-setting combined with positive performance feedback, assist patients in rebuilding their damaged self-efficacy and sense of control over the rehabilitation process. By implementing precise interventions targeting this bridge symptom, it is anticipated that its driving effect on the entire symptom network can be attenuated through a de-centering effect, thereby effectively interrupting the pathological transmission from somatic dysfunction to emotional symptom clusters and achieving a structural optimization of the overall symptom burden.

5. Limitations

This study employed network analysis to preliminarily delineate the symptom network structure characterized by decreased self-care ability as the core symptom during the acute phase after minimally invasive surgery for hypertensive intracerebral hemorrhage, thereby providing an empirical foundation for precision symptom management in clinical practice. Nevertheless, several limitations of this study should be acknowledged. First, the cross-sectional design captures only a snapshot of the symptom network at a single time point during the acute postoperative phase, which precludes making inferences about causal directions among symptoms or the dynamic evolution of the network structure over time. Future research employing longitudinal cohort designs is warranted to observe the trajectories of symptom networks from the acute phase through the recovery period. Second, the use of convenience sampling and the recruitment of participants from a single center may have introduced selection bias, potentially limiting the generalizability of our findings to broader populations. Future multicenter investigations with stratified sampling strategies are needed to validate and extend our conclusions. Third, the current analysis focused exclusively on symptom-symptom associations and did not

incorporate clinical variables such as blood pressure control, surgical modality, hematoma volume, or caregiver support. Consequently, we were unable to examine the moderating effects of these factors on network structure and core symptom strength. Subsequent studies incorporating multivariate network models are recommended to further explore the pathways through which these clinical variables influence the symptom network.

6. Conclusions

This study, employing exploratory factor analysis and network analysis, systematically delineated the symptom clusters and core symptoms in patients during the acute phase after minimally invasive surgery for hypertensive intracerebral hemorrhage. Three distinct symptom clusters were extracted. Centrality analyses identified decreased self-care ability as the core symptom and distress over being unable to do desired activities as the bridge symptom. Based on these findings, clinical nursing practice should prioritize the restoration of self-care ability as the primary objective, while implementing targeted interventions directed at the bridge symptom. An integrated strategy encompassing physical rehabilitation, cognitive support, and emotional counseling is recommended to interrupt the deleterious transmission among symptom clusters and optimize the overall symptom network architecture, ultimately alleviating the postoperative symptom burden and facilitating early recovery. Future research employing longitudinal designs and multicenter samples is warranted to dynamically validate the evolutionary trajectories and causal pathways of the symptom network, thereby providing higher-level evidence for precision symptom management.

Declarations

Conflict of interest disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Contribution

XW: Conceptualization, Writing–original draft, Formal analysis, Visualization; SS: Data curation, Validation; CL: Resources, Project administration, Software; BW: Investigation; MD: Data curation,

Visualization; TX: Methodology, Writing–review & editing, Supervision; YJ: Supervision, Writing–review & editing. All authors reviewed the manuscript

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Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request. Due to the sensitive nature of the data collected for this study, which include potentially identifiable patient information, the data are not publicly available to protect participant privacy and confidentiality in accordance with the ethical approval and informed consent agreements.

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Figures

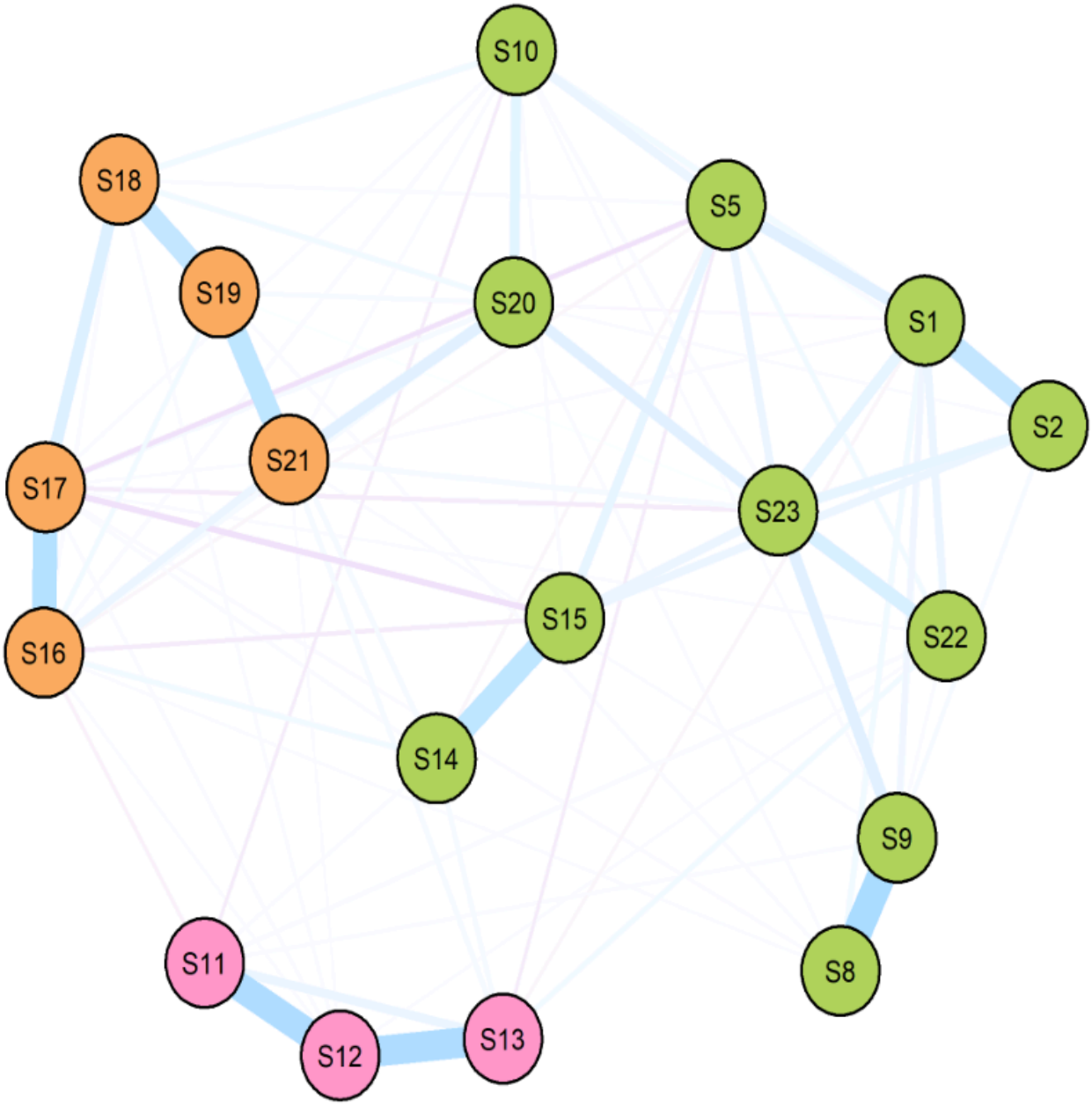


Figure 1

Note: S1, limited physical activity; S2, limb weakness; S5, upper limb flexion contracture; S8, incoordination of limb movements; S9, inability to maintain balance; S10, decreased limb sensation; S11, memory decline; S12, decreased attention; S13, slowed reaction; S14, slurred speech; S15, choking during eating; S16, easily agitated; S17, depressed mood; S18, disappointment about the future; S19, loss of interest in surroundings; S20, distress over being unable to do desired activities; S21, lack of initiative; S22, fatigue; S23, decreased self-care ability.

Figure 1 Symptom network of patients during the acute phase after minimally invasive surgery for HICH

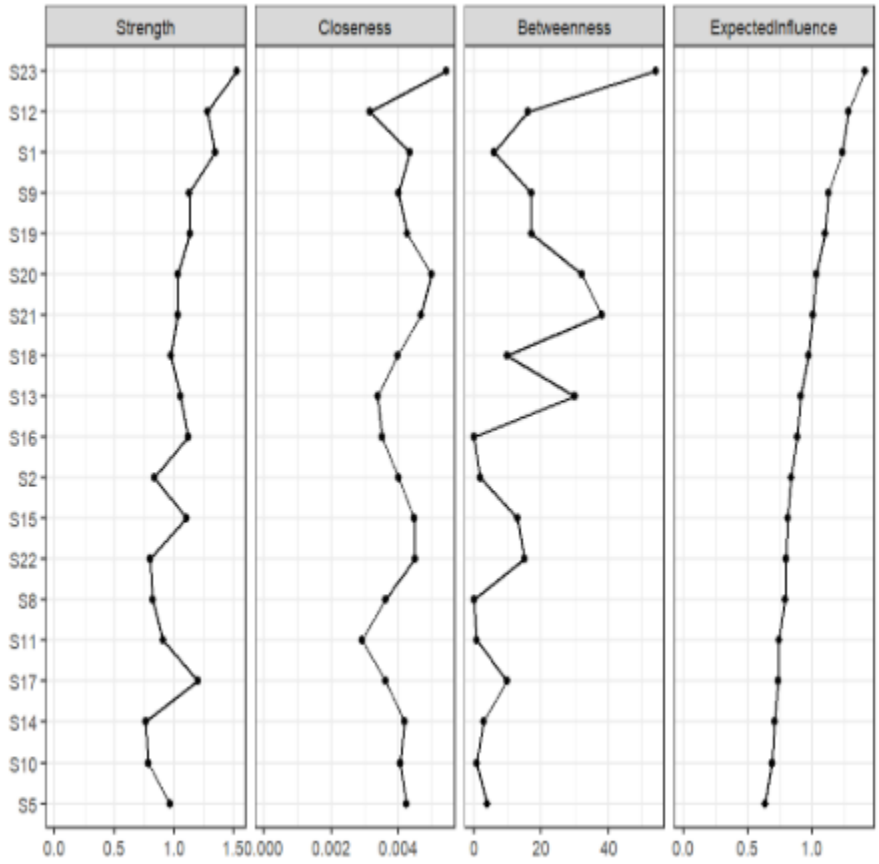


Figure 2

Centrality indices of all symptoms in the symptom network.

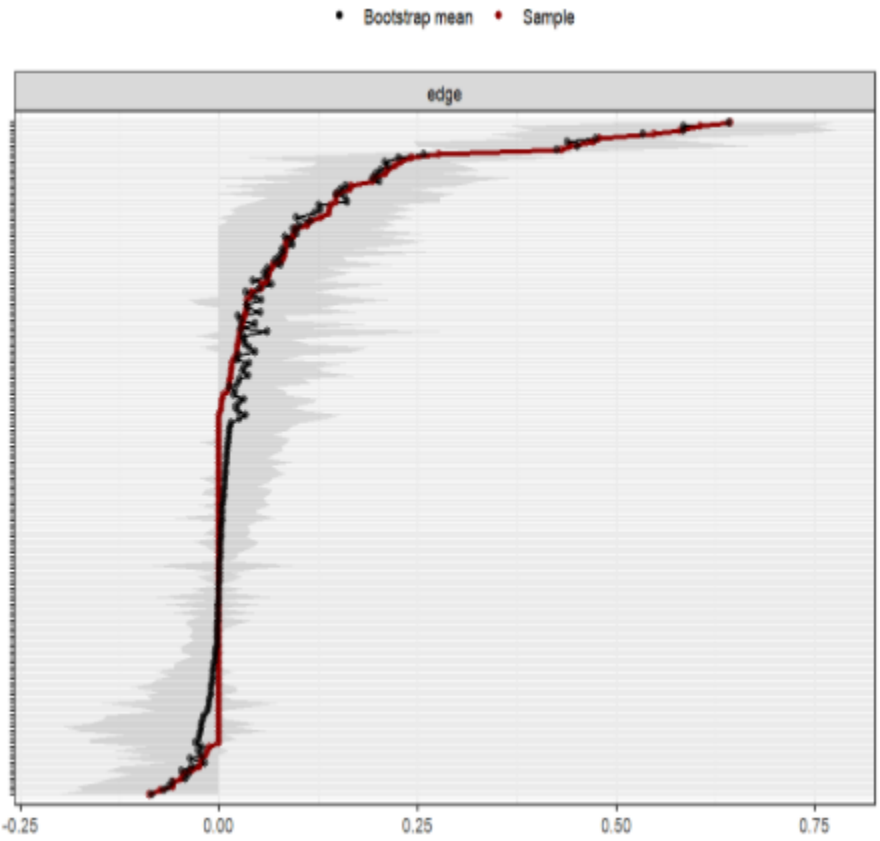


Figure 3

Bootstrap confidence intervals for edge weights in the regularized partial correlation network.

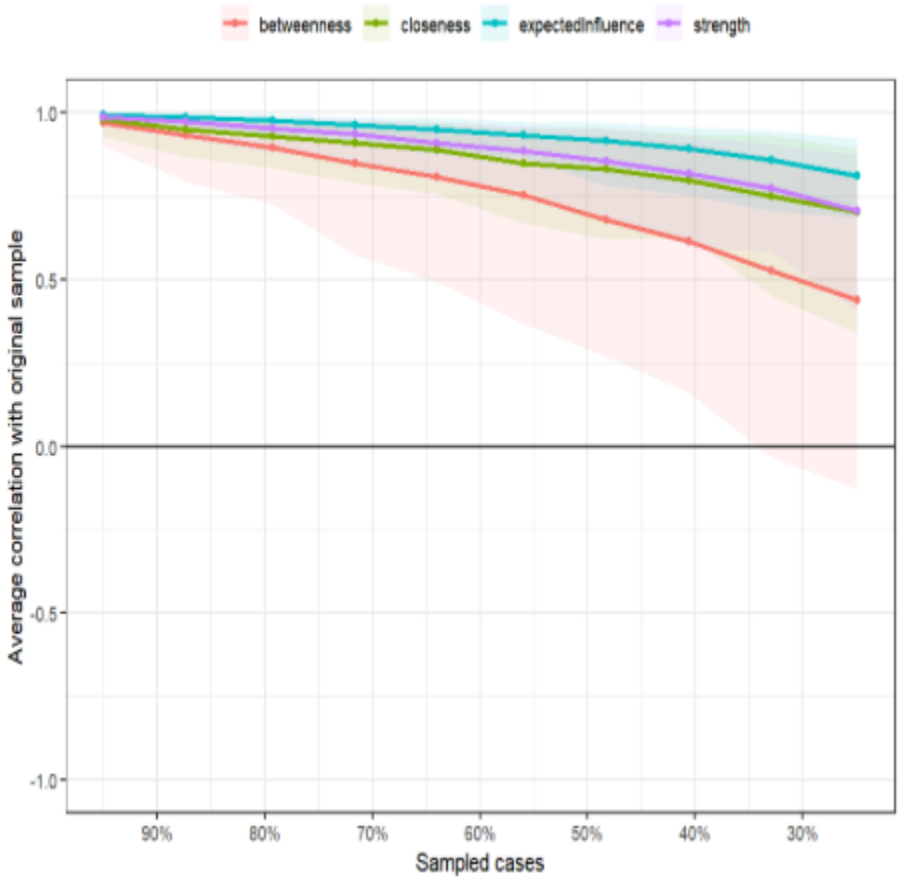


Figure 4

Bootstrap stability analysis of centrality indices in the symptom network