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ORIGINAL RESEARCH

Exploring the Effectiveness of Nursing Interventions for Postoperative Pain Management in Aortic Dissection: A Fuzzy Logic and Network Analysis

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Objective: To explore effective nursing interventions for severe pain in the early postoperative period following aortic dissection, using a configurational and network perspective.

Methods: Convenience sampling was employed, selecting 116 patients from the Vascular Surgery Department of Shanxi Provincial People's Hospital between August 2021 and March 2024. Patients who underwent aortic dissection surgery and had a VAS (Visual Analog Scale) pain score of 6 or higher were provided comprehensive nursing interventions for one week, which included analgesics, cold compresses, musicotherapy, mental intervention, posture guidance, and light physical activity. Nursing intervention was treated as the antecedent variable, while changes in VAS scores were considered the outcome variable of analgesic efficacy. Fuzzy-set qualitative comparative analysis (fsQCA) and network analysis were used to identify the most effective analgesic interventions.

Results: No single nursing intervention was found to be a necessary condition for good postoperative analgesia. Five configurations were found to contribute to effective analgesia, with an overall consistency of 0.959 and overall coverage of 0.262. Cold compresses and musicotherapy emerged as important core conditions. Network analysis showed that cold compresses, posture guidance, and musicotherapy had a direct positive effect on pain relief, while analgesics and mental interventions had less apparent effects, and light physical activity could potentially be detrimental to pain relief.

Conclusion: For early postoperative pain following aortic dissection, besides providing analgesics and psychological counseling as needed, cold compresses and musicotherapy should be tailored according to patient preferences to promote analgesic efficacy.

Keywords: aortic dissection, postoperative analgesia, nursing interventions, configurational perspective, network analysis

Introduction

Aortic dissection refers to a pathological condition where blood from the aorta enters the middle layer of the aortic wall through a tear in the inner lining, causing a separation along the longitudinal axis of the aorta and forming an intramural hematoma. This dissection propagates along the length of the aorta, creating a double-layered lumen within the aortic vessel wall.[1] Aortic dissection is a severe vascular condition that poses a significant threat to human health due to its acute onset and rapid progression, with an estimated global annual incidence of 5 per 100,000 people and a mortality rate of approximately 1.5 per 100,000. Without surgical intervention, 20–30% of patients may die within the first 24 hours of onset, and if untreated, the overall 30-day mortality rate can reach up to 45%.[2,3] Clinically, aortic dissection typically presents with sudden, intense chest, back, or abdominal pain. Although surgical treatment is considered the optimal management strategy and significantly improves patient survival, postoperative pain management remains a core challenge in the postoperative care process. While thoracic aortic dissection primarily results in nociceptive pain due to the surgical incision and manipulation of the chest cavity, abdominal aortic dissection patients often experience pain

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related to abdominal region incisions and possible organ involvement. Pain severely affects patients' psychological and mental states,[4] exacerbates patients' anxiety and fear; secondly, pain stimulation causes sympathetic excitation, causing muscle and blood vessel contraction, and blood pressure increase.[5] Postoperative pain in patients with both thoracic aortic dissection (TAD) and abdominal aortic dissection (AAD) is primarily nociceptive, arising from the surgical trauma to the chest or abdominal cavity. However, both groups may also experience neuropathic pain, depending on the extent of nerve involvement or damage during the procedure. There is no primary or secondary distinction between the pain types; both nociceptive and neuropathic pain can occur in equal measure. In TAD patients, pain is typically localized to the chest region due to the incision and surrounding tissue manipulation. In AAD patients, pain may be more localized to the abdominal region, with additional considerations for organ manipulation or damage during surgery. Both pain types are important to address in postoperative care. Effective pain management can reduce patient discomfort, accelerate post-operative recovery, lower the risk of complications, and shorten the length of hospital stay. However, there are still significant challenges associated with current pain management strategies, particularly in the early postoperative period, such as difficulty in pain assessment, side effects of analgesics, and difficulties in individualized pain control.[6]

Currently, postoperative pain management for aortic dissection primarily relies on pharmacological approaches, especially opioid medications. Increasing evidence suggests that prolonged use of opioids may lead to tolerance, addiction, respiratory depression, and other adverse effects.[7] As such, comprehensive non-pharmacological nursing interventions that aim to reduce the use of pharmacological analgesia have gained attention in recent years, which may include cold compresses, musicotherapy, mental interventions, and other adjunctive treatments.[8,9] These non-pharmacological measures can improve postoperative pain management outcomes to some extent. For example, a study by Huang et al demonstrated that musicotherapy can significantly alleviate anxiety levels in postoperative patients, which in turn indirectly reduces their pain.[10]

Despite the progress made, several significant limitations persist in current research. First, most studies have focused on evaluating the "net effect" of a single nursing intervention after aortic dissection surgery, lacking systematic examination of the combined effects of multiple interventions.[11–13] Moreover, existing studies tend to concentrate on the relationship between intervention measures and outcome variables, failing to reveal the complex interactions and causal relationships between various variables in the care environment.[14] Additionally, individual differences and their influence on pain management have often been overlooked, leading to a lack of personalized care recommendations. For postoperative pain management in patients with aortic dissection, research is still in its exploratory phase, and there is a need for standardized and in-depth nursing pathways.[15]

Qualitative Comparative Analysis (QCA), proposed and developed by American sociologist Charles Ragin in 1987,[16] is a research method rooted in configurational thinking and is suitable for exploring issues of equifinality, where multiple causal pathways lead to the same outcome. Configuration refers to combinations of conditions that can produce a specific outcome and can be understood as how independent variables combine to result in a particular dependent variable outcome. By identifying multiple configurational pathways that lead to the same outcome, QCA allows the investigation of complex causal relationships between conditions and results. QCA primarily includes three types: crisp-set qualitative comparative analysis (csQCA), multi-value qualitative comparative analysis (mvQCA), and fuzzy-set qualitative comparative analysis (fsQCA). Based on this, our study adopts a configurational perspective to explore diverse nursing interventions for postoperative pain management in aortic dissection (both Type A and Type B) patients. By employing fuzzy-set qualitative comparative analysis (fsQCA), we aim to elucidate the combinatory effects of different nursing interventions to identify the optimal pain management strategies. Additionally, network analysis will be used to identify the core roles and relationships among different interventions, visually presenting the connections between various nursing measures. This approach will assist clinical nurses in selecting individualized care plans according to specific patient conditions, providing theoretical support and scientific evidence for future nursing practice.

Subjects and Methods

Study Subjects

The study was conducted by a research team comprising two senior physicians and three nurses with intermediate or higher professional titles. The subjects were recruited from patients who underwent aortic dissection surgery in the Vascular Surgery Department of Shanxi Provincial People's Hospital. The inclusion criteria were: (1) patients experiencing persistent thorax, back or abdominal pain within three days after aortic dissection surgery; (2) moderate to severe pain with a VAS score of no less than 6; (3) patients who were extubated, had stable blood pressure and heart rate, were conscious, and able to communicate clearly; and (4) patients who were willing to participate in the study for a duration of no less than one week. The exclusion criteria were: (1) patients with severe acute illness or contagious disease; (2) patients with pain due to other causes; and (3) patients who were long-term users of analgesics or were under other analgesic or anesthetic regimens. According to these criteria, a total of 116 patients, all of whom underwent non-acute aortic dissection surgery, were recruited. This included 83 patients who underwent Type A aortic dissection repair (via sternotomy with cardiopulmonary bypass) and 33 patients who underwent repair for severe Type B aortic dissection (via endovascular or open abdominal surgery). The cohort consisted of 50 male patients (43.10%) and 66 female patients (56.90%), with an average age of (64.28 ± 10.75) years. The sample size for this study was determined based on the guidelines for Qualitative Comparative Analysis (QCA), which is particularly suited for small to medium-sized samples. A minimum sample size is calculated as $(N-2)^2$, where N is the number of condition variables included in the analysis. In this study, with 6 condition variables, the minimum required sample size was 16 cases (4^2). The inclusion of 116 cases far exceeds this threshold, ensuring sufficient diversity among cases for reliable configurational analysis. Furthermore, network analysis typically recommends a sample size at least five times the number of variables analyzed. With a total of 7 variables, a sample of at least 35 cases would be necessary. Accordingly, our sample of 116 cases exceeded both benchmarks.

Visual Analog Scale (VAS)

The Visual Analog Scale (VAS) is a widely used subjective measurement tool for assessing pain intensity, known for its simplicity, sensitivity, and broad applicability, and has been extensively adopted in clinical research.[17,18] The VAS pain score is a self-evaluation measure, typically represented as a 10 cm straight line labeled at each end with "no pain" (0) and "worst pain imaginable" (10). Patients are asked to mark on the line the point that best represents their perceived pain intensity, thereby quantifying the pain level. This method is suitable for assessing both chronic and acute postoperative pain. For patients who have undergone aortic dissection, VAS scores effectively capture fluctuations in pain perception, enabling healthcare professionals to accurately adjust pain management plans based on these data.

Pain Nursing Intervention Plan

The pain nursing intervention plan in this study was designed based on several considerations. First, the selected interventions (such as patient-controlled analgesia and the comprehensive multimodal intervention plan) are readily available and feasible options commonly used in postoperative pain management in most general hospitals, ensuring strong clinical practicality. Second, the choice of these interventions was informed by previous studies and clinical practice. Interventions were selected and implemented by a multidisciplinary team consisting of two senior physicians and three nurses with intermediate or higher qualifications. Prior to intervention, each patient underwent a comprehensive pain assessment conducted by the research team within 3 days after surgery. The allocation of interventions was based on the patient's pain characteristics (eg, location, intensity, and type) and clinical needs. The interventions included patient-controlled analgesia (PCA), regional nerve blocks, psychological counseling, physiotherapy, distraction techniques (such as music therapy), and environmental modifications. The choice and sequence of interventions followed a standardized yet flexible protocol tailored to each patient. In cases of predominantly nociceptive pain, PCA or nerve blocks were prioritized; for mixed pain types, additional psychological or distraction techniques were introduced as supplementary methods.

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Analgesics

Following the principle of individualized care, intravenous patient-controlled analgesia (PCA) was preferred initially.[19] Dosages were adjusted based on body weight and pain severity (initial morphine dosage of 1–2 mg/h or fentanyl at 20–30 μg/h, with a maximum dose of 5 mg/h for morphine or 200 μg/h for fentanyl). Starting from 24 hours post-surgery, oral non-steroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen 400 mg every 8 hours were gradually introduced to reduce opioid use. For patients with concurrent neuropathic pain, gabapentin 300 mg per day was added and adjusted to 600 mg as needed. Nurses were required to closely monitor respiratory rate, blood pressure, renal function, and gastrointestinal function, and daily pain evaluations were conducted using the VAS score to ensure adequate pain relief while minimizing adverse drug reactions.

Cold Compress

During the first 48 hours post-surgery, cold compresses were applied for 10–15 minutes at a temperature of 15–20°C, with intervals of one hour between sessions, 6–8 times a day. The compresses were primarily applied to the lower back or abdominal area, depending on the location of postoperative pain. Rarely, cold compresses were applied to the chest, and only with caution, due to the sensitivity of this area and to avoid potential complications. After 48 hours, the frequency was reduced to 3–4 times daily, with the duration and temperature unchanged. Before each application, skin assessment was conducted, and ice packs were wrapped in soft cloth to prevent frostbite by avoiding direct contact with the skin. Nurses carefully monitored skin changes throughout the process, and the application was halted if blanching or numbness occurred.

Musicotherapy

Musicotherapy was utilized to alleviate postoperative anxiety and pain. A minimum of one session (20–30 minutes) per day was arranged for all patients during the intervention period. The total number of sessions varied depending on the patient's length of hospital stay and personal preferences; however, no patient received fewer than one session per day. Patients could select the type of music from options including soft, rhythmic, or natural sounds (such as classical music, nature sounds, or rhythm and blues) with the volume controlled at 40–60 dB to prevent overstimulation. Nurses monitored patients' emotional responses during the music sessions and discontinued the therapy immediately if any discomfort was reported.

Mental Intervention

During the first 72 hours post-surgery, psychological support was provided once daily, for 15–20 minutes per session, with the frequency gradually decreasing depending on patient recovery. The intervention primarily encouraged patients to express their feelings, offered positive guidance to frame pain as a normal postoperative phenomenon, and taught basic relaxation techniques such as deep breathing. Nurses closely observed patients for signs of anxiety or depression, intensifying the intervention as needed and involving mental health professionals if required.

Position Guidance

Postoperative posture guidance was implemented to reduce pain and improve circulation. For the first 24 hours post-surgery, patients' positions were adjusted every two hours to alleviate discomfort caused by prolonged bed rest. The semi-recumbent position (30°-45°) was adopted to reduce chest pressure and facilitate breathing. After 48 hours, with assistance from nurses, patients gradually transitioned to a seated or lying position, and comfort levels were continually assessed. Any complaints of discomfort or changes in blood pressure necessitated immediate adjustments to posture to ensure comfort and safety.

Light Physical Activity

Light physical activity was introduced to promote recovery and reduce the risk of venous thrombosis. Starting 24–48 hours post-surgery, patients were encouraged to engage in simple activities such as stretching and breathing exercises for 5–10 minutes, 2–3 times daily. Nurses were required to accompany patients throughout these sessions, monitoring blood pressure, heart rate, and respiratory function to prevent overexertion. If patients experienced chest tightness or fatigue, activity was halted, and further assessment was conducted.

A personalized nursing intervention plan was formulated in collaboration with the patient based on their consent and clinical evaluation, and the care intervention was carried out for three days. To avoid overlapping effects, no more than four interventions were applied within a 24-hour period. The multidisciplinary team regularly reviewed each patient's response to prior interventions during daily evaluations and adjusted the treatment plan accordingly. This study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines to ensure rigor and transparency in the methodology and reporting process.

Data Analysis

The nursing interventions included analgesics, cold compresses, musicotherapy, mental interventions, posture guidance, and light physical activity as condition variables. musicotherapy was quantified by the number of hours, while other condition variables were treated as binary variables (adopted/not adopted). The difference in VAS scores before and 72 hours after the intervention (all positive values) was taken as the outcome variable to evaluate the analgesic effect.

Fuzzy-set qualitative comparative analysis (fsQCA) was conducted using the fsQCA 3.0 software. To meet the requirements of the analysis, raw data of the subjects were converted into membership scores ranging from 0 to 1. All variables were transformed into membership values between 0 and 1.[20] Categorical variables were coded as "0" for not adopted and "1" for adopted, while continuous variables (eg, the duration of musicotherapy and the difference in VAS scores) were calibrated using the "calibrate" function into membership scores between 0 and 1. Calibration required setting three anchor thresholds: full membership, the crossover point, and full non-membership. For example, the calibration for musicotherapy duration set the anchor points as 1.5, 0.5, and 0, representing "long", "neither long nor short", and "short" durations respectively. The duration value was calibrated based on these three reference points, and for cases with a membership score of 0.5, a value of 0.001 was added to avoid exclusion from fuzzy-set analysis, adjusting the value to 0.501.[21] Similarly, the difference in VAS scores had anchor thresholds set at 5, 3, and 2 to represent analgesic effects as "good", "average", and "poor", respectively. Following the recalibration of these variables, fsQCA was used to identify necessary conditions (conditions without which the outcome cannot occur) and sufficient conditions (conditions that, although not always present, can produce a particular outcome). The fsQCA model was used to calculate consistency (similar to accuracy) and coverage (the percentage of cases covered by the configuration), leading to the identification of configurations for both good and poor analgesic outcomes.

Network analysis was conducted using the qgraph package[22] and the bootnet package[23] in R version 4.2.1 to analyze the condition and outcome variables. In the network model, each variable was represented as a node, and the relationships between variables were represented by edges. The weight of each edge indicated the strength of the correlation between nodes, and edges could reflect positive or negative associations, differentiated by different colors (positive associations in green, negative associations in red). The thickness of the edge indicated the strength of the association between nodes. Three centrality indices were commonly used:[23] node strength, closeness, and betweenness to represent the importance of nodes in the network. Node strength refers to the sum of the weights of all edges directly connected to the node, indicating the strength of its direct connection to other nodes. Closeness represents the inverse of the sum of the shortest paths from one node to all other nodes; the higher the value, the faster the node can influence others. Betweenness reflects the frequency with which a node appears on the shortest path connecting two other nodes, thus measuring its role as a bridge. These indices are usually expressed as standardized z-scores, with higher values indicating greater importance of the node in the network. In the network graph, the shorter the edge between two nodes, the closer their relationship. To assess the accuracy and robustness of the network estimation, bootstrapping was used, with the sampling frequency set to 1,000.[24] First, accuracy was estimated by constructing bootstrapped confidence intervals (CIs) for each edge weight. The more overlap between the CIs of edge weights, the lower the graph's accuracy in representing differences between these weights. Second, stability of the centrality indices was assessed by bootstrap resampling of subsamples. We investigated how the correlation stability coefficient (CS-coefficient) of centrality changed as the proportion of subsamples decreased (eg, comparing the full sample with 30% of the sample). The CS-coefficient represents the maximum number of cases that can be removed from the data while maintaining at least a 0.7 correlation between the centrality indices calculated from the original network and those calculated with fewer cases (default value). The coefficient should not be below 0.25, preferably above 0.5.[23] The faster the change in centrality as the proportion decreases, the lower the stability of centrality. Finally, bootstrap analysis was conducted on pairwise differences between edge weights and centralities of different nodes to examine whether there were significant differences between edges or nodes.

Results

Fuzzy-Set Qualitative Comparative Analysis

Necessity Analysis of Single Conditions

Since none of the individual intervention condition variables had a consistency greater than 0.9 along with coverage greater than 0.5,[25] it was determined that no single antecedent condition was necessary for achieving either good or poor analgesic outcomes. The detailed results are presented in Table 1.

Sufficiency Configuration Analysis of Antecedent Conditions

Through the configuration analysis of antecedent condition variables, the core and marginal conditions of the causal relationship between nursing intervention and good and poor analgesic effects were explored. When setting the threshold for the truth table, referring to FISS's (2011)[25] research, since frequency describes the number of samples covered by the configuration, to ensure the minimum number of cases used to evaluate the relationship, the minimum case frequency threshold for good and poor analgesic effect configurations was set to 3 and 2 (ie, more than 1.00% of the sample size is considered to have practical significance), and the minimum consistency was set to 0.80. For the PRI setting (PRI represents the "proportion of inconsistency reduction"; used to avoid the simultaneous occurrence of results and non-concentrated configurations, that is, the same cause and different effects), referring to past research experience, the natural truncation value of PRI is used.[26] In this study, 0.842 and 0.896 were set as the natural truncation values for PRI. As shown in Table 2, the five paths leading to good analgesic effects can explain 26.2% of the cases (overall consistency

Table 1 Analysis of the Necessity of Antecedent Conditions Affecting Analgesic Efficacy

Antecedent Conditions	Good analgesic Efficacy		Poor Analgesic Efficacy	
	Consistency	Coverage	Consistency	Coverage
Analgesics	0.551	0.600	0.576	0.400
~Analgesics	0.449	0.624	0.424	0.376
Cold compress	0.603	0.762	0.295	0.238
~Cold compress	0.397	0.469	0.705	0.531
Musicotherapy	0.579	0.853	0.280	0.263
~Musicotherapy	0.500	0.521	0.843	0.561
Mental intervention	0.572	0.605	0.586	0.395
~Mental intervention	0.428	0.619	0.414	0.381
Position guidance	0.629	0.731	0.363	0.269
~Position guidance	0.371	0.477	0.637	0.523
Light physical activity	0.457	0.531	0.634	0.469
~Light physical activity	0.543	0.699	0.366	0.301

Note: "~" denotes "NOT" in logical operations.

Table 2 Results of the Dynamic QCA Configuration Analysis.

Condition variable	Good analgesic					Poor analgesic		
	a	b	c	d	e	f	g	h
Analgesics	⨂	⨂	•	•	•	●	⨂	•
Cold compress	●		●	●	⊗		⨂	⨂
Musicotherapy	●	●	●	⊗	●	⨂	⨂	⊗
Mental intervention		●	●	●	●	⨂	●	●
Position guidance	•	•	⊗	⊗	•	⨂	⊗	●
Light physical activity	⊗	⊗	⊗	●	•	●	●	●
Consistency	1.000	0.956	0.978	0.919	0.953	0.994	0.903	0.907
Raw coverage	0.106	0.098	0.039	0.042	0.042	0.138	0.093	0.097
Unique coverage	0.041	0.033	0.039	0.042	0.042	0.138	0.093	0.097
Overall PRI			0.842				0.896	
Minimum number of configuration cases			3				2	
Overall solution consistency			0.959				0.940	
Overall solution coverage			0.262				0.328	

Note: Black circles ("●") indicate the presence of a condition, and circles with a cross-out ("⊗") indicate its absence. Furthermore, large circles indicate core conditions, and small circles refer to peripheral conditions.

= 0.959; total coverage = 0.262). The first is the configuration with the use of cold compresses, musicotherapy, and no analgesics as core conditions, and the use of position guidance and no light physical activity as marginal conditions (consistency = 1.000; original coverage = 0.106); the second is the configuration with the use of musicotherapy, mental intervention, and no analgesics as core conditions, and position guidance and no light physical activity as marginal conditions (consistency = 0.956; original coverage = 0.098); the third is the configuration with the use of cold compresses, musicotherapy, and mental intervention as core conditions, and the use of analgesics, no position guidance, and light physical activity as marginal conditions (consistency = 0.978; coverage = 0.039); the fourth is the configuration with the use of cold compresses, mental intervention, and light physical activity as core conditions, and the use of analgesics and no musicotherapy and position guidance as marginal conditions (consistency = 0.919; coverage = 0.042); the fifth is the configuration with the use of musicotherapy and mental intervention as core conditions, and the use of analgesics, position guidance, light physical activity, and no cold compresses as marginal conditions (consistency = 0.953; coverage = 0.042). The three paths leading to poor analgesic effects explain 32.8% of the cases (overall consistency = 0.940; coverage = 0.328). The first is the configuration with the use of analgesics, light physical activity, and no musicotherapy, mental intervention, and position guidance as core conditions (consistency = 0.994; original coverage = 0.138); the second is the configuration with the use of mental intervention, light physical activity, no analgesics, cold compresses, and musicotherapy as core conditions, and no position guidance as a marginal condition (consistency = 0.903; original coverage = 0.093); the third is the configuration with the use of mental intervention, position guidance, light physical activity, and no cold compresses as core conditions, and the use of analgesics and no musicotherapy as marginal conditions (consistency = 0.907, original coverage = 0.097).

Network Analysis

Figures 1 and 2 present the network structure and centrality of nursing interventions as they relate to analgesic efficacy in the early postoperative period for patients with aortic dissection. As depicted in Figure 1, cold compresses, musicotherapy, and posture guidance were major contributors to effective analgesia, whereas light physical activity demonstrated a negative impact on pain relief. Figure 2 highlights the centrality indices within the network, showing that, apart from the high but adverse strength of light physical activity, interventions such as posture guidance, cold compresses, and musicotherapy displayed high strength and closeness values, emphasizing their pivotal role in the pain management network.

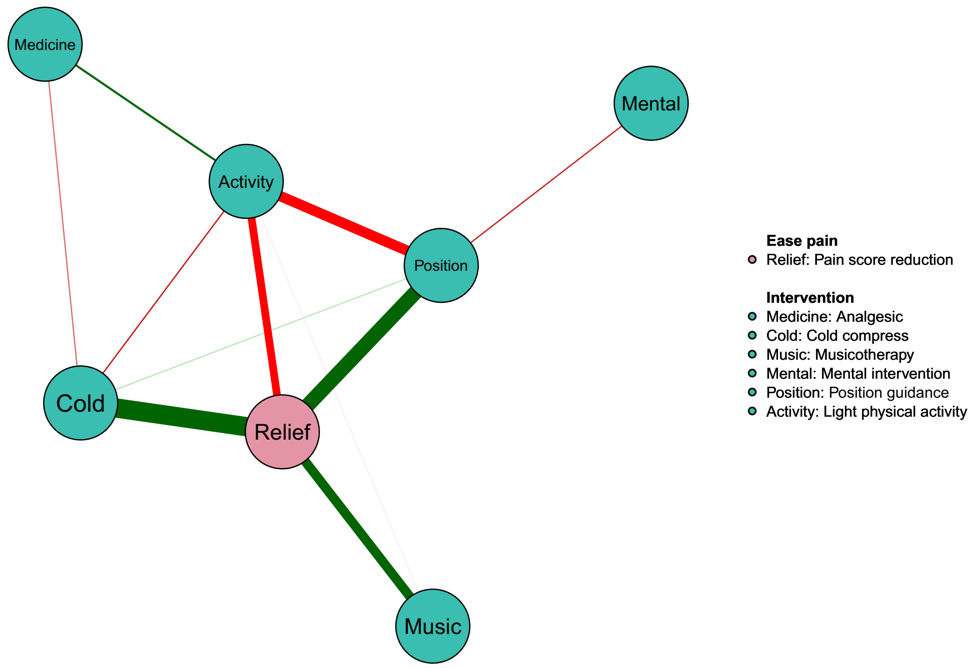


Figure 1 Network of Intervention and Ease pain.

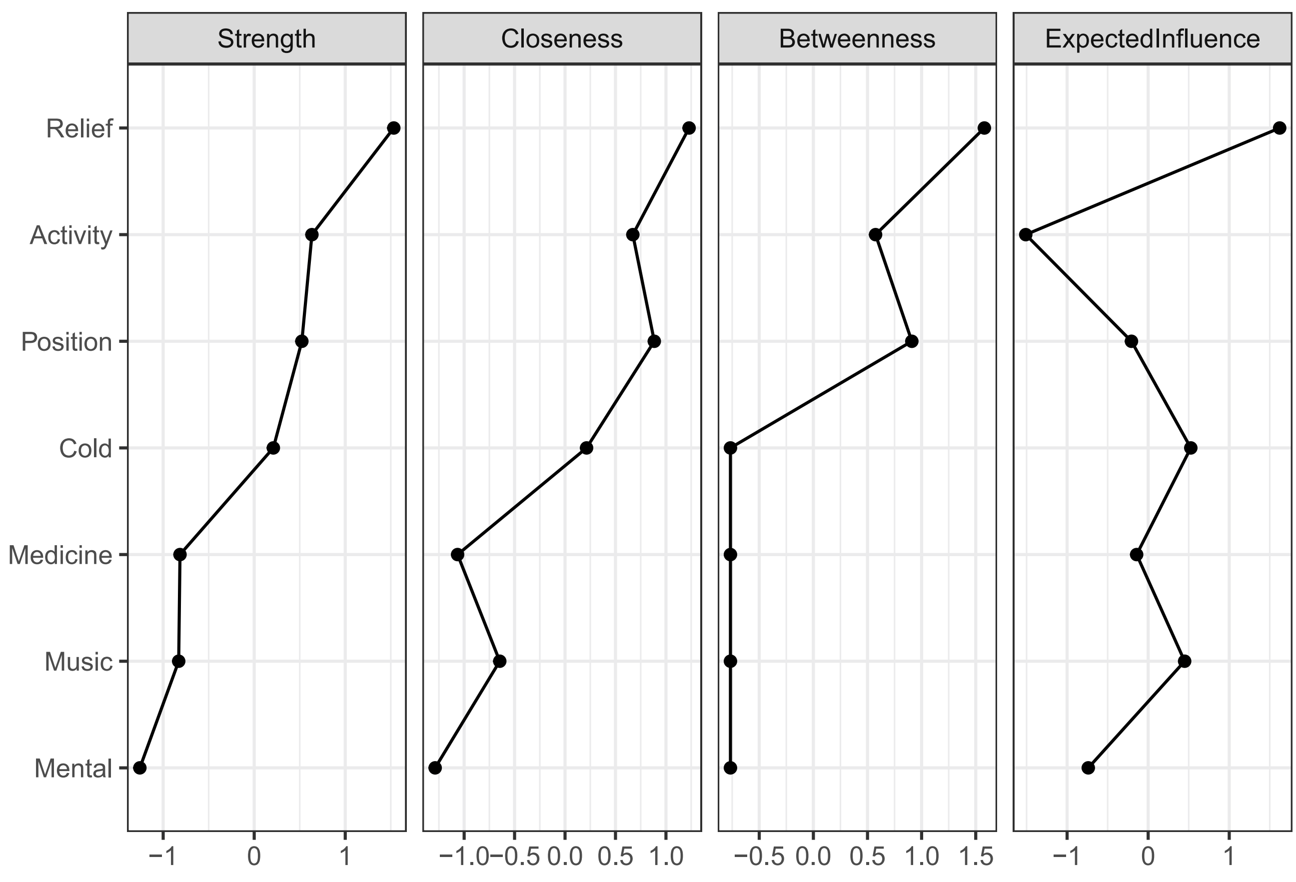


Figure 2 Centrality indices of the network.

A more detailed analysis of the relationships between these interventions, as illustrated in Figure 3, reveals that the strongest associations were between "analgesic efficacy and local cold compress", "analgesic efficacy and musicotherapy", and "analgesic efficacy and posture guidance". These associations, with confidence intervals consistently on the positive side of zero, reinforce the conclusion that cold compresses, musicotherapy, and posture guidance are particularly effective in enhancing analgesic outcomes. Conversely, the effects of analgesic use and mental intervention were less prominent, likely due to factors such as patient anxiety or the delayed pharmacological action in the immediate postoperative phase.

Figure 4 demonstrates the stability of network centrality across varying sampling ratios. The results show that the values for strength, closeness, and betweenness remained relatively stable even as the proportion of sampled data decreased. Specifically, the correlation stability (CS) coefficients for strength, closeness, and betweenness were 0.595,

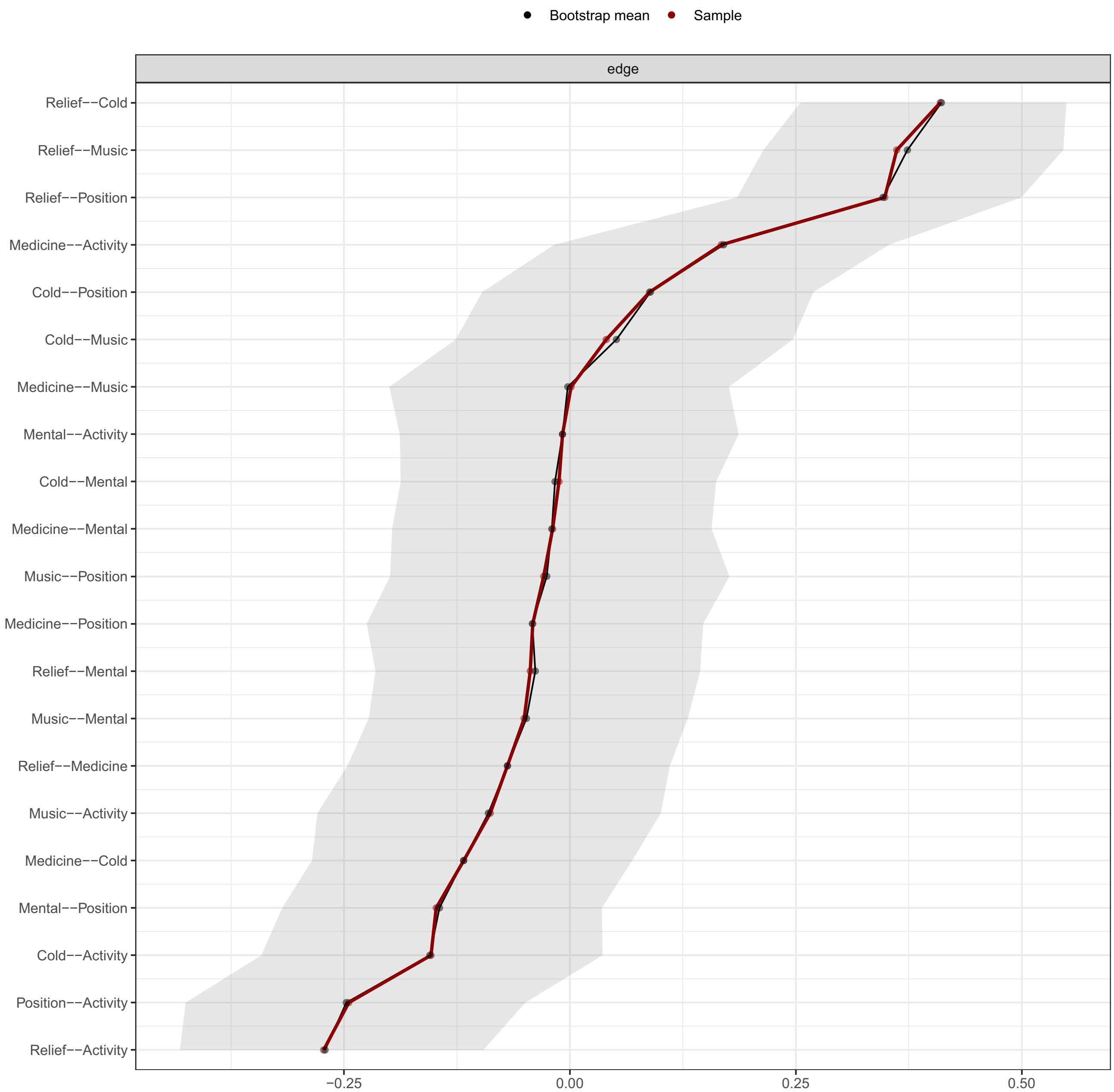


Figure 3 Edge-weight Bootstrapped CIs of the network.

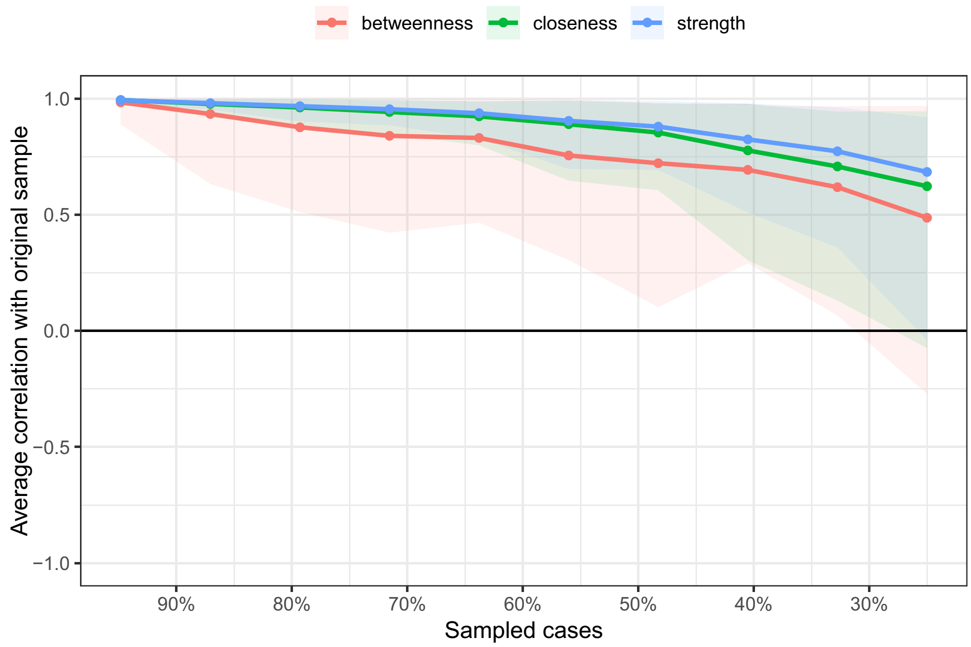
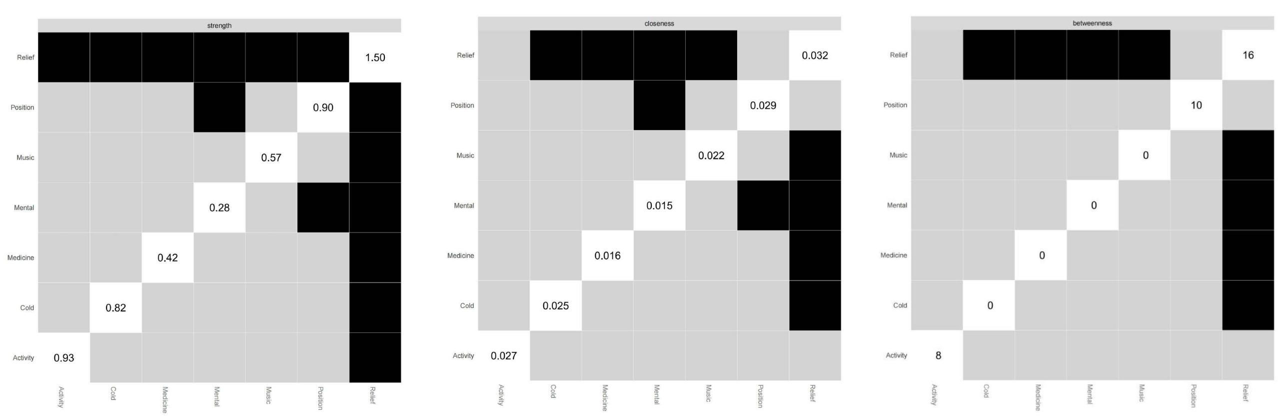


Figure 4 Centrality stability of the network.

0.517, and 0.207, respectively. Although the CS coefficient for betweenness was comparatively lower, the stability of strength and closeness remained robust. Notably, even with the removal of approximately 59.5% of the observations, the correlation for strength remained at 0.7, underscoring the resilience of the network's core metrics.

Figures 5a–c further illustrate the differences in node centrality across various nursing interventions and analgesic outcomes. The darker squares indicate statistically significant differences between nodes, while the lighter squares denote non-significant variations. These findings suggest that most nursing interventions and analgesic outcomes exhibited substantial differences in centrality. Specifically, Figure 5a and b show that mental intervention had significantly different centrality and closeness values compared to posture guidance, suggesting that mental intervention, while beneficial, had a more limited direct impact on analgesic outcomes compared to other interventions such as posture guidance.



a Strength differences **b Closeness differences** **c Betweenness differences**

Figure 5 Centrality differences of the network.

Note: In Figure 5a–c, white squares represent the value of node strength, closeness and betweenness respectively. The y-axis and x-axis correspond to each node. Black squares indicate nodes with significant differences, while grey squares denote non-significant differences.

Discussion

This study is based on the nursing practice of patients in the early stage after aortic dissection surgery, exploring the impact of various intervention measures on pain management. The configuration results show that a single intervention measure is difficult to effectively control postoperative pain. In Table 2, cold compresses and musicotherapy are at least in three of the five configurations that lead to good analgesic effects as core conditions; and in the three configurations that lead to poor analgesic effects, the non-set (not adopted or less adopted) of these two interventions also serves as core conditions, which sufficiently indicates that cold compresses and musicotherapy can be regarded as core effective interventions leading to good analgesic effects in patients in the early stage after aortic dissection surgery. Similarly, the use of psychological therapy, although appearing as a core condition in four of the configurations leading to good analgesic effects, also appears as a core condition in two of the configurations leading to poor analgesic effects, indicating that its causal relationship with postoperative pain relief is not obvious, and the effect of analgesic use on analgesia is similar. Light physical activity appears in all three configurations leading to poor analgesic effects as a core condition, indicating that light physical activity may have a negative effect on analgesia. In the configurations leading to good analgesic effects, position guidance is a marginal condition, but this condition appears (in three configurations) more times than it does not appear (in two configurations); in the configurations leading to poor analgesic effects, its non-appearance (one configuration as a core condition, one as a marginal condition) is more than its appearance (one configuration as a core condition), indicating that overall, position guidance has a certain positive effect on analgesia. Network analysis further supports the results of the configuration analysis, that is, cold compresses, musicotherapy, and position guidance and other interventions show significant analgesic effects, which can achieve the purpose of rapid postoperative recovery.[27]

This study shows that analgesics have a certain analgesic effect in the early postoperative stage but are not the best nursing interventions, suggesting that the proportion of opioid use should be reduced in postoperative nursing, and comprehensive analgesia should be achieved through non-pharmacological intervention measures as much as possible. At the same time, although the direct effect of mental intervention in short-term analgesia is not as expected, its long-term value in alleviating emotional fluctuations, anxiety, and depression should not be ignored. Clinical nursing staff can help patients better face the challenges of the postoperative recovery period through positive communication and support. Light physical activity in the early postoperative stage may exacerbate the patient's discomfort,[28] although moderate activity is usually helpful for promoting blood circulation and preventing venous thrombosis, but in the case of uncontrolled pain, early physical activity may backfire, indicating that when formulating postoperative activity plans, nursing staff should adjust the intensity and frequency of activities according to the patient's individual condition, ensuring that patients gradually restore physical functions on the basis of balancing activity and rest with a moderate level of subjective pain.

Based on the results and conclusions of this study, the following clinical recommendations are proposed to optimize the nursing pathway after aortic dissection surgery:

1. Prioritize non-pharmacological intervention measures: It is recommended that nursing staff use cold compresses and musicotherapy as routine analgesic nursing measures, and dynamically adjust the frequency and method of intervention according to patient needs.
2. Gradually reduce the use of opioids: In the early postoperative stage, chest bandaging is used to fix the wound, and PCA (Patient-Controlled Analgesia) is used to control pain within 24 hours after surgery. During mechanical ventilation treatment, an appropriate amount of analgesic drugs is pumped according to the doctor's order. The decision to remove the tracheal tube and remove the ventilator is based on the patient's mental state, body temperature, pulmonary function, and other vital signs. If the vital signs are stable after waking up, the tracheal tube should be removed as soon as possible, and the patient should be assisted with back patting and sputum removal. After weaning from the ventilator and the analgesic effect is stable, it is gradually transitioned to non-steroidal anti-inflammatory drugs (NSAIDs) and other drugs to reduce the dependence on opioids.

3. Flexibly arrange position and light physical activity: In the early postoperative stage, the position should be reasonably adjusted according to the patient's physical condition to reduce pain and discomfort. The patient can be guided to blow balloons for respiratory muscle training to promote pulmonary function recovery. A semi-reclining position of 30°~45° can be adopted after surgery, turning over every 2 hours to prevent complications.
4. Strengthen personalized psychological support: Nursing staff should maintain positive communication with patients, help them establish a positive recovery belief, and combine breathing relaxation training and other techniques to reduce their psychological pressure.

The aforementioned approaches can effectively and efficiently achieve the expected outcomes in postoperative pain management for aortic dissection patients through psychological relaxation, goal distraction, and physical analgesia. In addition, the pain management protocol in this study emphasizes simplification of procedures while ensuring a certain level of personalization. By employing a configurational synthesis approach, we have developed a highly practical and flexible pool of personalized options designed to meet the specific needs of individual patients.

limitations

Although this study provides new insights into nursing pathways during the early postoperative period following aortic dissection surgery, there are several limitations to acknowledge. First, the sample for this study was drawn from a single medical institution, and while the sample size of 116 cases exceeded the methodological requirements for Qualitative Comparative Analysis (QCA), the convenience sampling approach and relatively limited sample size may still affect the generalizability of the conclusions. Future studies could address these limitations by expanding the sample size, conducting subgroup analyses based on population characteristics (eg, distinctions in gender, age, and region), and implementing multi-center studies to enhance the robustness and applicability of the findings.[29] Second, due to resource and logistical constraints, this study primarily focused on short-term outcomes, such as pain relief within the first 72 hours post-surgery, without a systematic evaluation of the long-term effects of nursing interventions.[30] Subsequent research could include longer follow-up periods to explore the impact of nursing interventions on patients' long-term quality of life and functional recovery. Lastly, the individual differences among patients, such as variations in baseline health, pain tolerance, and psychological state, may have influenced the effectiveness of the nursing interventions. While this study aimed to standardize nursing pathways to ensure comparability, further research is warranted to refine and evaluate the effectiveness of personalized nursing pathways, especially when tailored to specific physiologic or demographic factors.

Conclusion

This study highlights the efficacy of cold compresses, musicotherapy, and other multimodal nursing interventions in optimizing postoperative pain management for aortic dissection patients. These tailored interventions provide significant potential to reduce opioid reliance, improve early recovery outcomes, and address individual patient needs. Further validation through long-term follow-up and multi-center research will enhance the robustness of these approaches in clinical practice.

Abbreviations

VAS, Visual Analog Scale; fsQCA, Fuzzy-set Qualitative Comparative Analysis; NSAIDs, Non-steroidal anti-inflammatory drugs; PCA, Patient-Controlled Analgesia; PRI, Proportional reduction in inconsistency; TAD, Thoracic aortic dissection; AAD, Abdominal aortic dissection; CIs, Confidence intervals; CS, correlation stability.

Data Sharing Statement

All the data are derived from the self-established databases. The datasets requested and/or used during all else studies are available from the corresponding author upon reasonable request.

Ethics Approval

This study was approved by the Ethics Committee of Shanxi Provincial People's Hospital (2021-017). The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Consent to Participate

Informed consent was obtained from all individual participants included in the study.

Consent to Publish

All individual participants signed informed consent regarding publishing their data.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

All authors declare that there is no conflict of interest in this work.

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