



Research Article

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Application of Attribute Hierarchy Model in Nursing Skills Assessment Scoring Standard

Wang Yuanyuan^{1,2}, Jestoni Maniago^{2,*}, Song Jiawei^{3,*}, Li Yingying¹ and Zhang Di¹

¹School of Medicine, Bozhou Vocational and Technical College, Bozhou 236800, China

²College of Nursing and Allied Health Sciences, St. Paul University Manila, Metro Manila1004, Philippines

³Clinical Pharmacy Center, Bozhou People's Hospital, Bozhou 236800, China



Abstract

Objective: To develop a nursing skills assessment scoring standard using the Attribute Hierarchy Model (AHM) and evaluate its effectiveness in daily teaching and practice.

Methods: Based on the scoring standards for intravenous indwelling needle infusion in the national vocational college nursing skills competition, assessment indicators were identified. AHM was employed to determine the relative weights of these indicators. The developed AHM-based scoring standard was applied to assess the intravenous indwelling needle infusion skills of 290 higher vocational nursing students. Student performance and the effectiveness of the evaluation were analyzed.

Results: The average student score was 77.59 ± 8.86 . 9 cases (3.1%) scored ≥ 90 , 96 cases (33.1%) scored between 80 and 90, 146 cases (50.3%) scored between 70 and 80, and 39 cases (13.5%) scored below 70. Analysis revealed deficiencies in several secondary assessment indicators, including non-standard disinfection (63%), inaccurate drip rate adjustment (43%), and failure to perform necessary checks during the procedure.

Conclusion: The AHM-based scoring standard provides a robust theoretical foundation for evaluating nursing skills. The evaluation results demonstrate its scientific validity and practicality. By accurately identifying areas of weakness in student performance, this approach facilitates "process-result" based evaluation and offers a valuable reference for assessing the practical abilities of nursing students.

Keywords

Attribute hierarchy model, Nursing, Skill assessment, Scoring criteria

National Nursing Skills Competition advocates a new concept of practical teaching. It is an assessment tool that reflects the core skill level of nursing students and has been included in the talent training quality evaluation system [1-5]. In order to implement the concept of "competitions promote daily teaching, and daily teaching leads to competitions" [6], the author embeds the key points of operation in the nursing skills competition of the National Vocational College Skills Competition into daily practical teaching and assessment. Each operation in the competition involves multiple evaluation indicators [7]. When applying it specifically, teachers and students question the basis for the score of each indicator. In addition, the full score for intravenous indwelling needle infusion operation in the competition is 20.5 points, while the full score for students' daily operation assessment is 100 points. When the full score changes, the scores of each indicator also change. Therefore, it is very necessary to scientifically determine the scores of each indicator and establish a theoretically based scoring standard

to comprehensively and accurately present the students' skill level.

The attribute hierarchical model (AHM) is an unstructured decision-making method based on attribute mathematics. It solves the problem of the failure of the maximum membership criterion in fuzzy comprehensive evaluation by solving the weight of indicators through relative attributes. It can

***Corresponding author:** Song Jiawei, Clinical Pharmacy Center, Bozhou People's Hospital, Bozhou 236800, China, Tel: 0558-5677150; Jestoni Maniago, College of Nursing and Allied Health Sciences, St. Paul University Manila, Metro Manila1004, Philippines

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evaluate a single indicator or comprehensively evaluate all indicators. The results are accurate and scientific. At present, it is widely used in bank internal control, earthquake disaster assessment, primary medical status assessment, clinical drug evaluation and internship teaching assessment and evaluation [8-13], but its application in nursing skills assessment and evaluation has not been reported. The author applied AHM to nursing skills assessment and scoring to provide a reference for scientifically evaluating the practical ability of nursing students and reflecting the students' skill level impartially and objectively. Because intravenous infusion is the most basic nursing operation in daily nursing work [14], this study took intravenous indwelling needle infusion as an example.

Objects and Methods

Research subjects

The 23rd grade nursing major and the 21st grade five-year nursing major students of the Medical College of Bozhou Vocational and Technical College were selected as the research subjects. Inclusion criteria for the research subjects: complete information, completion of the assessment on time, and detailed records of the scoring results. Exclusion criteria: ① The operation was not completed within the time limit; ② The specific score records in the scoring were not detailed. In the basic nursing intravenous indwelling needle infusion training course in the spring semester of 2024, the teaching was carried out according to the operation procedures and observation points in the intravenous indwelling needle infusion scoring standards of the nursing skills competition. The final skills assessment used the intravenous indwelling needle infusion scoring standards based on AHM to collect student scores and analyze them. Finally, 290 students' operation scores were included as research subjects.

Methods

Establishment of AHM assessment indicators for intravenous indwelling needle infusion

According to the scoring criteria for intravenous indwelling needle infusion in the nursing skills competition of the higher vocational group of the 2023 National Vocational College Skills Competition, 10 first - level indicators and 34 second-level indicators were determined (Table 1).

Calculation of relative weight coefficients of scoring indicators based on AHM

AHM is a practical multi-objective decision analysis method that decomposes complex problems into different factors in an ordered hierarchical structure. The most critical issue is how to obtain the weight value of each influencing factor [15]. Based on AHM, the relative weight of indicators is established, and their relative importance is compared and the weight of each indicator is established. The weight is quantified into a numerical value for comparison. The numerical value has no specific unit and only represents its relative importance relative to another indicator. The larger the value, the higher the importance, and vice versa [16]. μ_{ji}

represents the importance value of the i^{th} indicator relative to the j^{th} indicator; μ_{ji} represents the importance value of the j^{th} indicator relative to the i^{th} indicator; μ_{ii} represents the comparison of the i^{th} indicator itself. According to mathematical rules, $\mu_{ii} = 0$, $\mu_{ji} + \mu_{ij} = 1$. Construct a judgment matrix, and perform a consistency test on the judgment matrix according to formula (1). Then, the relative attribute weight vector of the indicator is obtained according to formula (2). $w_c(i)$: weight coefficient of the i^{th} indicator; n : number of evaluation indicators; μ_{ji} : importance value of the i^{th} indicator relative to the j^{th} indicator. By constructing a judgment matrix and performing mathematical operations such as weighted average, the importance of each indicator at each level, i.e., relative weight, is determined [17].

$$g(x) = \begin{cases} 1, & x > 0.5 \\ 0, & x \leq 0.5 \end{cases}$$

$$Q_i = \{j : g(\mu_{ij}) = 1, 1 \leq j \leq n\}$$

$$g(\mu_{ik}) = g\left[\sum_{j \in Q_i} g(\mu_{ik})\right] \geq 0, 1 \leq k \leq n \quad (1)$$

$$W_c(i) = \frac{2}{n(n-1)} \sum_{j=1}^m \mu_{ij} \quad (2)$$

Calculation skills assessment operation score 1

Based on the established AHM intravenous indwelling needle infusion operation scoring standard, the students' operation is scored. According to the determined relative weight coefficient, the corresponding scores of the 34 secondary assessment indicators C1-C34 are assigned. If the students do not operate the corresponding assessment indicators in a standardized manner, the corresponding scores will be deducted, that is, the skill assessment score = 100 - (0 or 1) × C1 - (0 or 1) × C2 - (0 or 1) × C3 - (0 or 1) × C4 - (0 or 1) × C5 - (0 or 1) × C6 - - (0 or 1) × C34, where if the indicator operation meets the standard, the corresponding indicator score is 0, and if the indicator operation does not meet the standard, the corresponding indicator score is 1.

Statistical analysis

The students' age, gender, weight coefficient and score of the assessment index and the test results of intravenous catheter infusion operation were statistically analyzed using Microsoft Excel 2010. The count data were expressed as cases (%) and the measurement data that conformed to the normal distribution were expressed as $\bar{x} \pm s$.

Results

Construction and score of the first-level assessment indicator matrix

A matrix was constructed based on the AHM method, and the weight coefficients of the 10 first-level assessment indicators were calculated. The corresponding scores were assigned to each first-level indicator based on the daily teaching intravenous indwelling needle infusion operation scoring standard with a full score of 100 points (Table 2).

Table 1: Scoring criteria for intravenous indwelling needle infusion in the 2023 National Vocational College Skills Competition – Higher Vocational Nursing Skills Competition.

First level indicator	Secondary indicators
Verification and Inspection	C1 Seven-step hand washing method, wearing a mask
	C2 Two people check the doctor's order, infusion card and bottle label
	C3 Check the label of the drug solution
	C4 Check the quality of the liquid medicine
Prepare the solution	C5 Label the bottle, open the bottle cap, and sterilize the bottle stopper twice until the bottle neck
	C6 Check the infusion set packaging, expiration date and quality, and insert the infusion set needle into the bottle stopper
Check Explanation	C7 Prepare all the necessary supplies and bring them to the patient's bedside, check the patient's information (bed number, name, hospitalization number), explain the purpose of the infusion and obtain cooperation
	C8 Assess the patient's skin, blood vessels, and limb activity
Initial exhaust	C9 Check the quality of the liquid medicine again and hang the infusion bottle on the infusion stand
	C10 Check and open the indwelling needle package and connect the infusion set
	C11 Exhaust gas in the device
	C12 Check for bubbles
Skin disinfection	C13 Assist the patient to take a comfortable position; use a small pillow and treatment towel
	C14 Select a vein and tie a tourniquet (10 cm above the puncture point)
	C15 Disinfection of skin (diameter ≥ 8 cm; disinfection twice or follow the instructions for use of the disinfectant)
Venipuncture	C16 Recheck
	C17 Remove the needle cover and vent again until a small amount of liquid drops out
	C18 Check for bubbles and loosen the outer sleeve by rotating it
	C19 Fixes the blood vessels, asks the patient to loosen his fist, and inserts the needle
	C20 Lower the angle and insert the needle slightly to push the entire hose into the blood vessel.
Fixed needle	C21 Puncture, loosen the tourniquet, open the regulator, ask the patient to loosen his fist, and remove the needle core.
	C22 Is properly fixed, and the pipe label should indicate the pipe placement date, time and signature
Adjust drip rate	C23 Adjusts the drip rate according to the patient's age, condition and drug properties (oral)
	C24 Adjusts the dripping time to at least 15 seconds and reports the dripping rate
	C25 Check the patient after operation
	C26 Notice of matters needing attention
Organize records	C27 Place the patient in a safe and comfortable position, place the call button in an accessible place, and tidy up the bed unit and supplies
	C28 Seven-step hand washing method, record card for infusion execution
Stop the infusion	C29 Check Explanation
	C30 Remove the infusion patch, press the sterile dry cotton swab lightly above the puncture point, close the adjustment clip, and quickly pull out the indwelling needle
	C31 Instruct the patient to press until there is no bleeding and inform him of precautions
	C32 Assist the patient to take a safe and comfortable position and ask if
	C33 Clean up the treatment items and place them in categories
	C34 Wash hands in seven steps, remove the mask, and record the end time of infusion and the patient's reaction

Table 2: Weight coefficient and score of the first-level assessment index of intravenous indwelling needle infusion.

Assessment indicators (level 1)	Verification and Inspection	Prepare Liquid	Verification explain	Preliminary exhaust	skin disinfect	Vein puncture	fixed Needles	adjust Dripping speed	tidy Record	stop Infusion	Weight coefficient	index Points
Verification and Inspection	0	0.70	0.70	0.45	0.50	0.20	0.55	0.4 0	0.75	0.25	0.1000	10.00
Prepare the solution	0.30	0	0.40	0.20	0.30	0.10	0.40	0.30	0.60	0.15	0.0611	6.11
Check Explanation	0.30	0.60	0	0.35	0.40	0.10	0.50	0.30	0.65	0.20	0.0756	7.56
Initial exhaust	0.55	0.80	0.65	0	0.60	0.25	0.65	0.50	0.70	0.35	0.1122	11.22
Skin disinfection	0.50	0.70	0.60	0.40	0	0.20	0.65	0.4 0	0.60	0.30	0.0967	9.67
Venipuncture	0.80	0.90	0.90	0.75	0.8 0	0	0.85	0.70	0.90	0.70	0.1622	16.22
Fixed needle	0.45	0.60	0.50	0.35	0.35	0.15	0	0.4 0	0.75	0.2 0	0.0833	8.33
Adjust drip rate	0.60	0.70	0.70	0.50	0.60	0.30	0.60	0	0.75	0.40	0.1144	11.44
Organize records	0.25	0.40	0.35	0.30	0.40	0.10	0.25	0.25	0	0.10	0.0533	5.33
Stop the infusion	0.75	0.85	0.80	0.65	0.70	0.30	0.80	0.60	0.90	0	0.1411	14.11

Table 3: Weight coefficients and scores of intravenous indwelling needle infusion assessment indicators.

Target layer	Indicator layer					
Protection reason Technique able big Race quiet pulse Keep Place Needle lose liquid Comments point Standard allow	First level indicator	Weight coefficient	Index score	Secondary indicators	Weight coefficient	Index score
	Verification and Inspection	0.1000	10.00	C1	0.25	2.50
				C2	0.25	2.50
				C3	0.25	2.50
				C4	0.25	2.50
	Prepare the solution	0.0611	6.11	C5	0.6 0	3.67
				C6	0.4 0	2.44
	Check Explanation	0.0756	7.56	C7	0.5 0	3.78
				C8	0.5 0	3.78
	Initial exhaust	0.1122	11.22	C9	0.22	2.43
				C10	0.22	2.43
				C11	0.33	3.74
				C12	0.23	2.62
	Skin disinfection	0.0967	9.67	C13	0.23	2.26
				C14	0.33	3.22
				C15	0.43	4.19
	Venipuncture	0.1622	16.22	C16	0.14	2.19
				C17	0.15	2.35
				C18	0.14	2.27
				C19	0.29	4.70
				C20	0.29	4.70
	Fixed needle	0.0833	8.33	C21	0.55	4.58
				C22	0.45	3.75
	Adjust drip rate	0.1144	11.44	C23	0.32	3.62
				C24	0.27	3.05
				C25	0.21	2.38
				C26	0.21	2.38
	Organize records	0.0533	5.33	C2 7	0.5 0	2.67
				C2 8	0.50	2.67
	Stop the infusion	0.1411	14.11	C 29	0.15	2.16
				C3 0	0.23	3.29
				C3 1	0.15	2.16
				C3 2	0.15	2.16
				C3 3	0.15	2.16
				C3 4	0.15	2.16

Construction and score of the secondary assessment indicator matrix

A judgment matrix was constructed to calculate the weight coefficients of the 34 secondary assessment indicators, and then the corresponding scores were assigned to each secondary assessment indicator according to the scores of the primary assessment indicators (Table 3).

Students’ operation scores and the achievement of secondary assessment indicators

290 students, 246 were girls (88.62 %) and 33 were boys (11.38 %); the average age of the students was 19.3 ± 1.24 years old. Based on the scoring criteria constructed by AHM, the highest score was 92.75, the lowest score was 56.14, and the average score was 77.59 ± 8.86. The student scores are shown in Table 4. The statistical results of the secondary assessment indicators that met the standards and those that did not meet the standards are shown in Table 5.

Discussion

Advantages of the AHM-based nursing skills assessment scoring standard

Cao Xi [18] pointed out in his research that in addition to reforming the practical teaching method, teachers should also reform the practical assessment model, establish objective, visual and structured scoring rules, and reduce subjective scoring. Based on the attribute hierarchy model, the author established the hierarchical structure and comparison matrix of AHM, sorted and weighted each scoring factor according to the hierarchy, and obtained the relative weight coefficients

of 10 first-level indicators and 34 second-level indicators of intravenous indwelling needle infusion operation. This can help determine the weight of different indicators in the scoring and determine the score of each indicator in the scoring rules. It has a quantitative basis, reduces the influence of subjective factors on the scoring results, and theoretically solves the controversy between fuzzy evaluation and experience evaluation [19], making the evaluation results more reasonable.

Furthermore, the weight coefficient of each indicator is calculated based on the AHM scoring standard. No matter how the total score changes, the weight of each indicator will not change. Multiplying the weight of each indicator by the total score can get the first-level indicator and the second-level indicator score. This solves the problem that the intravenous indwelling needle infusion operation in the 2023 National Vocational College Skills Competition Higher Vocational Nursing Skills Competition has a full score of 20.5 points, while the full score for this operation in the students' usual operation assessment is 100 points, which is inconvenient for daily teaching due to different scores. This AHM -based scoring method can be flexibly adjusted according to the characteristics of different competitions, and the scoring rules can be dynamically optimized and adjusted according to the actual situation of daily teaching, which is both scientific and improves its applicability.

Advantages of application in daily teaching assessment

AHM based scoring standard for intravenous indwelling needle infusion in nursing skills competitions was applied to daily teaching and practical assessment. On the one hand, it

Table 4: Students' intravenous indwelling needle infusion scores.

Student intravenous indwelling needle infusion score	Number of people	Composition ratio (%)	Score level
Score ≥ 90	9	3.1 %	excellent
80 ≤ Score < 90	96	33.1 %	good
70 ≤ Score < 80	146	50.3%	Pass
Score < 70	39	13.5%	Fail

Table 5: Analysis of the failure to meet the secondary assessment indicators and reasons [n=290, cases (%)].

Secondary assessment indicators	Number of cases that did not meet the standard (%)	Number of cases meeting the standard (%)	Main reasons for failure to meet the standards
C5	113 (39)	177 (61)	Disinfection is not standardized and violates the principle of sterility
C11	84 (29)	206 (71)	The exhaust was not successful at once, and there are bubbles.
C15	183 (63)	107 (37)	Knowing the disinfection range and the second disinfection is smaller than the first, but the technique is incorrect and there are gaps in the disinfection
C16	110 (38)	180 (62)	Forgot to check
C19	61 (21)	229 (79)	Incorrect needle insertion angle and technique
C20	99 (34)	191 (66)	Cannot properly withdraw the needle
C24	125 (43)	165 (57)	Inaccurate adjustment
C25	102 (35)	188 (65)	Forgot to check
C30	78 (27)	212 (73)	Forgetting to turn off the regulator when removing the needle

achieved a deep integration of teaching and competition [20], and on the other hand, the evaluation was more scientific and reasonable. Studies have shown that when teaching based on the assessment elements of the skills competition, the overall level of students' operational skills is good, and 86.5% of students scored 70 points or above. However, there is still a certain proportion of students who need to strengthen training and improvement. In which aspects do these students need to strengthen training? By counting the non-compliance of the secondary indicators, the weak points of students' operations can be found, helping students to find deficiencies and make up for them, so as to achieve precise teaching and improve teaching effects.

Table 5 shows that students failed to meet the standards for 9 secondary assessment indicators, including 63% for non-standard disinfection, 43% for inaccurate drip rate adjustment, and 38% for failure to check during operation. The analysis found that students had mastered the operation requirements for these three indicators in theory, but they were not aware of the three checks and seven comparisons in actual operation. They remembered to check before operation, but were prone to omissions during and after operation. They knew that disinfection should be done twice and the specific requirements, but the actual operation was not standardized and the awareness of aseptic was not strong enough. They knew how to adjust the drip rate, but the adjustment was not accurate. This may be related to the fact that students mostly stayed in passive learning, thinking that they had mastered it in theory but lacked active practice, and were unable to effectively connect and transform theory with practice, resulting in the inability to strictly abide by the operation in behavior. It is also consistent with previous studies on the characteristics of clinical operation of nursing students and new nurses [21]. Through the feedback of the results, the weak points of the operation of 146 students with poor performance and 39 unqualified students were strengthened, and students were urged to practice diligently to transform theory into skills. The students finally met the standards and their operation skills were improved. The AHM-based scoring standard for intravenous catheter infusion operations not only has a quantitative basis, but also realizes the "process-result" two-way evaluation, optimizes the talent evaluation model, and improves the quality of talent training.

Conclusion

The attribute hierarchy model provides a scientific and effective method for the formulation of the scoring standard for higher vocational nursing skills assessment. Since the research has just started, this article only takes the "intravenous indwelling needle infusion" operation in the nursing skills competition as an example. In future research, we will try to apply it to other higher vocational nursing skills operation projects to further test the feasibility of the nursing skills assessment scoring standard based on AHM. We also hope that more nursing educators and managers will jointly explore the application of the attribute hierarchy model in the reform of nursing assessment and evaluation to promote the high-quality training and development of nursing talents.

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