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The accuracy of the pediatric assessment triangle in assessing triage of critically ill patients in emergency pediatric department

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ABSTRACT

Background: The Pediatric Assessment Triangle (PAT) is a rapid evaluation tool that establishes a child's clinical status and his or her category of illness in order to direct initial management priorities. However, only few studies have examined its accuracy in assessing triage of critically ill patients in the emergency pediatric department (EPD) in China.

Objective: To quantitatively validate the accuracy in assessing critically ill medical children and nurses' acceptance of PAT in the EPD.

Methods: This is a prospective observational study performed at The First People's Hospital of Kunshan from January to May 2019. Ill children arriving to the EPD were assessed by trained nurses with the PAT and Pediatric early warning score (PEWS) at the same time. The five-level triage system used as the gold standard for comparing the accuracy of PAT was tracked following the triage. PEWS was compared with PAT in terms of assessment time and the degree of nurse' acceptance.

Results: A total of 1608 subjects were included in this study, of whom 74 were critically ill. The AUROCC to screen out the critical children evaluated by PAT was 0.963. When the cut-off value of PAT score was 1, its sensitivity, specificity, PPV and NPV were 93.24%, 99.15%, 84.15% and 99.67%, respectively. The maximum value of the YI of PAT scored with 1 was 0.924. For the different categories of diseases, PAT had a better performance in assessing non-respiratory critical diseases (vs. respiratory critical diseases), with values of AUROCC of 0.986 vs 0.930, YI of 0.969 vs 0.858, respectively. For the different age of sick children, PAT had a better performance in assessing critical diseases in children aged 1 to 36 months (vs. 3 to 14 years), with values of AUROCC of 0.978 and 0.899, YI of 0.952 and 0.797, respectively. The assessment time of PAT was 13.81 ± 6.41 s, while PEWS score was 37.24 ± 10.29 s ($t = 17.27$, $p < 0.001$). The VAS scores of nurses' acceptance of PAT and PEWS were 9.27 ± 0.87 and 8.57 ± 1.52, respectively.

Conclusions: PAT can be used as a rapid and effective assessment tool in emergency triage in China. When a child's PAT score is 1 or more, the child's condition is critical and priority treatment should be arranged.

1. Background

The number of newborn babies in China is increasing, and it is estimated that it will reach 1 to 2 million every year [1]. A survey on the development status of pediatrics in the tertiary grade A hospital in Guangzhou showed that the number of emergency pediatrics from 2012 to 2016 is on the rise, and the number of hospital visits has significantly increased, much faster than an increase in pediatric medical staff [2]. We investigated the visits to the emergency department of Kunshan First People's Hospital in China and found that the number of emergency visits in pediatrics had increased year by year, from 100,000 in 2015 to nearly 140,000 in 2018. In 2019, the number of pediatric emergency department (EPD) visits increased sharply by 180,000, which put a great burden on the triage work of emergency nurses.

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Although there is a large number of visits to the EPD, the proportion of children with acute and severe illness is very small. Tao et al. [3] found that only 10% of children in the pediatric emergency room were critically and severely ill. On the other hand, Su et al. [4] noted that only 20% of children in the EPD were critically and severely ill. So, there is an urgent need for a rapid assessment tool to help triage nurses to accurately distinguish who is a critical child from the large number of ill children, so that they can be treated in time [5].

Currently, the tools being widely used to assess the condition of critically ill children include the vital signs assessment method including the consciousness breath blood pressure pulse (CRBP) [6], pediatric critical illness score (PCIS) [7] and pediatric early warning score (PEWS) [8]. For CRBP, due to the great changes in the physiology and growth of infants and children, the vital signs of children in various stages are different, so the reference standards are significantly different [9]. In addition, there are some changes in vital signs when the children cry, resulting in irregular changes in the vital signs [10]. At present, there is a lack of consensus about the parameters of the vital signs in normal children in China and globally. Most of the parameters on normal vital signs are derived from studies on healthy children [11] and even under the perfect conditions, vital signs are not always reliable or accurate [12].

The PCIS score includes electrolytes and other indicators, resulting in poor assessment of the condition of severe cases of non-electrolyte disorders [13], such as respiratory, nervous and connective tissue disorders, which is obviously a limitation in evaluating prognostic efficacy [14]. In addition, the assessing time of PCIS is relatively longer. On the other hand, PEWS is a commonly used assessment tool for pediatric patients. It can be used as a reference for different triage of children at EPD, and helps to determine whether children need to be admitted to the intensive care unit [15]. Zhou et al. [16] found that emergency children with a PEWS score of 3 or more had a significantly higher probability of admission to pediatric intensive care unit (PICU), with a sensitivity of 97.0% and a specificity of 78.2%. PEWS has a good predictive ability on respiratory, circulatory and neurological diseases, but poor ability for hematological, nephrological and toxicological diseases. While a study by Lillitos et al. [17] showed that emergency children with a PEWS score above 3 had a specificity of 93%, the sensitivity was only 32% for the diagnosis of medical diseases.

The Pediatric Assessment Triangle (PAT) proposed by Dieckmann RA et al. [18] in 2000 includes three aspects: Appearance, Work of breathing and Circulation to the skin. The main content was revised in 2014 and changed to three arms of PAT triangle: Consciousness (child's action, interaction, consolability), Breathing (a. abnormal airway sounds: hear the child's stridor, wheezing, or groans without a stethoscope; b. changes in breathing work: compulsive posture, three-concave sign, nasal agitation) and Color (pallor, cyanosis, and mottling on the child's skin), namely C-B-C [19]. If any arm of the PAT triangle is abnormal, the child is considered to be in an "abnormal" state, indicating that the child's condition is unstable. The application of PAT, as the first step of the clinical assessment, can predict the type and severity of the child's diseases (respiratory, circulatory, central nervous or metabolic disorders) [20]. It can also ensure that more serious cases are prioritised and that timely and effective measures are taken to prevent the deterioration of the condition. When PAT is used to assess the child's condition, medical staff can quickly judge whether the child's condition is "normal" or "abnormal", only by "seeing" and "listening" instead of medical equipment and laboratory indicators. The evaluation time is only 30–40 s. Gausche-Hill et al. [21] explored the accuracy of PAT to identify the severity of a child's condition among prehospital emergency nurses and found that the sensitivity and specificity were 77.4% and 90.0%, respectively. In 2017, Paniagua et al. [22] performed a retrospective cohort study to determine whether PAT predicts the hospitalization of children with acute asthma attacks and found that abnormal PAT was an independent risk factor for hospitalization. The results of another retrospective cohort study conducted by Fernández et al. [23] in 2016 showed that children with abnormal PAT needed to be given quick intervention, and their risk of hospitalization was higher. However, in china, there are only few studies that reported the application of PAT in emergency situation. In 2014, Chen et al. [5] applied PAT to the triage of the EPD and found that PAT improved the early identification of patients with potential critical illness in the pediatric EPD and reduced children' mortality, although the Chen's study did not analyze the sensitivity and specificity of PAT. Therefore, there is an urgent need to further explore the application of C ill patients in EPDs in China.

2. Methods

2.1. Study design and setting

This was a prospective observational study in which we analyzed a cohort of children attending the EPD of a tertiary general hospital in China during a period of 5 months (January to May 2019). The study was approved by the ethics committee of The First People's Hospital of Kunshan (No.2018-08-L002). Considering the urgency of the child's condition and the innocuous nature of the PAT assessment of the condition, the informed consent form was signed after triage. After critical group entered the emergency rescue room in a stable condition, the children's family members were informed of their condition and signed an informed consent form. Non-critical group signed the consent form in the waiting process.

2.2. Study population

Patients who were < 14 years in age and attending the EPD with an internal medical problem were included. Patients with the following conditions were excluded: (1) Newborn babies; (2) Pre-hospital death; (3) Visiting hospital regularly; (4) Voluntary discharge; (5) Relatives or caregivers who refused to cooperate with the medical assessment.

2.3. Researcher training

In order to ensure that the nurses participating in this study master the application of PAT, nurses who were responsible for assessing and classifying ill children at the triage setting of EPD received the theoretical and practical training of PAT. A total of 30 nurses were divided into two groups. Each group received an hour session training. A LEC large-screen timer was used for timing and checked daily by nurses. Firstly, a multimedia lecture was delivered by the researcher at the demonstration classroom of EPD. The first part was theoretical education of PAT including the concept, assessing procedures and scoring method of PAT. The detailed contents included: (1) It is a rapid assessment tool consisting of three aspects of consciousness, work of breathing, circulation to the skin that establishes a child's clinical status and his or her category of illness to direct initial management priorities; (2) It involves a three-step process. First, the nurse notes whether each aspect of the PAT is normal or abnormal with specific criteria. Consciousness is to observe a child's action, interaction, consolability. Work of breathing describes the child's respiratory status. Clinical signs such as abnormal airway sounds (eg, stridor, grunting, and wheezing), abnormal positioning, retractions, or flaring of the nostrils on inspiration determine an abnormal work of breathing. Circulation to the skin reflects the general perfusion of blood throughout the body. Observe the skin for any of the following conditions: pallor, cyanosis and mottling. Second, the nurse uses the pattern of abnormalities to form a general impression: respiratory diseases, gastrointestinal diseases, neurological diseases, infectious diseases, accidental damage, circulatory diseases, blood diseases, endocrine diseases. Third, the nurse utilizes the results of assessment to determine immediate management priorities. (3) Each abnormal parameter scores 1 point with a maximum score possible of 3. PAT $= 0$ means that the condition of the child is relatively stable, while PAT ≥ 1 is unstable.

The second part was the practical part of the training: mainly for nurses to master how PAT assesses ill children. The nurses assessed the eight simulated cases using PAT and gave the complete triage procedures, respectively; and simultaneously timed. After the assessment, the nurse was instructed to record the assessment results on "PAT Study Form". Lastly, the nurses were tested for mastery of PAT theory by a written examination. The criterion for passing was 90 percent of the total score. The criterion for the accurate use of PAT tools was the correct PAT scoring of three cases. Those who failed to pass the examination were retrained and reassessed.

2.4. Assessment tools

2.4.1. Pediatric assessment triage (PAT)

The PAT was developed by the American Academy of Pediatrics in 2000 as a tool for the initial assessment of pediatric patients in a pre-hospital environment [18].In 2014, the American Academy of Pediatrics published the third edition of the pediatric Pre-hospital Emergency Standardized Simulation Course, in which PAT content was revised. The revised tool assesses 3 arms (consciousness, work of breathing, and circulation to the skin) describing the child's physiological status and guiding the initial approach to treatment. An abnormality noted in any of the arms of the PAT denotes an unstable child, that is, a child who will require some immediate clinical intervention. It requires no equipment and takes only a few seconds to perform assessment. Fernández et al. [23] found that patients with abnormal findings in the PAT applied by trained nurses at triage showed that the patients were at a higher risk of hospitalization. This would indicate that PAT seems to be a valid tool for identifying the most severe patients as a first step in the triage process.

2.4.2. Pediatric early warning score

Pediatric early warning score (PEWS) was formulated by Monaghan et al. [24] in 2005 based on early warning score (EWS). PEWS combines the physiological and the pathological characteristics of children. It is a commonly used tool to assess the severity of ill children. In the EPD, PEWS can serve as a tool for nurses to triage ill children [15]. PEWS is composed of three major assessment projects of consciousness, cardiovascular system and respiratory system. Observation indexes include 11 specific indicators (irritability, hypnosia, lethargy, coma, skin color, capillary refill time, heart rate, breathing, aspirating depression, groan, fraction of inspiration O_2). It is convenient to use and easy to operate, with a total score of 0–9. Previous studies have shown that PEWS score 3 is the best cut-off for predicting critically ill children, indicating the trend of deterioration of the condition and that the patient can be transferred to intensive care unit [17,25,26]. PEWS, as a regular tool in EPD in China, was taken as a tool for comparison in this study.

2.4.3. Pediatric five-level triage system

The criteria and procedure of pediatric five-level triage system are formulated by Children's Hospital of Fudan University, based on the Australasian Triage Scale and the Canadian Triage and Acuity Scale [27]. It assesses a range of elements including waiting time, age, temperature, symptoms of various categories of diseases and accidental trauma. According to the results of its assessment, a patient is classified into one of five triage levels: emergency, high urgency, urgency, low urgency and no urgency. For each level, there is a maximum recommended waiting time until medical intervention. The waiting times from Levels 1 to 5 are immediate, within 15 min, within 60 min, within 120 min and above 180 min, respectively. The child with level 1 or level 2 is divided into the critical group which is defined as a condition of sufficient potential severity that could result in acute mortality [27]. The child with any of the other three levels is divided into the non-critical group.

2.4.4. Visual analog scale score

Visual analog scale (VAS) score is widely used for the evaluation of pain in clinical practice. It is characterized by high sensitivity and simplicity. It is also used to evaluate subjective data such as satisfaction and acceptance [28,29]. The method is to use a moving ruler marked with 10 scales, with 0 and 10 ends respectively. A score of 0 means very unacceptable, and 10 means very acceptable. VAS was used to assess the degree of nurses' acceptability of PAT and PEWS. At the end of this study, the nurses were scored directly on a moving ruler based on their subjective feelings after using PAT and PEWS.

2.5. Data collection and processing

When a child arrived at the EPD, nurse A using PAT and nurse B using PEWS would assess them at the same time and the time was recorded. Using the LEC large-screen timer, they recorded the duration of assessment and filled out corresponding "PAT Study Form" which contained the demographic data of the patient, PAT assessment sheet and PEWS assessment sheet. Nurse A then continued to collect the child's clinical data needed for assessment of the five-level triage system within 6 h by reviewing the emergency records, laboratory examination results, outpatient and emergency medical records of the ill child since admission. Based on the data collected, different levels of the severity of the ill children were divided into two groups, critical group or non-critical group, using the five-level triage system as the standard.

2.6. Outcomes

The primary outcomes were the diagnostic performance of PAT which included the area under the receiver operating characteristic curve (AUROCC), sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and Yorden index (YI). The secondary outcomes were the assessing time and the degree of nurses' acceptability of PAT and PEWS.

2.7. Data analysis

Categorical variables were described using frequencies and percentages. The statistical analysis was performed using Microsoft Excel 2010 and IBM SPSS software (version 19.0). The diagnostic performance of PAT to predict the severity of illness in children attending EPD were determined by AUROCC, sensitivity, specificity, PPV, NPV and YI. To determine the most appropriate cut-off of the PAT, we chose the cut-off with the maximum value of YI. Diagnostic performance measures (sensitivity, specificity) of the PAT were calculated as well as a range of cut-off points of the PAT using the VassarStats website. The assessing time of PAT and the degree of nurses' acceptability of PAT and PEWS were compared using two independent sample *t*-test.

3. Result

A total of 1636 children attended the EPD during the study period. Twenty-eight (1.7%) patients were excluded for refusing to participate in the study. The final analysis was based on 1608 patients' data. There were 897 (55.78%) male, 844(52.49%) children aged 1 to 36 months, and 1319 (82.03%) children with respiratory diseases. Age range was 1 month to 14 years. Baseline characteristics are summarized in Table 1.

There were 74 critically ill children in total and 1534 non-critically ill children (Fig. 1). The rate of agreement between the PAT assessment result and the actual situation of the sick child was 93.24%. Among the critically ill children, there were 30 children with non-respiratory diseases and 58 children aged 1 to 36 months. The rates of agreement between the PAT assessment result and the actual situation of the child with respiratory diseases and non-respiratory diseases were 26 (86.67%) and 43(97.73%), respectively; with 1 to 36 months and 3 to 14 years in age were 56(96.55%) and 13(81.25%), respectively (See Table 2).

Table1
Baseline characteristics of study population (n = 1608).

Characteristics	N(%)
Male	897(55.78)
Age groups	
1 to 12 mo	237(14.74)
13 to 36 mo	607(37.75)
3y < age < 8 y	521(32.40)
8 to 14 y	243(15.11)
Final diagnosis	
Respiratory diseases	1319(82.03)
Gastrointestinal diseases	170(10.57)
Neurological diseases	58(3.61)
Infectious diseases	45(2.80)
Accidental damage	11(0.68)
Circulatory diseases	3(0.19)
Blood diseases	3(0.18)
Endocrine disease	2(0.12)
Triage levels of Emergency Severity Index[a]	
1	43(2.67)
2	31(1.93)
3	732(45.52)
4	572(35.57)
5	230(14.30)

[a] Triage level indicates 5-level Emergency Severity Index; 1 = highest (immediate life threat) and 5 = lowest (no urgency).

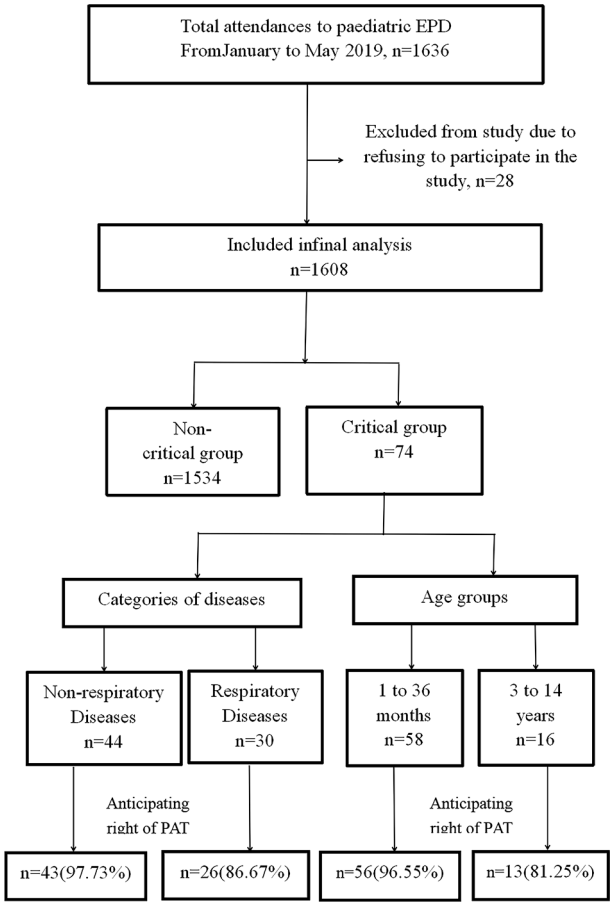

Fig. 1. Enrolment flow diagram EPD, emergency pediatric department.

3.1. The ROC and optimal cut-off value of PAT in assessing the severity of diseases in children

The AUROCC of PAT to screen out the critically ill children was 0.963. (Fig. 2). Further analysis the diagnostic performance of the PAT

Table 2
Diagnostic performance of PAT to identify critically ill children.

	Critical group (N)	Anticipation right N (%)	Anticipation wrong N (%)
All participants	74	69(93.24)	5(6.76)
Category of illness			
Respiratory	30	26(86.67)	4(13.33)
Non-respiratory	44	43(97.73)	1(2.27)
Age group			
1 to 36 mo	58	56(96.55)	2(3.45)
3 to 14 y	16	13(81.25)	3(18.75)

PAT, pediatric assessment triangle.

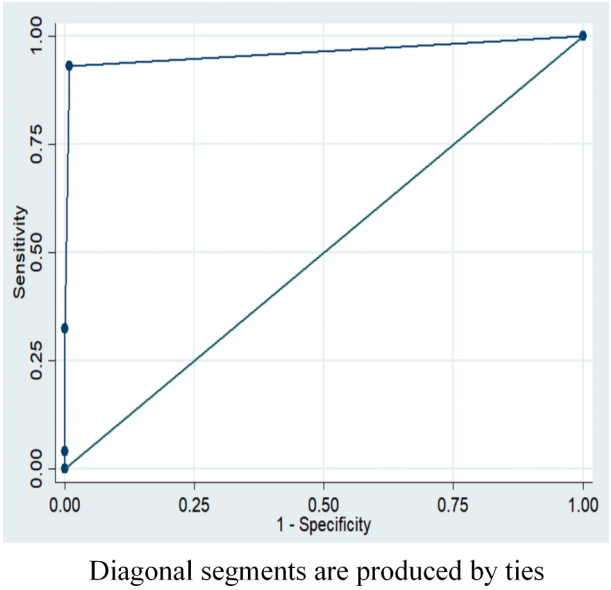

Fig. 2. PAT receiver operating curve for assessing the severity of illness in children at emergency pediatric department.

at different scores was: PAT = 0, it showed 100% sensitivity, but no specificity; while PAT = 2 or 3, it was 100% specificity, but poorly sensitivity. When PAT = 1, the optimal cut-off value with YI was 0.924, a sensitivity of 93.24%, specificity of 99.15%, PPV of 84.14% and NPV of 99.67%. A summary of diagnostic performance is outlined in table 3.

Further analysis of the diagnostic performance of the PAT at subgroups included: (1) For different categories of illness; the values of AUROCC were above 0.9 and YI were above 0.8 in both respiratory and non-respiratory diseases, while PAT had better diagnostic performance in non-respiratory diseases (AUROCC: 0.986, sensitivity:

97.73%, specifity: 99.18%, PPV: 96.00%, NPV: 99.61%, YI:0.969); (2) For different ages; PAT had better diagnostic performance in children aged 1 to 36 months than in children aged 3 to 14 years. It's AUROCC, sensitivity, specificity, PPV, NPV and YI were 0.978, 96.61%, 98.60%, 84.00%, 99.74%, 0.952, respectively. The comparison results

Table 3
Diagnostic performance of PAT to identify critically ill children at different scores.

PAT scores	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	YI
0	100.0	0.00	4.60	—	0.000
1	93.24	99.15	84.15	99.67	0.924
2	32.43	100.00	100.00	96.84	0.324
3	4.05	100.00	100.00	95.58	0.041

PAT, pediatric assessment triangle;PPV, positive predictive value; NPV, negative predictive value;YI, Yorden index.

are described in Table 4.

3.2. The diagnostic performance measures of the PAT and PEWS

In this study, PAT and PEWS performed very similarly with AUROCC of 0.963 and 0.966, respectively. The sensitivity, specificity, PPV, NPV and YI of the PAT in assessing the severity of the illness in children were all higher than those of PEWS, especially PPV which was more significant (84.15% and 76.40%, respectively). PAT's ability to assess true positive patients was superior to PEWS. A comparison of the diagnostic performance measures of the PAT and PEWS are shown in Table 5 and Fig. 3.

The assessing time and the degree of nurses' acceptability to PAT and PEWS were compared. The results showed PAT took less time to assess the child's condition (13.81 ± 6.41 s vs 37.24 ± 6.41 s) compared to PEWS. The VAS scores of nurses' acceptance to PAT and PEWS were 9.27 ± 0.87 and 8.57 ± 1.52, respectively, which indicated the nurses had a tendency to use PAT (See Table 6).

4. Discussion

Among the 1608 subjects recruited in this study, the male to female ratio was 1.26:1, which is consistent with the ratio (1.168:1) of the sixth census in China in 2010 [30]. The top five diseases in emergency pediatrics were respiratory diseases (82.03%), digestive diseases (10.57%), neurological diseases (3.61%), infectious diseases (2.80%), and accidental injuries of children (0.68%). Respiratory diseases were mainly airway infection and bronchial pneumonia; digestive diseases were mainly diarrhea and abdominal pain; neurological diseases were convulsions. Among the age of onset, the most of emergency visits (37.75%) were 13–36 months. The above information is basically consistent with the survey results of emergency pediatrics visits in other domestic medical institutions in recent years. For example, Zhou et al. [31] retrospectively analyzed the disease spectrum characteristics of 6463 children in EPD, and the results showed that the age of onset was primarily in 28d to 3 years old, and the top three diseases were upper respiratory tract infection (68.41%), bronchial inflammation (10.09%) and diarrhea (6.66%).

4.1. PAT's predictive performance

As a rapid assessment tool, PAT can predict the severity of the child's condition and the type of disease by evaluating his/her consciousness, breathing and circulation, which should be suitable for any grade of medical units [23]. Therefore, this study explored the ability of PAT to assess acute and severely ill children in emergency pediatrics in China and the results showed that the AUROCC and YI of PAT for predicting critically and severe ill children at the best cut-off value (with 1 score) were as high as 0.963 and 0.924, respectively. On the other hand, the NPV reached 99.67%, which indicated that the missed diagnosis rate of PAT was very small. This result would appear to be better than the findings of Gausche-Hill et al. [21] in which the sensitivity and specificity of PAT in assessing the severity of the child's condition were 77.4% and 90.0%, respectively. The difference in the performance of using PAT to assess the ability of children with critically and severe illness may be due to the different criteria for evaluating children who are critically and severely ill. In Gausche-Hill et al (32) study, the criterion was that the child's condition was stable or unstable and the disease spectrum included only five aspects, namely; respiratory distress or failure, shock, central nervous system disorders, metabolic disorders and heart failure [21]. However, in this study, the gold standard referred is the grading standard of five-level triage system [27], covering diseases ranging from respiratory system, digestive system, nervous system, urinary system, blood system, circulatory system, to allergic reaction, drowning, poisoning, electric shock, etc.. Therefore, the disease spectrum assessed is relatively broad. For the emergency room of a hospital, it is more appropriate to adopt the standards of this study that cover a

Table 4
Diagnostic performance of PAT (score = 1) for assessing the severity of illness in children with different categories of illness and different ages.

	Category of illness		Age group	
	Respiratory	Non-respiratory	1 to 36 mo	3 to 14 y
AUROCC	0.930	0.986	0.978	0.899
Sensitivity(%)	86.67	97.73	96.61	80.00
Specificity(%)	99.15	99.18	98.60	99.73
PPV(%)	70.00	96.00	84.00	86.00
NPV(%)	99.69	99.61	99.74	99.60
YI	0.858	0.969	0.952	0.797

AUROCC, the area under the receiver operating charateristic curve; PPV, positive predictive value; NPV, negative predictive value; YI, Yorden index.

Table 5
Comparison of diagnostic performance of PAT and PEWS for assessing the severity of illness in children at emergency department.

Test characteristics for diagnosing	PAT	PWES	χ^2	*p*
Optimumcut-off value(score)	1	3	—	—
AUROCC	0.963	0.966	0.10	0.746
Sensitivity(%)	93.24	91.89	0.10	0.754
Specificity(%)	99.15	98.63	1.90	0.168
PPV(%)	84.15	76.40	1.61	0.258
NPV(%)	99.67	99.61	0.10	0.758
YI	0.924	0.906	—	—

PAT, pediatric assessment triangle; PEWSPEWS, pediatric early warning score; AUROCC, the area under the receiver operating characteristic curve; PPV, positive predictive value; NPV, negative predictive value; YI, Yorden index.

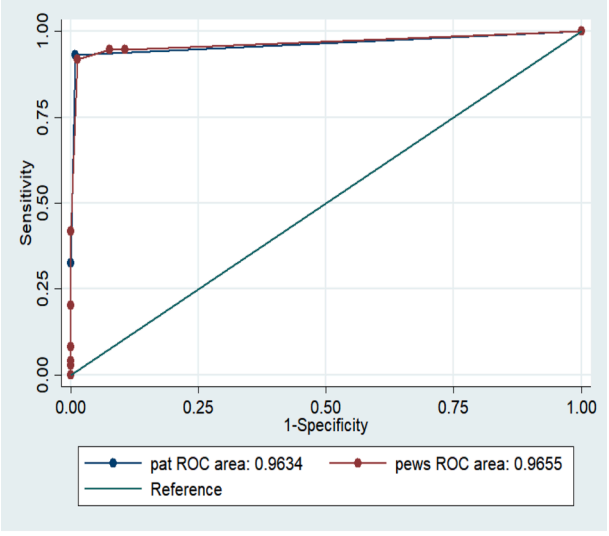

Fig. 3. Comparison of PAT and PEWS receiver operating curves for assessing the severity of illnessin children in emergency department.

Table 6
Comparison of the assessing time and the degree of nurses' acceptability of PAT and PEWS.

	PAT	PEWS	*t*	*p*
Assessing time(s)	13.81 ± 6.41	37.24 ± 10.29	17.27	< 0.001
VAS score(score)	9.27 ± 0.87	8.57 ± 1.52	2.50	0.018

PAT, pediatric assessment triangle; PEWS, pediatric early warning score.

broad spectrum of conditions. In addition, it is known from this study that PAT is very effective for triage screening in the emergency room of Chinese hospitals.

4.1.1. PAT's predictive ability in different categories of diseases

As a rapid assessment tool, PAT may have different levels of effectiveness in assessing the urgency and severity of different diseases [20,21].Due to fewer cases of diseases other than the respiratory diseases, this study divided the children into two groups: respiratory diseases and non-respiratory diseases. After analyzing the ability of PAT to evaluate critical diseases for the two groups, it was found that the effectiveness of PAT to assess non-respiratory critical and severe diseases was better than that of the respiratory critical and severe diseases. In this regard, the AUROCC were 0.986 and 0.930, and YI were0.969 and 0.858, respectively. The reason may be that during the onset of acute asthma and acute asthmatic bronchitis (SaO_2 > 95%) in children, these were considered to be an emergency rather than a critically ill child, compared with gold standard in which it is considered to be critical if there are abnormal breath sounds (wheezing, groaning) in PAT assessment. This may have resulted in slight poor performance in assessing some of respiratory diseases. However, one of the great advantages of PAT is that, for assessing the severity of respiratory diseases, it's negative predictive value reached 99.69, indicating that the probability of missed assessment of PAT is very small.

4.1.2. PAT's predictive ability in different age groups

In addition, this study analyzed the ability of PAT to assess critical diseases in children of different age groups, and found that PAT's ability to assess critical diseases in children under 3 years of age was better than that of children over 3 years old, with AUROCC of 0.978 and 0.899, with YI of 0.952 and 0.797, respectively. The possible reason is that in the early stage of severe disease in infants and young children, the more common clinical symptoms are wheezing, dyspnea and other abnormal breathing difficulty, while children over 3 years old are usually with high fever and their wheezing occurs relatively less [32,33]. As an assessment tool, PAT has a strong ability to evaluate breathing-related problems, but not high fever-related conditions [23], so the tool has a slightly weaker ability in assessing children' conditions over 3 years old.

4.2. Comparison of the effectiveness of PAT and PEWS to predict critically ill children in EPD

The domestic and foreign studies [17,25] have shown that PEWS has important application in predicting critical and severe conditions in children. When the PEWS score is $\geq$ 3 points, it indicates that the child is in serious condition and needs immediate intervention or admission to the PICU ward. This study took this tool as a reference to compare the predictive capabilities of the two tools. The results showed that the AUROC of PAT in predicting critically ill children was the same as that of PEWS and that both of PEWS and PAT have high resolution in predicting the severity of the disease in children. However, when applying PAT assessment, professionals do not need to use a stethoscope to listen to the child's stridor, do not need to detect vital signs, and do not need related laboratory indicators, so it is convenient and easier to use and should be promoted in the clinical settings.

4.3. Nurses' acceptance of PAT

Benito et al. [34] conducted a questionnaire survey of emergency medical staff who received PAT training to understand the doctor's acceptance of PAT. The results showed that 84.9% of emergency doctors after PAT training insisted on using PAT for initial assessment for children. In the evaluation, 81.6% of emergency doctors believed that the use of PAT helped in establishing a diagnosis and it is of great significance in clinical practice. In this study, we found that less time was taken using PAT for initial assessment for nurses in the emergency room and they were more willing to use PAT to assess children's critical situation instead of using PEWS. This finding is consistent with the results of Benito et al. [34].

4.4. Clinical practice

In the terms of PAT's predictive performance in EPD and nurses' acceptance of PAT, it can be used as a rapid and effective assessment tool in emergency triage in China in the future clinical practice.

5. Limitations

There were some limitations in this study. Firstly, only the ill children visiting emergency pediatric medical were included in this study, and the next step we will explore the effectiveness of PAT in emergency pediatric surgery children and children with diseases other than respiratory system. Secondly, the nurses' acceptance in this study was investigated only in the outpatient and emergency room of the studied hospital. Whether it is applicable to other hospitals requires further clinical research to verify.

6. Conclusion

(1) PAT can be used as an assessment tool for rapid screening of the severity of children in the emergency department in China;
(2) When the PAT score is more than or equal to 1 point, the child can be predicted to be critically ill and give priority to treatment;
(3) PAT is easily accepted by triage nurses in the emergency room, so this tool can be used as a quick and effective disease assessment tool in emergency pediatrics.

CRediT authorship contribution statement

Xiaomin Ma: Conceptualization, Data curation, Formal analysis. **Yuanyuan Liu:** Formal analysis, Writing - original draft. **Mingqing Du:** Investigation. **Omorogieva Ojo:** Writing - review & editing. **Lijuan Huang:** Investigation. **Xiaohua Feng:** Investigation. **Qiong Gao:** Investigation. **Xiaohua Wang:** Supervision, Writing - review & editing.

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