Research Square

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Exploring heterogeneity in ICU nurses' perceived intrahospital transport safety: a latent profile analysis with exploratory threshold identification

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Abstract

Background:

Intrahospital transport (IHT) of critically ill patients is a high-risk process in intensive care units (ICUs), in which nurses play a key role in ensuring patient safety. However, little is known about potential differences in ICU nurses' perceptions of IHT safety. This study aimed to explore heterogeneity in ICU nurses' perceived IHT safety using a person-centred analytical approach and to derive a preliminary perception-based reference threshold on the Intrahospital Transport Safety Scale (IHTSS).

Design:

A cross-sectional, exploratory study.

Methods:

ICU nurses from tertiary hospitals in Hunan Province, China, completed the Chinese version of the IHTSS. Latent profile analysis (LPA) was used to identify subgroups with distinct patterns of perceived IHT safety. Receiver operating characteristic (ROC) analysis was then conducted as an exploratory, internally referenced approach to examine potential reference thresholds in relation to the LPA-derived profiles.

Results:

Three latent profiles of perceived IHT safety (lower, moderate, and higher) were identified. ROC analysis demonstrated clear internal separation between the higher perceived safety profile and the remaining profiles, yielding an internally derived reference score of 101 on the IHTSS. Nurses with lower perceived safety more frequently reported limited IHT-related training exposure, reduced checklist use, greater IHT-related fear, and lower confidence.

Conclusions:

This study identified heterogeneity in ICU nurses' perceived intrahospital transport safety and proposed a preliminary, internally derived reference threshold on the IHTSS. The threshold should be interpreted as perception-based and exploratory, and external validation is required before broader application.

1. Introduction

Patient safety has received increasing global attention since the publication of To Err is Human (1). Although many countries have made substantial progress in improving patient safety, research in China remains relatively limited, particularly in high-acuity clinical settings such as intensive care units (ICUs)(2).

ICU nurses work in highly complex environments characterised by heavy workloads, high patient acuity, and rapidly changing clinical conditions. These factors create substantial challenges for maintaining patient safety, as risks associated with critical illness may be exacerbated by fragmented workflows, system inefficiencies, and environmental pressures (3) .

Intrahospital transport (IHT) of critically ill patients is a routine yet inherently high-risk activity in ICUs. Patients are frequently transferred to diagnostic or therapeutic areas, temporarily leaving the controlled ICU environment (4). Despite the availability of clinical guidelines, adherence to IHT protocols remains inconsistent in practice due to workload pressures, time constraints, and coordination challenges(5, 6). Consequently, IHT may expose patients to a range of adverse physiological events, including oxygen desaturation, haemodynamic instability, agitation, and altered levels of consciousness(7).

Importantly, it is necessary to distinguish between objectively measured IHT-related adverse events and ICU nurses' perceptions of IHT safety. Perceived safety reflects nurses' cognitive and emotional evaluations of transport conditions, including organisational support, equipment availability, teamwork, and individual preparedness. While such perceptions may influence behaviour and decision-making, they do not necessarily correspond to actual transport errors or patient harm.

In China, existing studies on IHT have mainly focused on transport procedures, equipment, and organisational processes, whereas ICU nurses' perceptions of IHT safety remain underexplored (9). Furthermore, little is known about whether distinct subgroups exist in nurses' perceived IHT

safety. Person-centred analytical approaches, such as latent profile analysis (LPA), offer a useful framework for identifying heterogeneity in perceptions beyond traditional mean-level analyses.(8).

Therefore, this study aimed to examine ICU nurses' perceived IHT safety using LPA. Specifically, the study sought to identify distinct patterns of perceived IHT safety among ICU nurses and to explore an internally derived reference threshold on the Intrahospital Transport Safety Scale (IHTSS) for research-oriented classification and needs assessment.

3. Methods

3.1 Aim

This study aimed to explore heterogeneity in ICU nurses' perceived intrahospital transport safety using a person-centred analytical approach. Specifically, the objectives were to: (1) identify distinct latent profiles of perceived IHT safety among ICU nurses using latent profile analysis; and (2) explore an internally referenced threshold on the IHTSS for research-oriented classification within the study sample.

3.2 Design

This study employed an exploratory cross-sectional design. LPA was applied to IHTSS item scores to examine heterogeneity in ICU nurses' perceived IHT safety. Receiver operating characteristic (ROC) analysis was subsequently performed as an exploratory, internally referenced procedure to derive a preliminary cut-off threshold corresponding to the safety profiles identified by LPA.

3.3 Setting

This study was conducted in the ICUs of 10 tertiary comprehensive teaching hospitals across four cities in Hunan Province, China: Changsha, Hengyang, Xiangtan and Shaoyang. These hospitals represent the highest level of integrated medical care, education, and research within the regional healthcare system. The participating ICUs included medical, surgical, emergency, and general mixed units, providing a broad range of critical care services. In routine practice, these units frequently manage IHT of critically ill patients for diagnostic and therapeutic procedures, such as computed tomography, magnetic resonance imaging, interventional treatments, and emergency surgery. In these settings, ICU nurses are primarily responsible for coordinating and performing IHT tasks, including pre-transport assessment, intra-transport monitoring, equipment operation, and post-transport stabilisation. Accordingly, nurses' perceptions of IHT safety are closely linked to their routine clinical responsibilities in high-acuity environments.

3.4 Participants and Sampling

Participants were ICU nurses working in 10 tertiary general hospitals in Hunan Province, China. Inclusion criteria were: (1) current employment in an ICU; (2) at least one year of ICU work experience; and (3) participation in the intrahospital transport of critically ill patients within the preceding six months. Nurses on leave or lacking recent transport experience were excluded.

A cluster sampling strategy was employed, with 10 tertiary hospitals randomly selected as sampling units. All eligible ICU nurses from medical, surgical, emergency and mixed general ICUs within these hospitals were invited to participate. Data were collected using an anonymous online questionnaire distributed via WeChat between October and December 2022. Of the 773 questionnaires returned, 653 were retained for analysis after data cleaning, yielding a response rate of 84.5%.

3.5 Measures

3.5.1 Sociodemographic and professional characteristics

Sociodemographic and professional characteristics were collected using a structured questionnaire developed for this study. Variables included age, gender, years of ICU work experience, educational attainment, professional title, and ICU type (medical, surgical, emergency or mixed general ICU).

3.5.2 Intrahospital Transport Safety Scale

Perceived intrahospital transport safety was measured using the Chinese version of the IHTSS (9). The IHTSS is a 24-item self-report instrument comprising four dimensions: organisation, tools and techniques, environment, and IHT-related tasks and collaboration. Items are rated on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher perceived IHT safety. Total scores ranged from 24 to 120. In the present study, the scale demonstrated excellent internal consistency (Cronbach's $\alpha = 0.97$).

3.6 Statistical analysis

3.6.1 Handling of missing data

Questionnaires with substantial missing responses or patterned response errors were excluded during data cleaning. For the retained questionnaires, item-level missingness was examined prior to analysis. As the proportion of missing data was low (< 5% for all items), complete-case analysis was applied and no imputation procedures were performed.

3.6.2 Latent profile analysis

LPA was conducted using the 24 item-level scores of the IHTSS to identify heterogeneity in ICU nurses' perceived IHT safety. Analyses were performed in Mplus version 8.3 using robust maximum likelihood (MLR) estimation. An unconditional model without covariate adjustment was specified, and sociodemographic variables were examined only in subsequent descriptive comparisons.

Model selection was guided by multiple statistical criteria and interpretability considerations, including the Akaike information criterion (AIC), Bayesian information criterion (BIC), sample-size adjusted BIC (aBIC), entropy, the bootstrap likelihood ratio test (BLRT), and the Lo–Mendell–Rubin test (LMRT). Lower AIC, BIC, and aBIC values indicated better model fit, whereas entropy values greater than 0.80 indicated adequate classification precision. Significant BLRT and LMRT results ($p < 0.05$) suggested that a model with k profiles provided a better fit than a model with k − 1 profiles. To ensure model stability and interpretability, each latent profile was required to include at least 5% of the sample.

3.6.3 Receiver operating characteristic analysis

ROC analysis was conducted using the pROC package in R (version 4.3.2) as an exploratory, internally referenced approach to examine potential reference thresholds on the IHTSS. Latent profiles derived from the LPA served as the internal reference framework. Nurses in the highest perceived IHT safety profile were treated as the reference group, whereas those in the remaining profiles were combined for comparison.

For each possible IHTSS cut-off score, sensitivity and specificity were calculated to evaluate the degree of internal separation between LPA-derived perceived safety profiles (10). The reference threshold was identified by maximising Youden's index, reflecting the optimal balance between sensitivity and specificity within the study sample (11). The area under the ROC curve (AUC) was calculated to summarise overall classification separation (12). Because both the reference classification and the predictor originated from the same instrument and dataset, the ROC analysis was interpreted as exploratory and internally referenced.

3.6.4 Comparisons based on the reference threshold

Based on the internally derived reference threshold, participants were classified into two groups according to whether their IHTSS scores fell below or above the threshold. Sociodemographic and professional characteristics were compared across both the LPA-derived profiles and the threshold-based groups to examine the consistency of observed patterns across analytic approaches. Chi-square tests were used for categorical variables, independent-sample *t*-tests for comparisons between the two threshold-based groups, and one-way analysis of variance (ANOVA) for comparisons across the three latent profiles.

4. Results

4.1 Sociodemographic characteristics of participants

A total of 653 ICU nurses were included in the final analysis. Overall, the sample comprised nurses with diverse demographic and professional backgrounds across age groups, educational levels, years of ICU experience, and ICU types. Distributions of sociodemographic and professional characteristics across the three latent profiles of perceived IHT safety are summarised in Table 1.

Table 1
Sociodemographic and professional characteristics of ICU nurses across perceived intrahospital transport safety profiles (n = 653)

Variable	Categories	Class1	Class2	Class3
		n (%)	n (%)	n (%)
Gender	Female	97(17.5)	326(59.0)	130(23.0)
	Male	30(30.0)	48(48.0)	22(22.0)
Age (year)	20–30	57(20.1)	158(55.8)	68(24.1)
	31–40	66(19.1)	199(57.5)	81(23.4)
	41–50	4(16.7)	17(70.8)	3(12.5)
Education level	Junior College	4(15.4)	9(34.6)	13(50.0)
	Bachelor's	112(19.9)	321(57.0)	130(23.1)
	Master's	11(17.2)	44(68.8)	9(14.1)
Years of ICU work	1–5	50(20.2)	133(53.9)	64(25.9)
	6–10	39(18.1)	128(59.5)	48(22.4)
	11–15	21(21.4)	53(54.1)	24(24.5)
	> 15	10(22.7)	24(54.5)	10(22.7)
Type of ICU	General ICU	45(21.4)	119(56.7)	46(21.9)
	Surgical ICU	35(18.4)	121(63.7)	34(17.9)
	Medical ICU	29(18.4)	84(53.2)	45(28.4)
	Emergency ICU	18(18.9)	50(52.6)	27(28.5)
Professional title	Primary nurse	12(21.4)	30(53.6)	14(25.0)
	Senior nurse	38(18.3)	122(58.6)	48(23.1)
	Nursing Supervisor	77(19.8)	222(57.1)	90(23.1)
Specialist Nurse	yes	44(16.9)	149(57.1)	68(26.1)
	no	83(21.2)	225(57.4)	84(21.4)
Participate in IHT-related training	yes	101(17.8)	327(57.6)	140(24.6)
	no	26(30.6)	47(55.3)	12(14.1)
Utilisation of the IHT Checklist	yes	73(15.1)	277(57.5)	132(27.4)
	no	54(31.6)	97(56.7)	20(11.7)
Note:				

ICU: intensive care unit, IHT: intrahospital transport;Class 1, Class 2, and Class 3 represent latent profiles characterised by lower, moderate, and higher levels of perceived intrahospital transport safety, respectively.

4.2 LPA results

LPA was conducted using all 24 item-level IHTSS scores to examine heterogeneity in ICU nurses' perceived IHT safety. Models with one to five profiles were estimated (Table 2). A three-profile solution was selected based on a combination of statistical fit indices and substantive interpretability. Compared with the two-profile model, the three-profile model demonstrated lower *AIC*, *BIC*, and *aBIC* values, high entropy (0.981) and significant *LMRT* ($p = 0.027$) and *BLRT* ($p < 0.001$) results, indicating adequate model fit and classification precision.

Although the four- and five-profile models showed slightly improved fit indices, they included smaller profiles and non-significant LMRT results, limiting their interpretability. Accordingly, the three-profile model was retained. The identified profiles were characterised as lower, moderate and

higher perceived IHT safety, with average posterior probabilities ranging from 0.985 to 0.997 (Table 3). Descriptive statistics of IHTSS total scores across latent profiles and reference threshold–based groups are presented in Table 4. Mean item-level IHTSS scores for each profile are illustrated in Fig. 1.

Table 2
Latent profile analysis of IHTSS with model fit results (n = 653)

Profile	*k*	*LL*	*AIC*	*BIC*	*aBIC*	*Entropy*	*LMRT*	*BLRT*	*Proportion (%)*
1	48	-18083.762	36263.524	36478.640	36326.240	1.000	/	/	1
2	73	-14022.848	28191.695	28518.851	28287.076	0.993	0.002	< 0.001	74.145/ 25.855
3	98	-11458.924	23113.847	23553.042	23241.892	0.981	0.027	< 0.001	19.449/57.274/23.277
4	123	-10789.89	21825.782	22377.016	21986.491	0.973	0.118	< 0.001	13.152/43.699/20.574/22.574
5	148	-10323.069	20942.138	21605.411	21135.512	0.977	0.548	0.549	1.072/13.236/19.334/43.018/23.340
Note:									

k The Free parameters, **LL** The Log likelihood, **AIC** Akaike information criterion, BIC Bayesian information criterion,

aBIC Sample-size adjusted Bayesian information criterion, **LMRT** Lo-Mendell-Rub test, **BLRT** Bootstrap likelihood ratio test

Table 3
Average posterior probabilities of latent profile membership for the three-profile solution (n = 653)

profile	**Class 1 (%)**	**Class 2 (%)**	**Class 3 (%)**
Class 1	0.985	0.015	0.000
Class 2	0.003	0.991	0.006
Class 3	0.000	0.003	0.997
Note:			

Class 1, Class 2, and Class 3 correspond to latent profiles characterised by lower, moderate, and higher levels of perceived intrahospital transport safety, respectively

Table 4
Descriptive statistics of IHTSS total scores by latent perceived IHT safety profiles and reference threshold–based groups (n = 653)

	Category	Mean (SD)	N (%)	Score range	Effect size
Latent profile analysis (LPA)	Lower perceived IHT safety profile	73.04(8.39)	127 (19.4%)	[29, 85]	d_{3-1}= 6.33
	Moderate perceived IHT safety profile	92.93 (5.18)	374 (57.3%)	[79, 108]	d_{3-2}= 3.23
	Higher perceived IHT safety profile	116.00(5.09)	152 (23.3%)	[102, 120]	d_{2-1}=4.48
Reference threshold–based classification	Higher perceived IHT safety (≥ 101)	116.00 (10.62)	152 (23.3%)	[102, 120]	*d* = 2.92
	Lower perceived IHT safety (< 101)	87.89 (5.09)	501(76.7%)	[28, 101]	
Note:					

Cohen's d_{3-1}: refers to the standardized mean difference between the lower and higher perceived IHT safety profiles; Cohen's d_{3-2}: refers to the standardized mean difference between the lower and moderate perceived IHT safety profile; Cohen's d_{2-1}: refers to the standardized mean difference between the moderate and higher perceived IHT safety profiles.

4.3 ROC analysis results

ROC analysis was conducted as an exploratory, internally referenced approach to examine potential reference thresholds on the IHTSS in relation to the latent profiles of perceived IHT safety. Using LPA-derived profiles as an internal reference, the ROC curve showed clear separation between nurses with higher perceived IHT safety and those in the remaining profiles.

Nurses classified into the higher perceived IHT safety profile were treated as the reference group, while those in the lower and moderate perceived safety profiles were combined for comparative purposes. The ROC curve demonstrated strong internal separation between perceived IHT safety profiles (Fig. 2**)**. Based on internal separation relative to the latent profile structure, an IHTSS score of 101 was identified as the optimal exploratory reference threshold (Table 5). These results reflect internal consistency between the reference threshold and the latent profile classification.

Table 5
Sensitivity and specificity of selected IHTSS reference thresholds in relation to perceived IHT safety profiles (n = 653)

Cut-off score	Sensitivity	Specificity	Youden's index
< 103	1.000	0.944	0.944
< 101	**0.990**	**0.984**	**0.974**
< 98	0.943	1.000	0.943

4.4 Comparisons based on the reference threshold

To further examine the consistency of the reference threshold–based classification, IHTSS item-level scores and selected sociodemographic and professional characteristics were compared between groups defined by the threshold. Participants with IHTSS scores below the reference threshold consistently reported lower scores across all IHTSS items compared with those whose scores met or exceeded the threshold ($p < 0.001$), with large standardised mean differences (Cohen's d range: 1.51–1.80).

In addition, significant differences were observed in several sociodemographic and professional characteristics across both the LPA-derived profiles and the reference threshold–based groups (**Table S1**). Participants with lower perceived IHT safety were more likely to report lower educational attainment, lack of IHT-related training, and non-use of transport checklists. They also reported greater fear related to intrahospital transport and lower confidence in performing transport tasks. These findings support the internal coherence of the reference threshold in relation to perceived IHT safety within the study sample.

5. Discussion

This study employed a person-centred analytical approach to explore heterogeneity in ICU nurses' perceived IHT safety and to examine a preliminary, perception-based reference threshold for the IHTSS. Rather than aiming to establish a diagnostic or screening tool, these findings contribute to a more detailed understanding of variation in safety perceptions among ICU nurses and provide an exploratory framework to inform future research and needs assessment in this field.

5.1 Heterogeneity in perceived intrahospital transport safety among ICU nurses

A key finding of this study is the marked heterogeneity in ICU nurses' perceptions of IHT safety. LPA identified three distinct levels of perceived safety within the study sample, indicating that nurses' experiences and evaluations of IHT safety are far from uniform. Notably, a substantial proportion of nurses reported lower perceived IHT safety, suggesting that concerns may be prevalent in contemporary ICU practice (13, 14).

This finding is consistent with the broader patient safety literature (7), which indicates that safety perceptions are shaped not only by individual competence but also by workload, environmental complexity and organisational context (2, 3, 15). By adopting a person-centred analytical framework, this study moves beyond mean-level descriptions and reveals meaningful variation in perceived safety that may not be apparent in variable-centred analyses. Importantly, the identified profiles represent descriptive patterns in perceived IHT safety rather than objective transport risk and should not be interpreted as categorical risk classifications.

5.2 Interpretation of the reference threshold and internal separation

The exploratory ROC analysis yielded a reference threshold on the IHTSS that showed a high degree of separation relative to the LPA-derived perceived safety profiles. However, the unusually high AUC value observed in this study warrants cautious interpretation. As both the latent profile classification and the ROC analysis were derived from the same measurement instrument and dataset, the near-perfect separation is more likely to reflect internal consistency rather than true discriminative or predictive performance (12). Internal referencing and model optimisation may exaggerate apparent classification performance, thereby increasing the risk of overfitting and overly optimistic estimates (16).

In this context, sensitivity, specificity, and effect size estimates should be interpreted as indicators of internal separation between perceived IHT safety profiles, rather than as evidence of clinical utility or screening performance. The identified reference score of 101 therefore serves as a preliminary, perception-based benchmark for research-oriented classification and hypothesis generation, rather than for diagnostic decision-making or intervention allocation. External validation using independent samples and outcome-linked designs is required before broader or confirmatory applications can be considered.

5.3 Organisational and educational factors associated with perceived intrahospital transport safety

Although the reference threshold requires cautious interpretation, the observed associations between perceived IHT safety and institutional factors provide useful insights. Nurses who reported lower perceived IHT safety also indicated limited exposure to IHT-related training, reduced checklist use, heightened fear, and lower confidence during IHT-related tasks. These associations suggest that perceived IHT safety is closely linked to organisational structures, training opportunities, and the availability of supportive tools, rather than representing solely an individual-level characteristics (13, 17). From a clinical and managerial perspective, these findings underscore the potential value of targeting modifiable system-level factors—such as structured training programs, checklist implementation, and team coordination—in shaping nurses' perceptions of IHT safety (18). Importantly, the present findings do not demonstrate that use of the reference threshold improves training effectiveness or patient outcomes. Rather, they highlight areas where organisational support and educational emphasis may influence nurses' perceived safety during intrahospital transport, thereby informing future intervention development and evaluation (19).

5.4 Strengths, limitations, and system-level implications

Several limitations should be acknowledged when interpreting the findings of this study. First, the study was conducted among ICU nurses from tertiary hospitals in a single Chinese province, which may limit the transferability of the findings to other regions, healthcare systems, or organisational contexts with different staffing models, transport protocols, or safety cultures. Replication in more diverse institutional settings would therefore be valuable for assessing the generalisability of the identified perception profiles.

Second, although latent profile analysis provides a useful person-centred approach for identifying heterogeneity in perceived IHT safety, profile selection inevitably involves a degree of subjectivity and relies on a combination of statistical fit indices and substantive interpretability. In addition, the reference threshold identified through ROC analysis was both derived and evaluated using the same instrument and dataset. This methodological circularity means that the observed high degree of separation is more likely to reflect strong internal consistency rather than true predictive or discriminative performance. Independent validation using external datasets and outcome-linked designs is therefore required before broader applications of the reference threshold can be considered.

Third, the cross-sectional design precludes causal inference regarding the relationship between IHTSS scores and actual transport processes, adverse events, or patient outcomes. Future studies incorporating longitudinal data and objective transport-related indicators may help clarify how perceived IHT safety relates to real-world transport practices and safety outcomes.

Despite these limitations, the present findings offer several insights relevant to organisational and educational strategies aimed at strengthening transport safety in ICU settings. The observed associations between perceived IHT safety and factors such as training exposure, checklist use, and confidence during IHT suggest that nurses' safety perceptions may reflect broader system-level conditions, including organisational support, team coordination, and availability of structured safety tools. From a health services perspective, these findings highlight the potential value of strengthening institutional training programmes, reinforcing standardised transport checklists, and promoting interprofessional coordination during IHT processes. Such system-level efforts may contribute to improving nurses' preparedness and confidence during transport activities, while supporting a broader culture of safety in critical care environments. Importantly, these implications should be interpreted as exploratory and supportive, reflecting perceived safety rather than objectively measured transport risk or clinical outcomes.

6. Conclusions

This study identified heterogeneity in ICU nurses' perceived intrahospital transport safety using a person-centred approach and derived a preliminary, internally referenced threshold on the IHTSS. The reference score of 101 showed strong internal separation across latent profiles and should be interpreted as perception-based and exploratory rather than diagnostic or predictive. Lower perceived safety was associated with reduced training exposure, checklist use, and confidence, highlighting the relevance of organisational and educational factors. External validation is required before broader application.

Abbreviations

IHT*Intrahospital transport*

IHTSS: *Intrahospital Transport Safety Scale*

ICUs: *intensive care units*

LPA *Latent profile analysis*

ROC *Receiver operating characteristic*

MLR *maximum likelihood*

AIC *Akaike information criterion*

BIC *Bayesian information criterion*

aBIC *adjusted Bayesian information criterion*

ANOVA *one-way analysis of variance*

Declarations

8. Ethics approval and consent to participate

The study protocol was approved by the Medical Ethics Review Committee of the University of South China (approval number: xy-2021-39). All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to participation.

9. Consent for publication

No applicable.

10. Competing interests

The authors declare that there are no conflicts of interests.

11. Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

12. Funding

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13. Authors' Contribution

SSL: conceptualization, data collection, data analysis, writing-original draft & revising. AL, LT, and ZC: data analysis and interpretation of the data. WZ conceptualization, data collection, data analysis, writing-review & editing. All authors read and approved the final manuscript.

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Figures

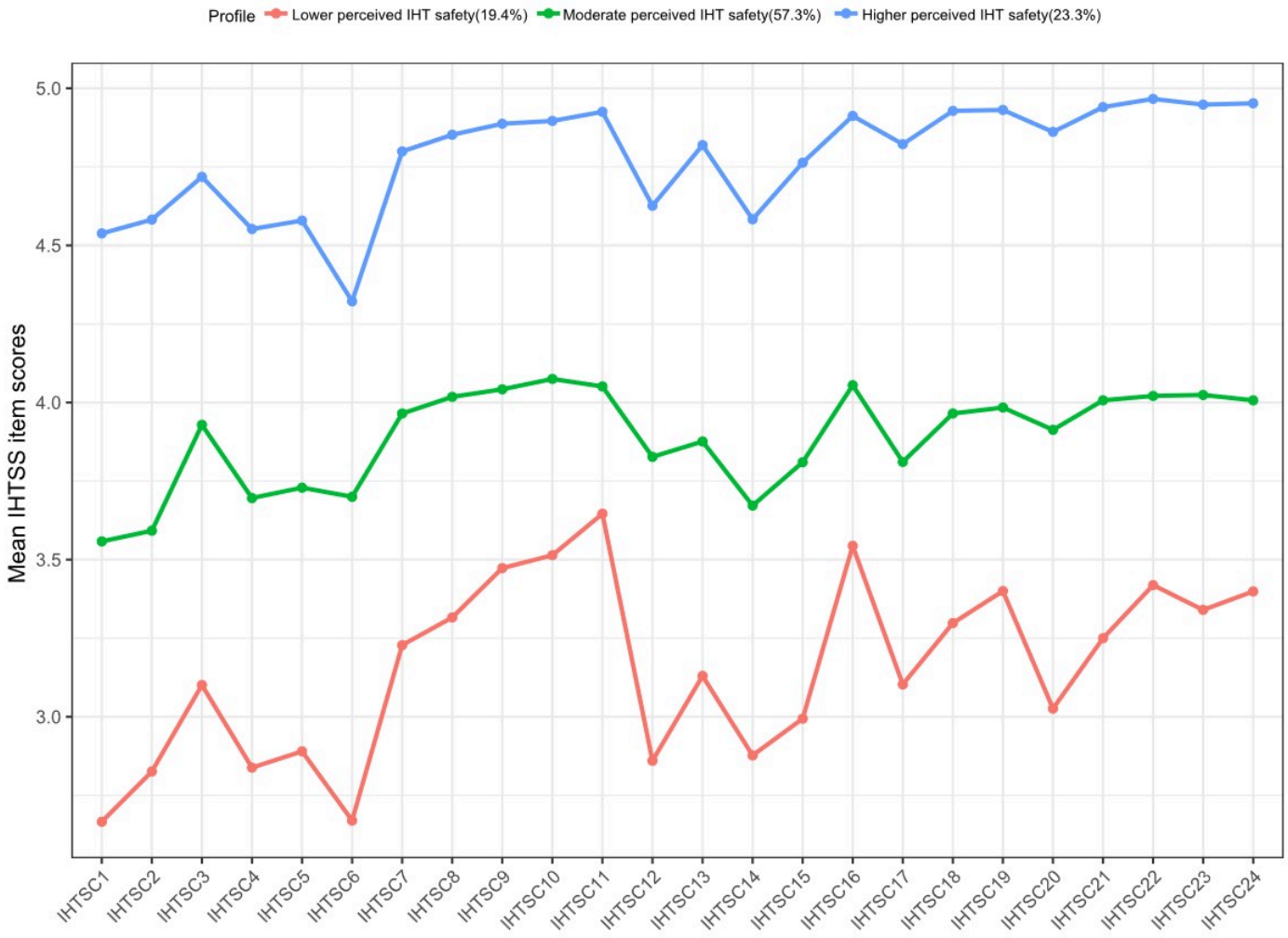


Figure 1

Mean item-level scores of the IHTSS across latent profiles(n = 653)

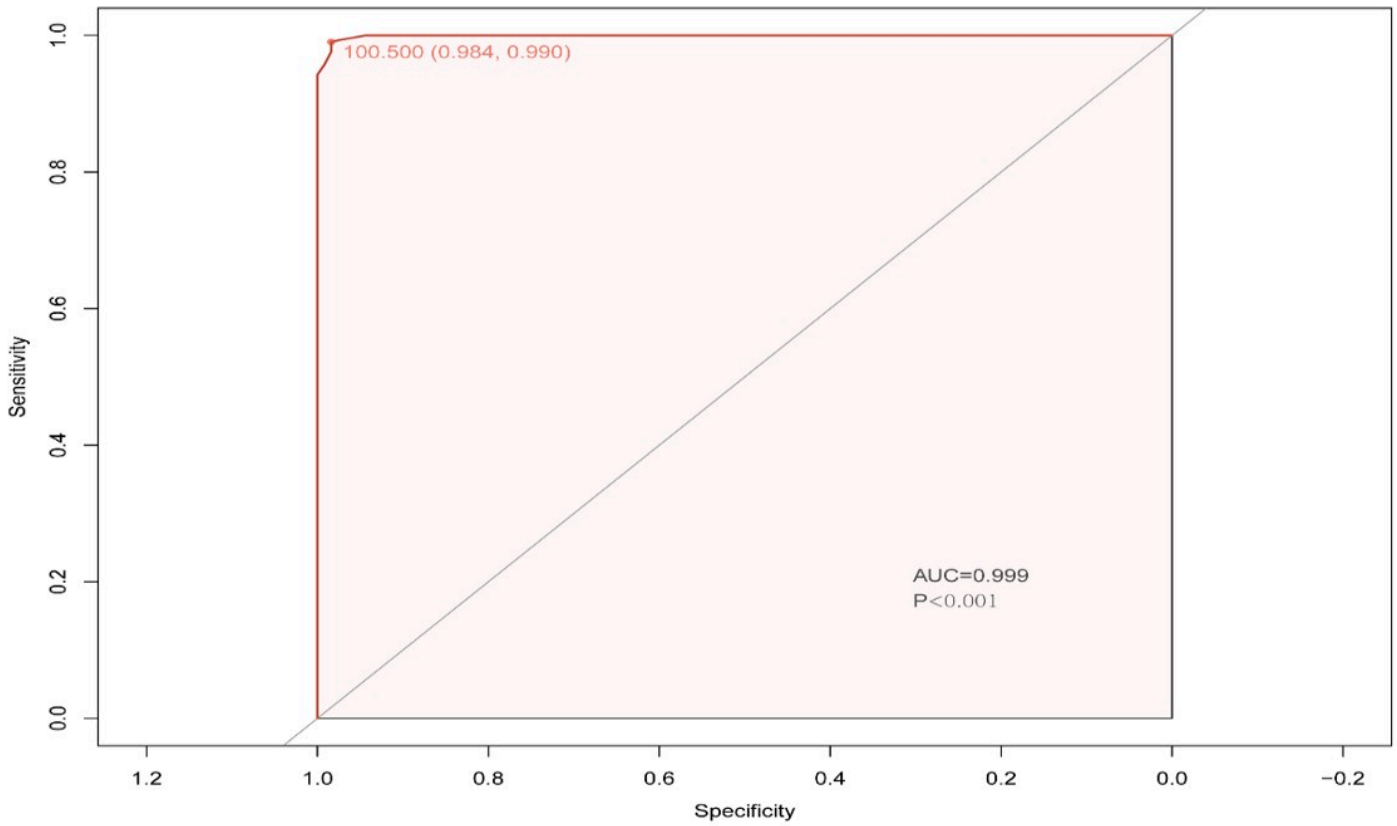


Figure 2

ROC curve illustrating internal separation of IHTSS scores in relation to perceived IHT safety profiles among ICU nurses (n = 653)

Supplementary Files

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- TableS1.docx