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RESEARCH

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Evaluation of different fall risk screening tools for risk prediction of ophthalmology inpatients

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Abstract

Aims and objectives To evaluate the risk factors for falls in adult ophthalmic inpatients and compare the accuracy and predictability of fall risk screening tools.

Methods A prospective cross-sectional study was conducted on a total of 1102 hospitalised patients in ophthalmology ward. Fall risk screening was performed within 8 h of admission using the following tools: Falling Risk Assessment Tool in Ophthalmology Inpatients (FRAT), Morse Fall Scale (MFS), Johns Hopkins fall-risk Assessment Tool (JHFRAT), St Thomas Risk Assessment Tool (STRATIFY), and Hendrich II fall-risk Model (HFRM). Taking the occurrence of falls or the occurrence of falls as a positive standard. The sensitivity, specificity, positive predictive value, negative predictive value and area under the curve of the risk assessment tool were calculated to determine accuracy and predictability.

Results In this study, 1102 met the inclusion criteria. The mean age was 56.81(58.00) and 536(48.6) were females. 61(5.54%) experienced falling or falling status. STRATIFY had the highest sensitivity(85.2%), followed by FRAT(70.5%). The specificity of MFS was the highest(91.7%), followed by FRAT(69.5%). However, in clinical practice, risk assessment tools are difficult to have high sensitivity and high specificity, so they are more inclined to high-sensitivity assessment tools to avoid missing high-risk groups. According to the evaluation results, FRAT has both good sensitivity and specificity. Furthermore, we identified significant risk factors for falls in ophthalmic patients, such as fall history, visual acuity, age, excretion and gait.

Conclusions FRAT was the most suitable fall assessment tool and was essential for reliable screening of people at high risk of ophthalmic falls.

Patient or public contribution After explaining the purpose, the patients received our fall risk assessment and answered the corresponding questionnaire questions.

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Keywords Fall, Ophthalmic patients, Risk assessment, Predictive validity

Introduction

In general, a fall is a sudden, involuntary, unconscious change in position, and a fall on the ground is defined as a fall on a lower plane, with or without injury [1]. Fall state refers to the patient in the process of falling, with the help of others, in the absence of causing a fall or timely prevention of falls, timely find a support point [2]. The World Health Organization established the World Alliance for Patient Safety to coordinate and maintain patient safety [3]. It is estimated that falls in 2015 were the 13th leading cause of death worldwide [4]. From 1990 to 2015, the number of fall-related deaths increased by 55%, with approximately 540,000 people dying from falls every year [5]. Since 2011, the Chinese Ministry of Health has officially included preventing and reducing the occurrence of accidents such as patient falls and falling beds an evaluation item for tertiary general hospitals in China. Falls, as an adverse event, are highly concerning to nurses at all levels. According to the statistics of the National Nursing Quality Data Platform, a survey of 18,024 fall patients in 490 tertiary hospitals revealed that falls with no injuries accounted for 32.04% of falls, Grade II injuries accounted for 15.65%, Grade III injuries accounted for 12.45%, and deaths accounted for 0.22% [6]. Therefore, it is necessary for nurses to assess the risk of patients falls through assessment tools and prevent the occurrence of these falls [7]. Studies have shown that sex, age [8], history of falls, visual impairment, eye disorders [9], balance disorders, musculoskeletal disorders, chronic diseases [10], mental health status [11], and medication [12] are the main risk factors for falls in patients.

Vision serves as the primary source of sensory information for humans (> 82%). Visual impairment not only affects visual function but also significantly impairs patients' independent living capabilities, increasing socioeconomic burden on families and society. According to the World Health Organization (WHO) in 2020, 1.1 billion people globally suffer from vision impairment, including 43 million blind individuals, 295 million with moderate to severe vision impairment, 258 million with mild vision impairment, and 510 million with myopia [13]. Visual impairment (VI), also known as visual disability, encompasses two categories: blindness and low vision. It refers to a visual dysfunction caused by various factors that results in reduced visual acuity in both eyes or a narrowed visual field, which cannot be restored or improved through surgery, medication, or conventional refractive correction, thereby exerting a substantial negative impact on daily life and social participation [14]. In 2023, the World Health Organization (WHO) put forward the use of "vision in daily life" as the criterion for evaluating visual impairment. This impairment is divided into mild, moderate, severe visual impairment, and blindness. Specifically, a visual acuity (VA) of less than 0.3 indicates moderate visual impairment, a VA of less than 0.1 represents severe visual impairment, and a VA of less than 0.05 means blindness. Moderate and severe visual impairments are equivalent to the traditional concept of "low vision". Additionally, a peripheral visual field radius of less than 10°is also classified as blindness [15].

Among them, visual loss is a recognized risk factor for falls, and several visual indicators are associated with higher fall rates [16, 17]. In different situations, the factors leading to falls differ. Ophthalmic diseases can cause visual impairment, such as decreased vision and a reduced visual field, affecting the movement and orientation of patients [18, 19]. Such patients are at high risk of falls and of brittle hip fractures because they cannot accurately judge their balance. Notably, not only elderly but also young and middle-aged people have a great risk of falls [20]. This not only interferes with their daily life and social participation but also delays recovery from such diseases and increases the risk of falling again, leading to physical disability and even death.

In the world, Morse Fall Scale (MFS), the Itaki Fall Risk Scale (Itaki FRS), and the Hendrich II Fall Risk Model (Hendrich-II) are the most commonly used fall risk tools in all adult units, including the neurology clinic with stroke patients, medical and surgical ward inpatients [21, 22]. However, in China, most of the commonly used fall risk assessment scales are aimed at the elderly population [23]. The evaluation content focuses more on musculoskeletal weakness, balance disorders, fall history, urination status/urination disorders, etc., and lacks an evaluation of eye symptoms and visual impairment. When assessing the risk of falls in patients with ophthalmic diseases, a large proportion of patients with high risk of falls often are not detected by these evaluations [24]. To improve the accuracy and scientific validity of risk assessment for ophthalmic patients, our team developed the Falling Risk Assessment Tool in Ophthalmology Inpatients (FRAT); in the early stages of test, this assessment has shown good reliability and validity [1, 25].

At the hospital where the study was conducted, FRAT was being used in ophthalmic inpatients [1]. However, nurses had concerns about the predictive performance of the FRAT and ophthalmic inpatients are a special group with a high risk of falls, and there is no uniform standard for fall risk assessment [25]. The Morse Fall Scale (MFS) [26], the Johns Hopkins Fall-Risk Assessment Tool (JHFRAT) [27], the St Thomas Risk Assessment Tool (STRATIFY) and the Hendrich II Fall-Risk Model

(HFRM) [28, 29] are all commonly used and recognized fall risk assessment tools in hospital. Therefore, it was considered to compare the ability of the FRAT developed by our team with four other fall risk assessment tools to screen for patients at risk of falls in ophthalmic inpatients, thus determining whether the FRAT is a more accurate fall risk assessment tool for ophthalmic inpatients and providing a reference for clinical intervention.

Methods

Aim

The main purpose of this study was to identify the best fall risk assessment tool, among the FRAT, the MFS, the JHFRAT, the STRATIFY and the HFRM, for use by ophthalmology departments at a tertiary teaching hospital. Fall risk factors in hospitals were also analysed in this study, focusing on the items of each fall assessment tool.

Study design and participants

The study is an observational prospective study design. Over the period February 2023 - January 2024, 1102 patients of the ages of 18 and above who were being monitored in the ophthalmology clinic of a state hospital after a diagnosis of an eye disease were consecutively invited to the research. The inclusion criteria for participants were as follows: (1) 18 years or older, (2) able to communicate orally in China and read the Chinese language, and (3) willing to participate in this study. The exclusion criteria were as follows: (1) impaired cognition.

Sample size

This study used a sample size calculation formula based on counting data rate: $N = Z^2_{\alpha/2}$ [P(1-P)]/ δ^2, where the statistical significance threshold is $\alpha = 0.05$, the bilateral $Z_{\alpha/2}$=1.96, P is an estimated value of the expected probability of occurrence; according to previous studies, the incidence of falls in hospitalized patients is approximately 40% [30]. In this study, δ was ± 10%. Therefore, the expected required sample size is $n = 93$, and considering a 20% no response rate, the final sample size is determined to be 117. This study included a total of 1105 samples, far exceeding the expected sample size.

Data collection methods

Prior to study implementation, investigators were trained and assessed using standardized criteria to ensure they gained comprehensive understanding of the five fall risk assessment tools, including the components, scoring of each item, and precautions. The entire data collection and assessment process was jointly completed by the second- and fourth-ranked authors within 8 h after the patient's admission [1]. 。The second author independently screened study participants according to the inclusion and exclusion criteria and collected general data, including gender, age, educational level, marital status, fall history, caregiver and visual acuity, based on medical records and on-site consultations. The fourth author completed the fall risk assessments using five scales and conducted ophthalmic examinations, such as visual field and visual acuity tests, to ensure consistency of measurement data.

Research tools

Demographic data collection

A self-designed Demographic Data Collection Form was developed, including gender, age, educational level, marital status, fall history, caregiver status, and visual acuity.

Ophthalmic assessments

Visual acuity and visual field examinations for all included participants were performed by the fourth author. Visual acuity testing used the Standard Logarithmic Visual Acuity Chart (GB 11533 – 2011), with a test distance of 5 m, and results were expressed as the reciprocal of the minimum resolvable visual angle. Visual field assessments were conducted using a Humphrey Field Analyzer (750i, Carl Zeiss Meditec, Germany).

Fall risk assessment instruments

A comparison of the items included in the five fall risk assessment tools is reported in Table 1.

i The Morse Fall Scale.
The MFS was developed and validated for acute care, long-term care and rehabilitation by Morse in 1989 [31, 32]. The tool consists of six items: history of falling, secondary disease, ambulatory aid, intravenous therapy/heparin lock, gait and mental status. The total score can range from 0 to 125. Here, the criteria for being considered high risk was a score of 45 or greater.

ii The Johns Hopkins Fall-Risk Assessment Tool.
The JHFRAT was developed by Johns Hopkins Hospital in 2005 and revised in 2007 [33, 34]. The tool consists of 7 items: age, fall history, elimination, medication, patient care devices, mobility and cognition. The total score can range from 0 to 34. Here, the criterion for being considered high risk was a score of 14 or greater.

iii The St Thomas risk assessment tool.
The STRATIFY was developed by Oliver in 1997 [28]. The tool consists of 5 items: fall history, cognition, visual impairment, elimination and mobility. The total STRATIFY score corresponds to the sum of all present risk factors and can range between 0 and 5. The higher the score is, the greater the risk a patient has of falling. Here, the criterion for being considered high risk was a score of two or

Table 1 Comparison of items included in the five fall risk assessment tools

	The Morse Fall Scale(MFS)(6 items)	The Johns Hopkins fall-risk Assessment Tool(JHFRAT)(7 items)	The St Thomas Risk Assessment Tool(STRATIFY) (5 items)	The Hendrich II fall-risk Model (HFRM) (8 items)	The Falling Risk Assessment Tool in Ophthalmology Inpatients (FRAT)(10 items)
Age		√			√
Gender				√	
Fall history	√	√	√		√
Medication		√		√	√
Intravenous therapy	√				
Elimination		√	√	√	√
Number of chronic diseases	√				√
Patient care devices	√	√			
Mobility	√	√	√	√	√
Mental status/ Cognition	√	√	√	√	√
Stroke history					√
Visual acuity		√	√		√
Corneal irritation sign					√
Visual field					√

greater. For the item "visual impairment," a positive finding was defined as visual acuity (VA) < 0.3 or a visual field radius < 10°.

iv The Hendrich II fall-risk Model.
The HFRM was developed to analyse the fall risk factors for acute care hospitals by Hendrich in 1988 and was revised in 1995 [31, 35]. The tool consists of eight items: confusion/disorientation/impulsivity, depression, altered elimination, dizziness or vertigo, sex (male), antiepileptics, benzodiazepines and the Get-Up-and-Go test. The total score can range from 0 to 16. Here, the criterion for being considered high risk was a score of five or greater.

v Falling Risk Assessment Tool in Ophthalmology Inpatients.
The FRAT was developed for ophthalmology inpatients by Li in 2023 [1]. The tool consists of ten items: Fall history, stroke history, chronic diseases, age, corneal irritation, visual acuity, visual field, balance, lower extremity sensation, excretion status, drug use and caregiver status. The total score can range from 0 to 110. Here, the criterion for being considered high risk was a score of eighteen or greater.

Data analysis

The data were entered into and analysed using SPSS 24.0. Another study team member conducted a cross-check in SPSS to ensure the accuracy of the data. Descriptive statistics were used to report the sociodemographic and clinical data of the patients, both overall and by falling outcome status. An independent t test was used to compare the normal continuous variables between the 'Faller' and 'Non-faller' groups. Pearson's chi-square test was used for categorical sociodemographic and clinical data. An independent t test was used to compare the normal continuous variables between the 'Faller' and 'Non-faller' groups. Pearson's chi-square test was used for categorical sociodemographic and clinical data. The sensitivity, specificity, positive predictive value and negative predictive value were calculated for the five screening tools for each of the falling outcomes. P values ≤ 0.05 were considered statistically significant.

Ethical considerations

The study complied with the principles of the Declaration of Helsinki and was reviewed by the Ethics Committee of Nanfang Hospital of Southern Medical University (No. NFEC-BPE-010). Informed consent was obtained from participants who agreed to participate.

Results

Demographic and clinical characteristics measured at baseline

A total of 1102 patients were recruited. A total of 61 (5.5%) patients were considered fallers (Table 2). The remaining 1041 (94.5%) patients with no fall outcomes were considered non-fallers (Table 1). Patients in the Faller group (mean age: 64.95 years; standard deviation, SD: 69.00 years) were significantly older than patients in the non-faller group (mean age: 56.02 years; SD: 57.00 years) ($p < 0.001$).

No significant differences were found between the two groups in terms of sex ($p = 1.00$) or marital status ($p = 0.098$). However, the groups were significantly different in terms of Age ($p < 0.001$), educational level ($p < 0.001$), disease type ($p < 0.001$), Falling of history ($p < 0.001$), Caregiver ($p = 0.012$) and low vision ($p < 0.001$) (Table 1).

Table 2 Socio-demographics of patients, overall and by falling outcome status

Socio-demographics	Groups	*N* = 1102	Faller(%) (*n* = 61)	Non-faller(%) (*n* = 1041)	$\chi 2$	*P*
Age (years)	Mean (SD[b])	56.81(58.00)	64.95(69.00)	56.02(57.00)	-4.915[c]	<0.001*
	Range	18–96	18–87	18–96	28.349[a]	<0.001*
	≤ 59	589(53.4)	15(24.6)	574(55.1)		
	60～69	297(27.0)	20(32.8)	277(26.6)		
	70～79	165(15.0)	20(32.8)	145(13.9)		
	≥ 80	51(4.6)	6(9.8)	45(4.3)		
Gender					0.008[a]	1.000
	Male	536(48.6)	30(49.2)	506(48.6)		
	Female	566(51.4)	31(50.8)	535(51.4)		
Education level					9.608[a]	0.008*
	High school or less	479(43.5)	38(62.3)	441(42.4)		
	College or university	612(55.5)	23(37.7)	589(56.6)		
	Master or PhD	11(1.0)	0	11(1.1)		
Marital status					4.652[a]	0.098
	Single	107(9.7)	2(3.3)	105(10.1)		
	Married	969(87.9)	56(91.8)	913(87.7)		
	Divorced/Widowed	26(2.4)	3(4.9)	23(2.2)		
Falling of history					210.524[a]	<0.001*
	Yes	44(4.0)	24(39.3)	20(1.9)		
	NO	1058(96.0)	37(60.7)	1021(98.1)		
Caregiver					6.349[a]	0.012*
	Family caregiver	534(48.5)	20(32.8)	514(49.4)		
	Self	568(51.5)	41(67.2)	527(50.6)		
Visual acuity [d]					27.931 [a]	<0.001*
	VA>0.3	848(77.0)	813(78.1)	35(57.4)		
	0.1< VA ≤ 0.3	178(16.2)	166(15.9)	12(19.7)		
	0.05< VA ≤ 0.1	45(4.1)	37(3.6)	8(13.1)		
	VA ≤ 0.05	31(2.8)	25(2.4)	6(9.8)		

*Significant value $P < 0.05$

[a] Chi-square test

[b] Standard Deviation (SD)

[c] Two-Independent-Samples Mann-Whitney U test

[d] Visual acuity in the better eye

Table 3 Logistic regression analysis of factors influencing the fall of ophthalmic inpatients ($n = 1102$)

Variables	B	SE	Wald χ^2	*P*
Constant	-5.277	1.152	20.997	
Age	0.027	0.012	4.968	0.026
Caregiver	0.239	0.322	0.549	0.459
Education level	-0.220	0.332	0.439	0.507
Falling of history	0.681	0.073	86.888	<0.001
Visual acuity	0.598	0.157	14.455	<0.001

Logistic regression analysis of the factors influencing falls in ophthalmic inpatients

This study used the occurrence of falls/falling status in ophthalmic inpatients as the dependent variable, assigning a value of 0 for 'no occurrence' and a value of 1 for 'occurrence'. Using the risk factors for falls in ophthalmic inpatients as independent variables, a binary logistic multivariate regression analysis was conducted. Age, visual acuity, and history of falls were independent factors affecting falls in ophthalmic inpatients ($p < 0.05$) (Table 3).

Receiver operating characteristic curve analysis of five fall risk assessment scales for screening the fall risk of ophthalmic inpatients

The ROC curves of the five fall risk assessment scales for the study data were determined. The AUC of the MFS was 0.695 ($p < 0.001$), the AUC of the HFRM was 0.657 ($p < 0.001$), the AUC of the JHFRAT was 0.749 ($p < 0.001$), the AUC of the STR was 0.756 ($p < 0.001$), and the AUC of the FRAT was 0.717 ($p < 0.001$), as shown in Table 4; Fig. 1.

The AUC, optimal critical value, sensitivity, specificity, Youden index, positive predictive value and negative predictive value results of the five fall risk assessment scales are shown in Table 4. The sensitivity of STRATIFY was the highest (85.2%), and the specificity and positive predictive value of the MFS were the highest (91.7% and

Table 4 Receiver operating characteristic curve analysis of five fall risk assessment scales in screening falls risk of ophthalmic inpatients

	MFS	JHFRAT	HFRM	STRATIFY	FRAT
Sensitivity (%)[a]	45.9	72.1	44.3	85.2	70.5
Specificity (%)[b]	91.7	66.7	77.1	56.6	69.5
AUC(%)	69.5	74.9	65.7	75.6	71.7
Positive predictive value (%)[c]	80.0	1.5	17.9	15.0	8.4
Negative predictive valued (%)[d]	94.9	93.5	95.3	96.4	97.8
Youden's indexes (%)[e]	37.6	38.8	21.4	41.8	40.0
Best critical value	20.0	5.50	1.5	0.5	25.5

a Fallers with high-risk score/total fallers × 100

b Non-fallers with low-risk score/total non-fallers × 100

c Fallers with high-risk score/patients with high-risk score × 100

d Non-fallers with low-risk score/patients with Low risk score × 100

e Sensitivity−(1 − Specificity) × 100

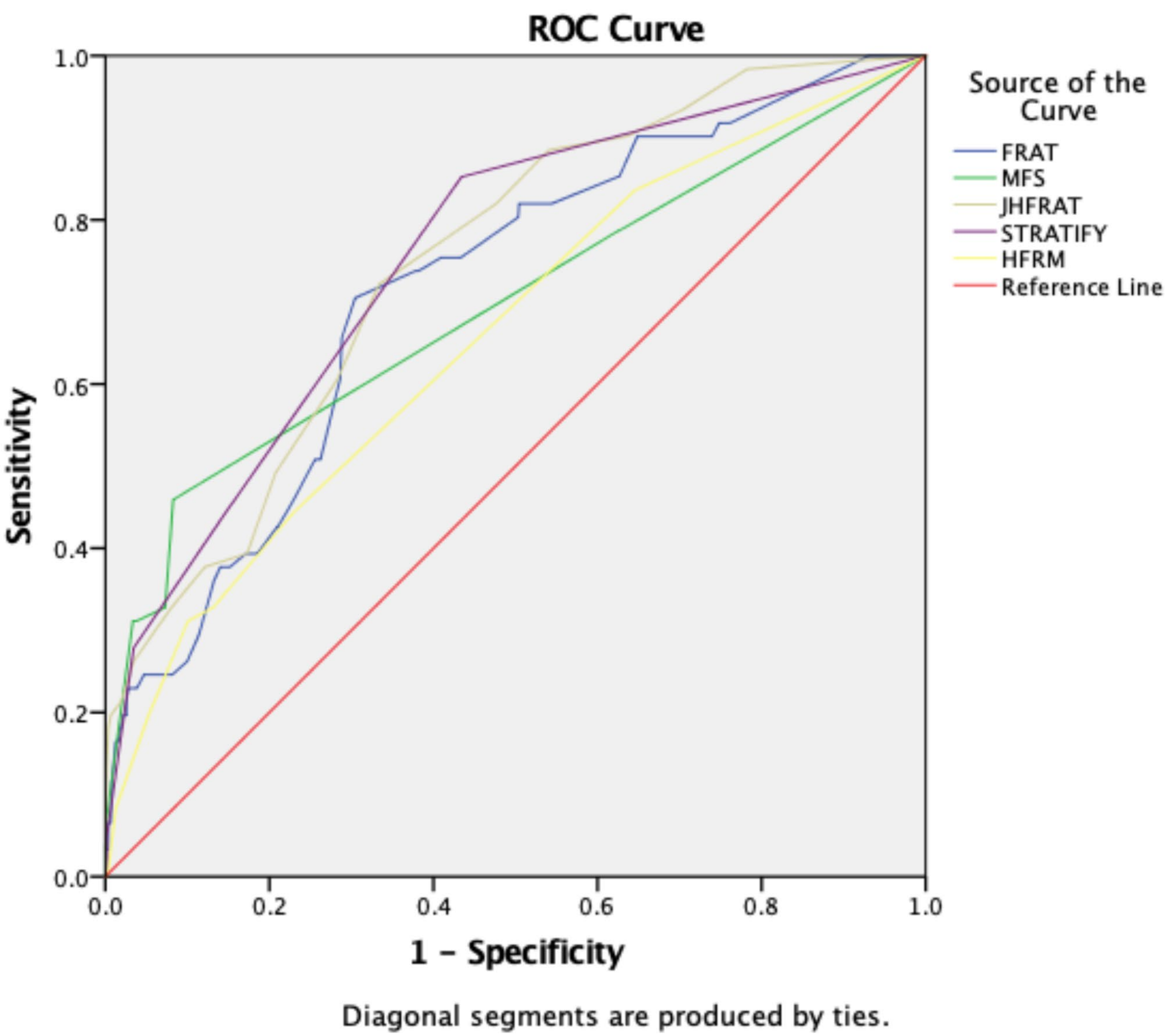

Fig. 1 ROC curve of five fall risk assessment scales

80%, respectively). The negative predictive value of the FRAT was the best at 97.8%. The Youden indices of the STRATIFY and FRAT were 41.8% and 40.0%, respectively. In the assessment of the risk of falls in ophthalmic inpatients, the optimal cut-off value of the MFS was 20, that of the JHFRAT was 5.5, that of the HFRM was 1.5, that of the STRATIFY score was 0.5, and that of the FRAT score was 25.5, as shown in Table 4.

Relationships between assessment items and falls

According to the univariate analyses, fall history and gait items on the MFS were significant predictors of patient falls. Gait (OR = 0.187) was the factor most significant predictor of patient falls, followed by fall history (OR = 0.030).

In the univariate analyses, age, fall history, elimination, and three items related to cognition in the JHFRAT were significant predictors of patient falls. The fall history item (OR = 27.450) was the most significant predictor of patient falls, followed by the elimination item (OR = 1.868) and the age item (OR = 1.395). In the univariate analyses, fall history and visual impairment items on the STRATIFY were significant predictors of patient falls. The fall history item (OR = 28.373) was the most significant predictor of patient falls, followed by the visual impairment item (OR = 2.182). In the univariate analyses, the altered elimination and Get-Up-and-Go test items on the HFRM were significant predictors of patient falls. The altered elimination item (OR = 1.665) was the most significant predictor of patient falls, followed by the Get-Up-and-Go test item (OR = 1.588).

In the univariate analyses, fall history, age, visual acuity, and excretion on the FRAT were significant predictors of patient falls. The fall history item (OR = 34.798) was the most significant predictor of patient falls, followed by the age item (OR = 3.273), the visual acuity item (OR = 2.041) and the excretion cases (OR = 1.974), as shown in Table 5.

Discussion

In clinical settings, the use of a fall risk assessment tool with high validity and reliability is essential for successfully identifying individuals who are prone to falls. In this study, the predictive performance of FRAT, which is used in the study hospital, was compared with that of the MFS, JHFRAT, STRATIFY and HFRM, and the relationship between the items of the five fall-risk assessment tools and fall occurrences was analysed. The predictive performance of the five tools was compared based on a cut-off score for being considered at high-risk of falling. While the difference was not considerably substantial, but there have been few previous studies on fall risk assessment in patients with eye disease, our results show that FRAT is superior to other fall risk assessment tools in terms of the combined Youden index and AUC sensitivity and specificity in patients with eye disease, which can provide guidance for clinical decision making. Furthermore, this study found that ophthalmic inpatients with fall history, excretion status, visual impairment, age and gait would be at risk of falls, suggesting that medical staff should strengthen health education and nursing evaluation for this group.

Fall risk assessment of ophthalmic inpatients should include all adult patients

Visual and eye diseases are very common comorbidities. These visual problems include contrast vision loss, dry eyes, diplopia due to impaired eye movement and cataracts. These problems may also complicate gait adaptation, as the ability to retrieve visual information from the environment is poor [36]. In fact, blurred vision has been shown to affect gait, especially in older people, leading to an increased risk of falls [37].

This study included adult ophthalmology inpatients. The results revealed that the average age was 56.81 (SD: 58.00) years, of which 53.4% of the subjects were young and middle-aged patients, indicating that the proportion of young people who needed hospitalization for ophthalmic diseases was relatively large. In addition, a total of 61 patients in this study, of which young patients accounted for 24.6% (see Table 1), had a history of falls, and the results revealed that there was a statistically significant ($P < 0.001$) link between disease and falls, indicating that the risk of falls in ophthalmic patients not only exists in elderly patients but also in young patients with eye diseases. Falls can lead to injury, loss of physical function, prolonged hospital stays, and increased nursing costs. As breadwinners and spiritual pillar of their families, young people often suffer more serious injuries after they fall. Moreover, falls are considered the fault of the nurse with a legal classification of crime and negligence [38, 39]. Nonetheless, the current commonly used fall assessment scales, which are mostly used in emergency settings or only for elderly patients, often ignore the importance of visual impairment and young groups in fall risk assessment. In this context, since there is currently no fall risk assessment tool suitable for ophthalmic inpatients in China, we previously proposed such an assessment scale to assess the fall risk of ophthalmic inpatients and conducted early stage testing showing good reliability and validity of the proposed scale. In addition, we evaluated the predictive performance of the four most commonly used fall risk assessment scales to verify the effectiveness of the MFS,

Table 5 Analysis of relationship between items of five tools

	B	SE	Wald χ^2	*P*	OR	95%CI
Morse Fall Scale						
fall history	3.511	0.381	85.082	<0.001	0.030	(0.014,0.063)
secondary disease	-0.176	0.318	0.307	0.579	1.193	(0.640,2.223)
ambulatory aid	-0.378	0.644	0.345	0.577	1.460	(0.413,5.155)
intravenous therapy/heparin lock	-	-	-	-	-	-
gait	1.677	0.602	7.755	0.005	0.187	(0.057,0.608)
mental status	-					
The Johns Hopkins fall-risk Assessment Tool						
Age	0.333	0.166	4.024	0.045	1.395	(1.008,1.932)
fall history	3.312	0.369	80.619	<0.001	27.450	(13.321,56.566)
elimination	0.625	0.242	6.666	0.010	1.868	(1.162,3.002)
medication	-0.164	0.187	0.771	0.380	0.848	(0.588,1.224)
patient care devices	-	-	-	-	-	-
cognition	-	-	-	-	-	-
mobility	0.136	0.081	2.792	0.095	1.145	(0.977,1.343)
The St Thomas Risk Assessment Tool						
fall history	3.335	0.360	85.679	<0.001	28.373	(13.930,57.791)
patient agitation	-	-	-	-		
visual impairment	0.763	0.315	5.873	0.015	2.182	(1.174,4.057)
incontinence	0.263	0.361	0.531	0.466	2.205	(1.402,3.467)
mobility	0.269	0.369	0.533	0.465	1.301	(0.641,2.640)
The Hendrich II fall-risk Model						
confusion/disorientation/impulsivity	-	-	-	-	-	-
depression	-	-	-	-	-	-
altered elimination	0.504	0.160	9.940	0.002	1.655	(1.210, 2.263)
dizziness or vertigo	-	-	-	-	-	-
gender (male)	0.076	0.269	0.081	0.777	1.079	(0.637, 1.827)
antiepileptics	-	-	-	-	-	-
benzodiazepines	-	-	-	-	-	-
Get-Up-and-Go test	0.463	0.119	14.996	<0.001	1.588	(1.257, 2.007)
The Falling Risk Assessment Tool in Ophthalmology Inpatients						
Fall history	3.550	0.401	78.273	<0.001	34.798	(15.851,76.394)
Stroke history	0.109	0.566	0.037	0.848	1.115	(0.367,3.383)
Age	1.186	0.351	11.435	<0.001	3.273	(1.646,6.506)
Chronic diseases	-0.873	0.459	3.619	0.057	0.418	(0.170,1.027)
Drug use	0.075	0.342	0.048	0.827	1.078	(0.551,2.107)
Corneal irritation sign	0.009	0.053	0.030	0.864	1.009	(0.910,1.119)
Visual field	0.130	0.341	0.145	0.703	1.139	(0.584,2.221)
Visual acuity	0.714	0.267	7.123	0.008	2.041	(1.209,3.448)
Balance ability	0.155	0.471	0.108	0.742	1.168	(0.464,2.937)
Lower extremity sensation	0.133	0.463	0.082	0.774	1.142	(0.461,2.834)
Excretion cases	0.680	0.255	7.091	0.008	1.974	(1.197,3.257)
Caregiver	-0.186	0.343	0.294	0.588	0.831	(0.424,1.626)

JHFRAT, STRATIFY, HFRM and FRAT in ophthalmic inpatients.

FRAT are more suitable for fall risk screening in ophthalmic inpatients

In this study, sensitivity refers to the percentage of patients with a risk assessment of fall risk in patients with actual fall history, reflecting the ability of the assessment scale to predict patients who will fall [40]. Specificity refers to the percentage of patients with no risk of falls among patients who actually did not fall [40], which reflects the ability of the assessment scale to predict patients who will not fall.

The sensitivity, specificity, positive predictive value, negative predictive value, AUC and Youden index of the MFS, JHFRAT, HFRM, STRATIFY and FRAT scales were calculated to analyse the predictive value of these scale. ROC analysis revealed the relationship between sensitivity and specificity for continuous changes based on the cut-off point. The ideal ROC curve has a low false negative rate and high accuracy. The AUC is the probability of accurately distinguishing true positives and true negatives according to the scale. ROC analysis revealed that the AUC of STRATIFY was the largest (0.756), followed by those of JHFRAT (0.749) and FRAT (0.717), while the AUCs of the MFS and HFRM were lower, 0.695 and 0.657, respectively. The accuracy was greater when the AUC was 0.560 ~ 0.700 [41].

According to this classification standard, STRATIFY, JHFRAT and FRAT have better accuracy than the remaining fall risk assessment tools. In this study, the STRATIFY scale had the highest sensitivity (0.852) for patient fall risk assessment, but the specificity was lower at 0.566, indicating that the false positive rate was higher. However, the sensitivity of the other four assessment scales were ordered as follows: JHFRAT (0.721) > FRAT (0.705) > MFS (0.459) > HFRM (0.443). Meanwhile, the specificities were as follows: MFS (0.917) > HFRM (0.771) > FRAT (0.695) > JHFRAT (0.667) > STRATIFY (0.566). The assessments could be ranked according to the Youden index as follows: STRATIFY (0.418) > FRAT (0.400) > JHFRAT (0.388) > MFS (0.376) > HFRM (0.214). In terms of the negative predictive value, the following ranking was observed: FRAT (0.978) > STRATIFY (0.964) > HFRM (0.953) > MFS (0.949) > JHFRAT (0.935). The reason why the positive predictive values are not compared is that the positive predictive values were generally very low. This may have been caused by most rating scales having generally low high-risk cut-off values, resulting in an increase in the number of people deemed high-risk relative to the actual number of people falling.

Second, the reason for the low positive predictive value of the FRAT scale may be that the predictive performance was not originally considered when verifying the reliability and validity of the scale, leading to the use of a simple interquartile range for the classification of fall risk. Therefore, ophthalmic patients with a score of ≥ 18 points are considered high risk, and the screening is not accurate enough. According to this study, when the score is ≥ 25.5, the patient's high-risk rate is the highest, and its scoring scheme should be further optimized. Some scholars [42] believe that an excellent assessment scale should ideally have high sensitivity (i.e., true positive rate) and specificity (i.e., true negative rate), but it is difficult to achieve both conditions in actual clinical nursing work. Fall risk assessment, i.e., identifying patients at risk of falls, is the primary measure for fall safety management. Therefore, an assessment scale with high sensitivity and high positive predictive value is more desirable; that is, assessment scales should have strong screening ability and a low probability of missing high-risk people rather than being having higher specificity. Therefore, the comprehensive results show that the JHFRAT and FRAT are more suitable for fall risk screening in ophthalmic inpatients.

As shown in Table 2, the MFS contains 6 items, the JHFRAT has 7 items, the STRATIFY has 5 items, the HFRM has 8 items, and the FRAT has 10 items. The five scale items are objective indicators, and their calculation method is simple. The number of items makes each easy to conduct. They are all convenient, scientific and objective assessment tools. However, these findings revealed that the FRAT, which showed better performance in assessing the risk of falls in ophthalmic inpatients, both include assessments of patients with visual impairment; this emphasizes the relationship between visual impairment and falls and allows these assessments to be more predictive. From the perspective of item content, the evaluation of the FRAT for ophthalmic factors is not limited to visual impairment but also includes the evaluation of visual field and ocular irritation symptoms. This content is more comprehensive and more conducive to accurate screening of high-risk populations for ophthalmic falls. In general, the FRAT is more suitable for fall risk assessment of ophthalmic inpatients due to its predictive performance and item integrity.

Fall history, visual acuity, age, excretion and gait are risk factors for falls in ophthalmic inpatients

Univariate analysis was performed to determine the relationships between the items of the five assessment scales and the falls of ophthalmic patients. A history of falls, excretion, visual acuity, age, and gait were found to be significant risk factors.

First, fall history is an important item in the MFS, JHFRAT, STRATIFY and FRAT. In particular, based on the STRATIFY, FRAT and JHFRAT items, the risk of falls in patients with a history of falls was 28, 34 and 27 times greater than that in patients without a history of falls, respectively. However, based on the MFS items, this risk difference is considered to be relatively small. These data also further emphasize the importance of nurses in assessing patients' fall history. In the health education of patients, attention should be given to increasing awareness of the importance of patients and their families in determining the risk of falls. At the same time, nurses also need to check whether there is a history of falls through the patient hospitalization system to avoid missing information.

The second important risk factor is excretion status. Among the research tools used in this study, the JHFRAT, STRATIFY, HFRM and FRAT all include patient excretion in the assessment process. The results showed that when considering the JHFRAT, HFRM and FRAT items, the risk of falls in patients with more frequent excretion was approximately 2 times greater than that in patients with normal excretion. In our actual investigation, we found that abnormal excretion occurs mainly at night when the patient's own vision is particularly impaired due to eye diseases. Night activities increase the risk of falls, with excretion always being associated with activity. This conclusion serves as a reminder to medical staff that ward inspections should be strengthened at night and that conditional wards should be equipped with lights for patients to use at night to improve the safety of patient activities [43].

The third item is visual acuity. Among the five fall assessment scales used in this study, the JHFRAT, STRATIFY and FRAT include visual-related assessment items, and the study findings revealed that these items are high-risk factors for falls in ophthalmic patients. In terms of the STRATIFY and FRAT items, the risk of falls was twice as high in patients with visual acuity as in patients with normal vision. This finding is similar to those of other research showing that visual impairment is a common risk factor for falls [44, 45]. Furthermore, multivariate analysis results (Table 1) revealed that increasing severity of visual impairment was associated with higher fall risk in patients ($p < 0.001$). Two specific types of factors lead to falls: external factors and internal factors. Among the external factors, environmental factors, such as insufficient lighting and the smoothness of the ground, are important causes of falls in patients. These conditions are closely related to falls caused by visual impairment [46]. Second, the integration of visual, vestibular and somatosensory inputs is crucial for postural adjustment. Defects in these sensory patterns can jeopardize postural stability and increase the risk of falls. Although visual impairment is not the only cause of falls, identifying its specific risk factors can facilitate the development of strong preventive measures [47]. Therefore, for ophthalmic patients, visual impairment is a common and important risk factor for falls. To accurately evaluate the risk of falls in ophthalmic patients, visual impairment must be considered. However, the JHFRAT cannot accurately calculate the risk due to visual impairment. This scale integrates visual assessment items with items such as mobility into one dimension, such that there is no significant relationship between the item and visual impairments. Furthermore, the STRATIFY tool was found to have ambiguous item descriptions for visual impairment, failing to specify concrete metrics such as visual acuity or visual field tests for assessing visual impairment. This ambiguity hinders clinical staff from conducting fall risk assessments and complicates its application in fall risk evaluation for ophthalmic inpatients.

The fourth factor is age, which is an important risk factor for falls in ophthalmic patients. In our study, there was a significant difference between the average age of the faller group and the average age of the nonfaller group, indicating that advanced age is an important factor for predicting falls in patients. Although falls can occur at any age, the risk of falling increases with age. This finding is similar to the conclusions of Hu et al. [24]. The study also found that the risk of falls in men is higher than that in women, but no significant difference was found in this study. The reason may be due to the fact that the scholar 's research did not focus on patients with a certain type of disease. Ophthalmic diseases, especially chronic diseases, are mostly accompanied by a clear age trend. The older the age, the more serious the disease.

The fifth factor is gait, which is an important risk assessment factor included in all five assessment tools. In particular, for the slow and uncoordinated movement item in the HFRM, the risk of falls in ophthalmic patients with slow and uncoordinated movements was 1.6 times greater than that in ordinary people. This finding is consistent with a previous study [48] showing that gait is an important factor in determining patients' fall risk. However, no significant differences were found for the other scales. The reason may be that in the clinical environment, gait assessment is more indirectly assessed through interviews with patients or caregivers than through direct observation by nurses. In the HFRM, the patient's gait and balance are evaluated via the "get-up-and-go" test. This test is more rigorous and objective than observation and evaluation by health care workers, so it is better for identifying quantitative differences. However, many current assessments of gait account for the general inability of elderly people to move. If a patient is unable to perform this test due to the use of a wheelchair or being bedridden, it may lead to an underestimation of the total fall risk assessment score. The above conclusions found that in clinical work, it is recommended that future medical workers should conduct gait assessment tests as far as possible to improve the accuracy of fall risk when conducting fall risk assessment when the patient 's own situation allows. However, in the face of patients with significant gait abnormalities, health education should be carried out to remind patients to walk slowly or use transportation tools. When walking uphill or standing up from tools such as wheelchairs, special attention should be paid to preventing falls [49].

Developing comprehensive measures to prevent falls can effectively reduce the incidence of falls in inpatients with ophthalmology

Visual impairment reduces individuals' ability to detect environmental hazards, and falls can exert severe impacts on personal physical and mental health as well as socioeconomic development [50]. Current domestic studies have identified numerous fall-related risk factors, including age, gender, severity of visual impairment, body mass index, psychosocial factors, physical environment, muscle strength, posture, and gait [51, 52]. Among patients with ophthalmic diseases, fear of falling is positively correlated with fall incidence. Studies have indicated that due to their heightened fear of falling, these patients experience diminished self-efficacy, leading to behaviors such as depression, avoidance, and reduced social interaction. This vicious cycle further exacerbates the risk of falls [53]. 。Therefore, developing comprehensive fall prevention strategies is critical for reducing fall incidence in ophthalmic inpatients.: ①Comprehensive fall risk assessment and monitoring serve as the foundational premise for fall prevention. To address this, our research team developed an ophthalmic-specific falls risk assessment tool (FRAT) and compared its utility, demonstrating better predictive and practical utility. Using standardized assessment tools like FRAT to screen high-risk patients enables nurses to conduct personalized assessments and implement targeted interventions based on individual patient conditions [54], However, guidelines also emphasize that nurses should not rely solely on assessment tools but must integrate their professional judgment and apply critical thinking to conduct comprehensive and dynamic fall risk assessments for patients [55].②Daily safety management is essential for reducing fall risk. Multiple studies have indicated that activities in spacious, clutter-free, and well-lit environments, combined with selecting appropriate protective devices based on patients' physical mobility, can effectively reduce fall risk in ophthalmic inpatients. These measures are characterized by low cost and easy implementation, making them recommended for clinical adoption [54, 56]. t is worth noting that CBM International, an international blindness prevention organization, has proposed the establishment of barrier-free facilities for blind individuals, including: Installing prominent red or yellow color bands in corridors to indicate walking directions; Keeping wall lamps illuminated at night; Placing call bells within easy reach of patients.③Education and training are effective approaches to enhance self-management skills for fall prevention in ophthalmic patients. Studies have shown that nursing staff should provide patients with fall prevention manuals and use multichannel communication to increase their knowledge of fall prevention. Notably, given the variability in patients' physical conditions and fall risk factors, nursing staff should tailor health education to individual needs to reduce fall risk effectively.

Limitations

This study had several limitations. Firstly, the study's single-center design may not reflect the varied experiences of ophthalmic inpatients across different Chinese healthcare settings. At the same time, since the purpose of our study was to compare the application of the prediction of fall risk, only 61 patients had fall or fall status in the end, which could introduce a risk of selection bias. In addition, this study mainly investigated the applicability and prediction of 5 commonly used fall risk assessment scales in ophthalmic patients, and there were few data analyses on the correlation between visual impairment and falls. In the future, our team will continue to improve the quality of ophthalmology, and further investigate the relationship between ophthalmic factors and falls, in order to provide a better theoretical basis for the continuous improvement of clinical quality of ophthalmology.

Conclusion

The purpose of this study was to determine the best tool for fall risk assessment of ophthalmic inpatients among the FRAT and the other four common fall risk assessment scales and to analyse the relationships between the items in the fall risk assessment tool and the occurrence of falls. The Youden index and AUC were used to compare the sensitivity and specificity. The results indicated that the FRAT had better predictive performance than other tools in the risk assessment of ophthalmic patients.

Relevance to clinical practice

Visual impairment especially visual acuity impairment has been consistently identified as a high risk factor for falls, but no in-depth research has been conducted on the risk of falls in ophthalmic patients. Risk assessments for falls are mostly conducted for elderly and emergency department patients. In this study, the fall risk assessment tool previously developed by our team was compared with four other commonly used fall risk assessment tools for the clinical evaluation of ophthalmic patients, and its predictive performance was tested, ultimately revealing its good clinical significance. We found that, regardless of which fall risk assessment tool was used, fall history, excretion, visual acuity, age, and gait were significant risk factors for falls in ophthalmic patients.

Abbreviations

AUC	Areas Under the Curve
CI	Confidence Interval
FRAT	The Falling Risk Assessment Tool in Ophthalmology Inpatients
HFRM	The Hendrich II fall-risk Model
JHFRAT	The Johns Hopkins fall-risk Assessment Tool
MFS	The Morse Fall Scale
NPV	Negative Predictive Value
OR	Odds ratio
PPV	Positive Predictive Value
ROC	Receiver operating characteristic
STRATIFY	The St Thomas Risk Assessment Tool

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Author contributions

Conceived and designed the experiments: Li ML, Yang J, Wang YJ. Acquisition of data: Huang QH, Xie L. Analysis and interpretation of data: Li ML, Wang YJ. Drafting and critical revision of manuscript: Li CM, Huang QH. Interpretation of data and critical revision of manuscript: Li CM, Huang QH. All authors devised the focus of this study.

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

Declarations

Ethics approval and consent to participate
The study complied with the principles of the Declaration of Helsinki and was reviewed by the Ethics Committee of Nanfang Hospital of Southern Medical University (No. NFEC-BPE-010). Informed consent was obtained from participants who agreed to participate.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

Clinical trial number
Not applicable.

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