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A validation study of three early warning scores in early identification of gastric cancer patients with deteriorating condition after gastrectomy

Xinli Shi[1†], Huijuan Jie[1†], Naifa Li[1†], Qiongshan Liu[1], Yue Wang[1], Changquan Wu[1], Wenwen Jiang[1], Bolin Zhang[1,3*†], Shurong Lai[2*†] and Honglu Xu[1*]

Abstract

Objectives Early warning scores (EWS) aim to rapidly identify patients at risk of critical illness or life-threatening events before deterioration occurs in clinical settings. This study aims to validate the ability of three commonly used early warning scores, namely the National Early Warning Score (NEWS), the Early Warning Score (SEWS), and the Modified Early Warning Score (MEWS), to identify patients with deterioration after gastric cancer resection in general wards.

Methods This retrospective case-control study included 110 patients who experienced clinical deterioration after gastrectomy for gastric cancer as case group, and 745 patients without deterioration as control group from a tertiary hospital in Guangdong Province, China. The discriminating ability (receiver operating characteristic curves), calibration (goodness-of-fit test) and net benefit (clinical decision curves) of the three EWS (NEWS, SEWS, MEWS) were explored to compare their early warning performance for patients at risk of post-operative deterioration.

Results MEWS (goodness-of-fit $p = 0.123 > 0.05$) and SEWS (goodness-of-fit $p = 0.235 > 0.05$) both demonstrate good calibration and good discrimination ability (AUC 0.710, 95% CI 0.654–0.766;AUC 0.756, 95% CI 0.701–0.811). In contrast, NEWS not only has good calibration (goodness-of-fit $p = 0.283 > 0.05$) but also exhibits the best discrimination ability among the three scoring systems (AUC 0.835, 95% CI 0.785–0.884) and the highest net benefit.

†Xinli Shi, Huijuan Jie, Naifa Li, Honglu Xu, Bolin Zhang and Shurong Lai contributed equally to this work.

*Correspondence:
Bolin Zhang
burningjump@gmail.com
Shurong Lai
laishr@mail.sysu.edu.cn
Honglu Xu
xuhonglu@sysush.com

Full list of author information is available at the end of the article

Conclusion Overall, NEWS may be more suitable for identifying gastric cancer patients at risk of post-operative clinical deterioration, as the early warning scoring model with best performance currently for post-gastrectomy observation.

Keywords Gastric cancer, Postoperative, Complications, Early warning scores

Introduction

Gastric cancer is a major health issue in China, with surgery serving as the primary treatment modality [1, 2]. However, postoperative complications after gastric cancer surgery are common, with reported incidence rates of 13.0-30.3% and postoperative mortality rates of 0.4–13.0% worldwide based on evidence from clinical studies [3]. Patients are at high risk of rapid clinical deterioration in the post-gastrectomy period due to poor condition and potential occult changes. Early identification of deterioration warning signs and timely intervention by physicians is important for preventing adverse outcomes. Early identification of gastric cancer patients at risk of postoperative deterioration remains challenging, especially for young nursing staff.

Early warning scores (EWS) were proposed as a potential solution in the late 20th century [4]. Currently, multiple EWS versions have been derived: Modified Early Warning Score (MEWS) [5], Standardized Early Warning Scoring Tool (SEWS) [6, 7] that better reflects patient condition, and National Early Warning Score (NEWS) [8–10] more suitable for assessment of emergency patients' outcomes and prognosis.

This study aimed to compare three commonly used EWS models (MEWS, SEWS, NEWS) to evaluate their early identification ability of postoperative deterioration in gastric cancer patients and select the most appropriate scoring model for early postoperative observation.

Materials and methods

Methods

Study population

This retrospective case-control study employed a convenience sampling method, dividing participants into two groups: cases and controls [11, 12]. The case group collected vital sign data from patients who developed complications within 24 [13] hours prior to their occurrence. Postoperative complications refer to those that occurred during hospitalization, with discharge time considered the endpoint of the study. The primary observation was whether complications occurred during hospitalization, with discharge marking the endpoint. Any missing data at the endpoint was handled through mean imputation [14]. Cases with more than two missing values were excluded. For controls, vital sign data within 24 h after gastric cancer surgery were selected, as this 24-hour postoperative period serves is a specific observation period [15]. The same methods as those used in the case group were followed [11].

The study included 855 gastric cancer patients who underwent gastrectomy at a tertiary hospital in Guangdong Province between August 2017 and October 2020, meeting the inclusion criteria. The specific process is shown in Fig. 1. Postoperative complications were graded according to criteria from the Japanese Clinical Oncology Group (JCOG) for gastric cancer [16]. The Japanese Clinical Oncology Group (JCOG) postoperative complication criteria are primarily used for the identification of early postoperative complications, but they can also be applied to the assessment of complications after discharge. The postoperative complication criteria are based on modifications and revisions of the Clavien-Dindo grading system, providing more detailed evaluation criteria to standardize the assessment of early postoperative complications [16, 17].Disease deterioration was defined as the occurrence of bleeding, digestive fistula, intestinal obstruction, delayed gastric emptying, infection, ICU transfer due to critical condition, or death after surgery. Bleeding refers to hemorrhage that requires blood transfusion, medical management, surgery, endoscopic, or interventional hemostatic interventions.Gastrointestinal fistulas refer to fistulas that require intervention, identified through oral contrast agents or drainage tube imaging.Intestinal obstruction refers to an obstruction that requires medical intervention following a diagnostic evaluation through clinical observation.Delayed gastric emptying refers to a condition identified through clinical observation or diagnostic evaluation that requires medical management (e.g., peristalsis stimulating drugs), NG tube placement, enteral/intravenous nutrition indicated, or intervention under general anesthesia indicated. Infection refers to a condition identified through clinical observation or diagnostic evaluation that requires medical management indicated (e.g., antibiotics), bronchoscopic aspiration, tracheal puncture, Intervention under anesthesia indicated (e.g., drainage, resuturing), At least one organ failure (e.g., pulmonary disorders requiring mechanical ventilation or nephropathy indicating dialysis), Sepsis or multiple organ failure [17].All patients were followed from admission until the final event post-inclusion.

Selection criteria

Inclusion criteria: (1) Meeting the ICD-10 diagnostic criteria for gastric cancer, codes C16.0 ~ C16.9; (2)

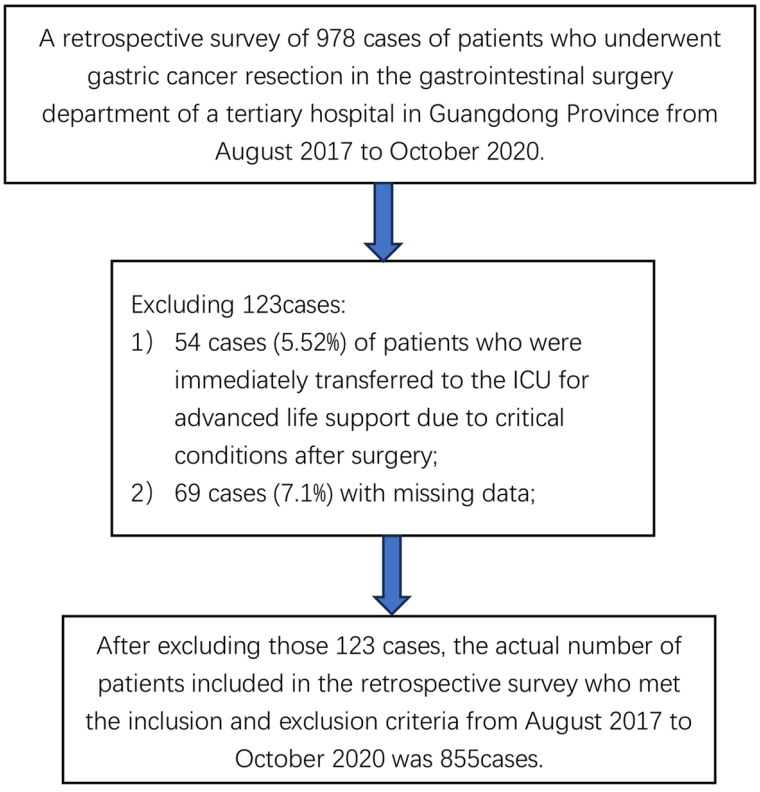

Fig. 1 Flow chart

Underwent gastrectomy (including curative or palliative resection); (3) Age ≥ 18 years old.

Exclusion criteria: (1) Patients with incomplete clinical data; (2) Age < 18 years old; (3) The subjects of this study were inpatients in general wards, excluding those who required immediate ICU transfer for advanced life support due to critical conditions after surgery (as this study focused on patients in general wards, such patients were excluded).

Study procedures

Data were collected using a self-designed form recording demographics, vital signs, consciousness, oxygen saturation and oxygen use. MEWS, NEWS and SEWS were calculated according to standard procedures based on corresponding parameters [5, 6, 8, 17, 18]. The significance level was set at 0.05 in all analyses.

Statistics: Logistic regression models were constructed using SPSS23.0 and R to compare discrimination (ROC), calibration (goodness-of-fit test) and net benefit (decision curve analysis) between the three scores.

Discrimination, the ability to distinguish patients who have experienced events from those who have not, is commonly assessed using receiver operating characteristic (ROC) curves [19, 20].It is generally believed that an area of less than 0.60 reflects poor discrimination; 0.60–0.75, possibly acceptable discrimination; and > 0.75, clearly good discrimination [21–24].

Decision curve analysis (DCA) is used to evaluate whether a model has utility in supporting clinical decisions and to compare which model variant leads to optimal decisions, and it is an important validation tool in addition to measures of discrimination and calibration [25–27].

Results

Complication conditions

Among the 855 patients who underwent gastric cancer resection in this study, 110 developed postoperative complications and were categorized as the case group. The complication rate was 12.87%. Among them, 6 patients died (0.70%), 24 patients were transferred to the ICU due to critical conditions (2.81%), 50 patients developed digestive tract fistula (5.85%), 27 patients experienced bleeding (3.16%), 83 patients had infections (9.71%), and 13 patients developed other complications (1.52%), as detailed in Table 1.

Comparison of case and control groups

The case and control groups were compared in terms of gender, surgery type (radical vs. palliative), smoking history, drinking history and age. There were no statistically significant differences between the two groups in gender,

Table 1 Complication conditions

Category	*N* (%)
Number	855(100%)
Complications	110(12.87%)
Death	6 (0.70%)
Transferred to ICU due to critical condition	24 (2.81%)
Digestive fistula	50 (5.85%)
infection	83 (9.71%)
Bleeding	27 (3.16%)
Other complications	13 (1.52%)

Table 2 Baseline characteristics of case and control groups

Characteristics	Control group (*N* = 745)	Case group (*N* = 110)	*P*- value
Age	57.7 ± 12.1	61.3 ± 10.7.3	0.003
Gender			0.109
Male	535(71.8%)	87 (79.1%)	
Female	210 (28.2%)	23 (20.9%)	
Palliative resection			0.345
No	739 (99.2%)	110 (100.0%)	
Yes	6 (0.8%)	0 (0.0%)	
Radical resection			0.381
No	39 (5.2%)	8 (7.3%)	
Yes	706 (94.8%)	102 (92.7%)	
Smoking			0.165
No	458 (61.5%)	60 (54.5%)	
Yes	287 (38.5%)	50 (45.5%)	
Drinking			0.596
No	579 (77.7%)	83(75.5%)	
Yes	166 (22.3%)	27(24.5%)	
Family history			0.421
No	673 (90.3%)	102 (92.7%)	
Yes	72 (9.7%)	8 (7.3%)	
TNM			
0	18(2.4%)	3(2.4%)	0.032
I	183(24.6%)	13(11.8%)	
II	155(20.8%)	25(22.7%)	
III	307(41.2%)	59(53.6%)	
IV	82(11.0%)	10(9.1%)	

Table 3 Comparison of scores between the control group and the complication group

		N	Mean Rank	Test Statistic	Sig.
MEWS	control group	745	409.46	-6.104	0.000
	complication group	110	553.59		
NEWS	control group	745	416.49	-3.605	0.000
	complication group	110	505.92		
SEWS	control group	745	403.77	-8.279	0.000
	complication group	110	592.14		

surgery type, smoking history, drinking history and Family history (all $P > 0.05$). However, age and TNM differed significantly between the groups ($P < 0.05$). According to previous studies, age and TNM is a risk factor for deterioration after gastric cancer surgery [28, 29]. Therefore, the case and control groups were considered balanced and comparable in baseline characteristics. The details are presented in Table 2. The differences among the three scoring systems within 24 h before the deterioration of the condition were statistically significant between the case group and the control group ($p < 0.01$). The details are presented in Table 3.

Model discrimination

The differences in the three scoring systems 24 h before the onset of deterioration were statistically significant between the case and control groups ($p < 0.01$), as shown in Table 4. The area under ROC curve of the three scoring systems 24 h before onset was 0.710, 0.756 and 0.835, respectively. In this study, MEWS and SEWS had good discrimination (AUC 0.710, CI 0.654 ~ 0.766; AUC 0.756, CI 0.701 ~ 0.811), and NEWS had better discrimination (AUC 0.835, CI 0.785 ~ 0.884). MEWS, SEWS, and NEWS all have good negative predictive values, which are (0.918, 0.932, 0.946) respectively. In comparison, NEWS has a higher positive predictive value (0.625) than MEWS (0.407) and SEWS (0.422). The ROC curve is shown in Fig. 2.

The x-axis of the figure represents specificity and the y-axis represents sensitivity. AUC represents the area under the ROC curve, with a larger area indicating better discrimination ability [29].

Model calibration

Calibration refers to the evaluation of how close the predicted probability values from a model are to the actual observed probability of outcomes. The closer the predicted values are to reality, the better the model's calibration [30]. Calibration ability is assessed using the Hosmer-Lemeshow goodness-of-fit test [23], as shown in Table 4. The results showed that the Hosmer-Lemeshow $\chi 2$ values for MEWS, SEWS and NEWS scores were 7.265, 5.553 and 9.751 respectively, with p values (sig) of 0.123, 0.235 and 0.283 (> 0.05), indicating no statistically significant difference between predicted and actual observed values [23], demonstrating relatively good calibration abilities. The calibration curves is shown in Fig. 3.

Decision curve analysis (DCA)

As shown in Fig. 4, the x-axis represents the threshold probability and the y-axis represents the net benefit after subtracting harms from benefits [26]. The three differently colored sloping lines each represent a different model. In addition to these, the two straight lines represent two extreme situations [31]. From the graph it can be seen that over a wide Pt interval range, NEWS has a higher net benefit than the extreme lines, followed by SEWS, with MEWS the lowest. Among them, NEWS provides the highest net benefit, and using NEWS to

Table 4 ROC analysis of the three early warning score models

Scoring System	ROC Area (AUC)	95% CI	Specificity	Sensitivity	Accuracy	Positive likelihood ratio	Negative likelihood ratio	Positive predictive value	Negative predictive value
MEWS	0.710	0.654 ~ 0.766	0.902	0.455	0.844	4.639	0.605	0.407	0.918
SEWS	0.756	0.701 ~ 0.811	0.886	0.564	0.844	4.940	0.493	0.422	0.932
NEWS	0.835	0.785 ~ 0.884	0.944	0.636	0.904	11.288	0.385	0.625	0.946

Sensitivity: percentage of patients who correctly test positive over those who experience a complicated course. Specificity: percentage of patients who correctly test negative over those who do not experience a complicated course. Positive predictive value: percentage of patients who experience a complicated course over those who test positive. Negative predictive value: percentage of patients who do not experience a complicated course over those who test negative. Positive likelihood ratio: change in the odds of experiencing a complicated course in patients with a positive test. Negative likelihood ratio: change in the odds of experiencing a complicated course in patients with a negative test

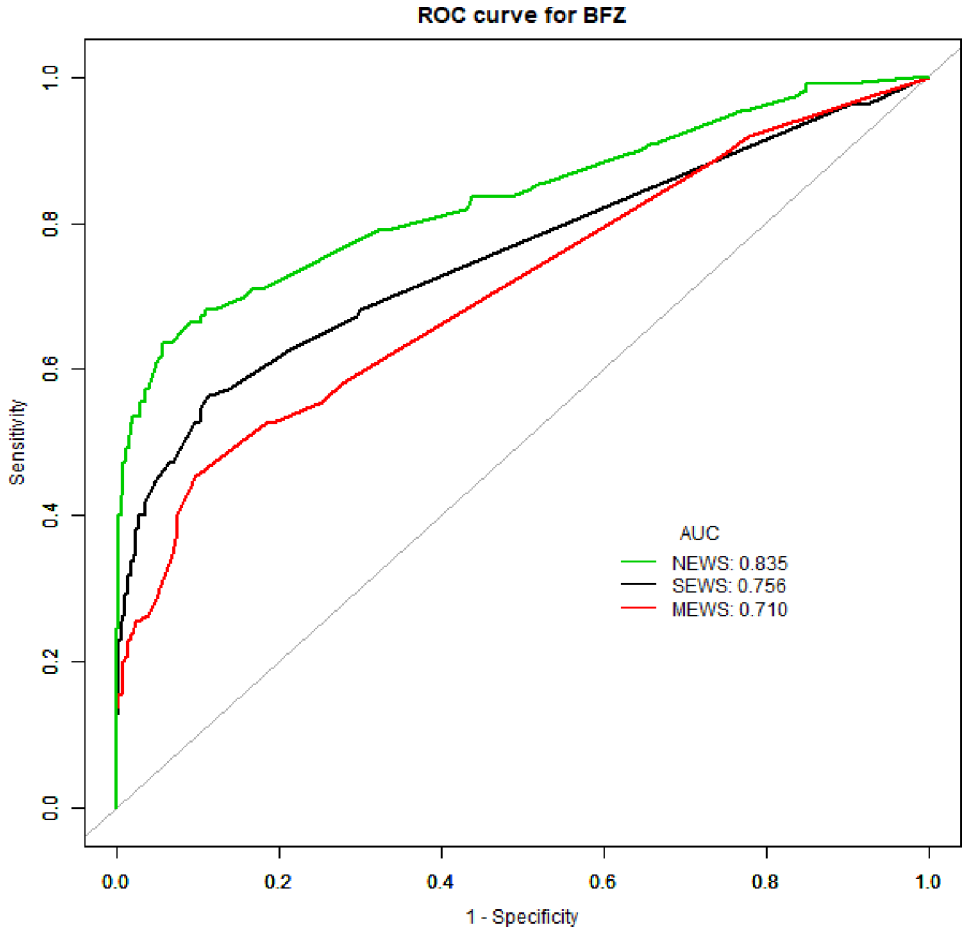

Fig. 2 ROC curves of the three early warning score models

Table 5 Hosmer and Lemeshow Test

	Chi-square	df	Sig.
MEWS	7.265	4	0.123
SEWS	5.553	4	0.235
NEWS	9.751	8	0.283

guide decisions at the same threshold probability value can provide patients with more net benefits and better clinical applicability, followed by SEWS.

Discussion

Postoperative deterioration in patients after gastric cancer surgery

Data from worldwide evidence-based medical research shows [3] that the overall complication rate for gastric cancer surgery is 13.0–30.3%, and the mortality rate is

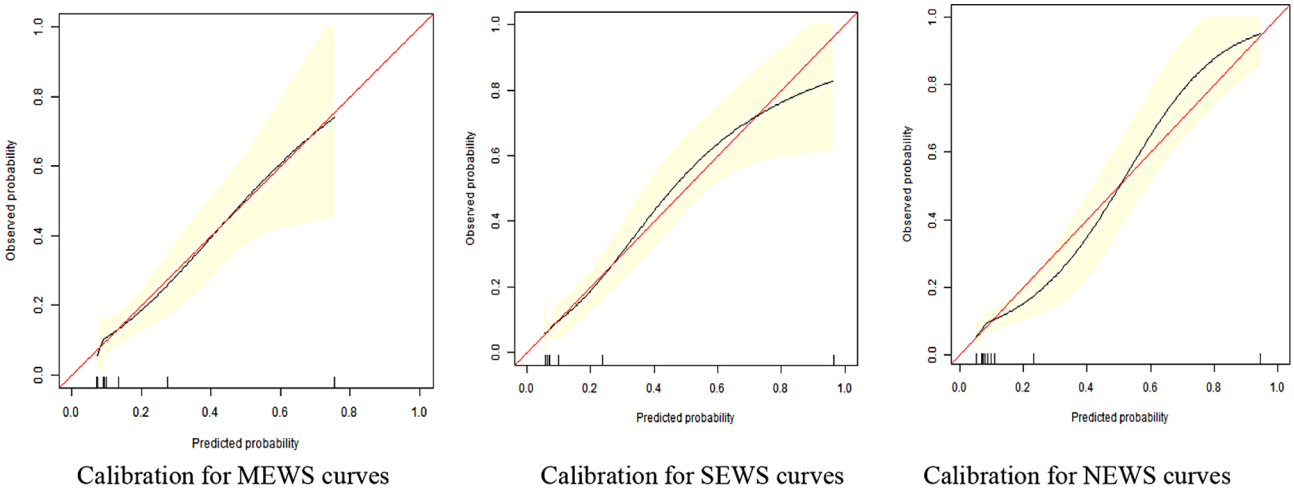

Fig. 3 The calibration curves

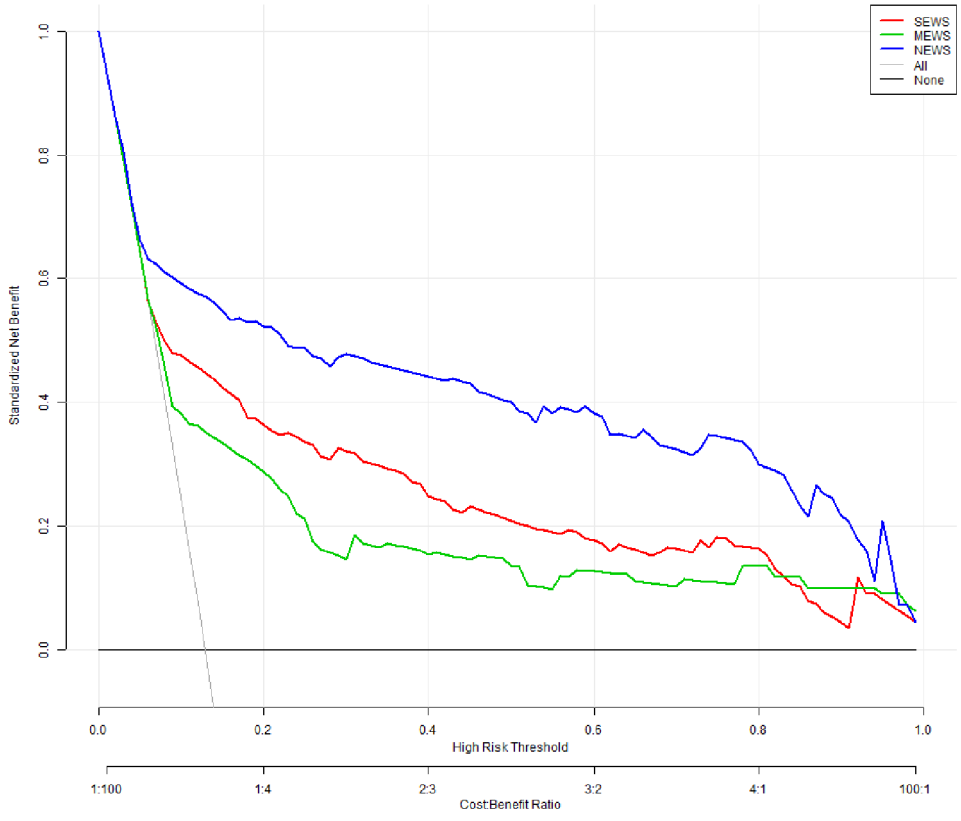

Fig. 4 Decision curve analysis for early warning score models

0.4–13.0%, consistent with this study. In this study of 855 patients who underwent gastric cancer resection, 110patients developed complications, with a complication rate of 12.87%, and 6 deaths, for a mortality rate of 0.70%. In a study by Wang Hao [32] et al. of 1728 patients undergoing gastric cancer surgery, the rate of postoperative transfer to the ICU due to critical conditions was 7.4% (129/1728), while in this study the rate of postoperative transfer to the ICU due to critical conditions was 2.81% (24/855), possibly related to the more experienced surgeons in this study, resulting in lower complication rates and lower ICU transfers due to critical conditions.

Postoperative complications of gastric cancer resection can be divided into early complications and late complications based on the time of occurrence [2]. Early complications refer to various complications occurring within about one month during hospitalization after surgery, such as bleeding, fistula formation at the anastomosis

site, and infections [33]. In this study, all complications in the case group were early complications, with infections accounting for the majority at 83cases (9.71%), followed by digestive tract fistula in 50 cases (5.85%), bleeding in 27 cases (3.16%), and other complications in 13 cases (1.52%). Postoperative infections after gastric cancer include abdominal infection, pulmonary infection, urinary tract infection, pleural effusion infection, surgical incision infection, and other infections, mainly abdominal infection [34]. Digestive tract fistula includes anastomotic fistula, duodenal fistula, stump fistula, etc [35]. It is worth noting that patients may suffer from more than one complication, such as patients with duodenal stump fistula who may also have concurrent infections and bleeding [36].

Modified early warning score (MEWS)

MEWS (Modified Early Warning Score) was proposed by Subbe et al. in 2001 [37], gradually modifying some parameters of EWS through clinical studies, including five physiological indicators: consciousness, temperature, heart rate, respiratory rate, and systolic blood pressure. Currently, MEWS has the widest application both domestically and internationally. Some Chinese scholars studied the relationship between vital signs and postoperative serious adverse events in pancreaticoduodenectomy patients at Guangdong Provincial People's Hospital from 2000 to 2017 [18], finding that the MEWS model could be used to identify pancreaticoduodenectomy patients at risk of postoperative complications. This study found that MEWS demonstrates some predictive ability for postoperative outcomes in patients undergoing gastric cancer resection, with relatively good calibration (accompanying probability $0.123 > 0.05$). It shows good discrimination (AUC 0.710, CI 0.654–0.766), although it is not as effective as SEWS and NEWS. Additionally, its net benefit is lower than that of both NEWS and SEWS. It is worth noting that while MEWS has a good negative predictive value and a high true negative rate, its positive predictive value [38] is only 0.407. This indicates that if NEWS scores identify patients with deteriorating conditions after gastrectomy, the actual probability of occurrence is only 40.7%, making false positive errors more likely.

Standardized early warning scoring (SEWS)

The SEWS scoring system includes six physiological parameters: respiratory rate, temperature, systolic blood pressure, heart rate, consciousness state, and oxygen saturation. Some Chinese scholars, such as Zhang Chen [39], Tang Weijun [40], and Tang Juhuax [41], compared the application value of MEWS and SEWS in postoperative patients in surgical wards and found that SEWS had better diagnostic efficiency than MEWS and is worthy of promotion. This is consistent with the findings of this study. Additionally, this study found that SEWS has good calibration (accompanying probability $0.235 > 0.05$) and good discrimination (AUC 0.756, CI 0.701–0.811) in identifying gastric cancer resection patients at risk of postoperative complications, providing more net benefits than MEWS, although its discrimination and net benefits are not as high as those of NEWS. It is worth noting that while SEWS has a good negative predictive value and a high true negative rate, its positive predictive value [38] is only 0.422. This indicates that if NEWS scores identify patients with deteriorating conditions after gastrectomy, the actual probability of occurrence is only 42.2%, making false positive errors more likely.

National early warning score (NEWS)

Existing studies have shown [36] that an increase in EWS can serve as a harbinger for predicting postoperative Grade IV/V complications. NEWS was derived from EWS by the Royal College of Physicians in 2012 and has since been promoted for use in hospitals of all levels in the UK [28]. In addition to including the physiological parameters required by MEWS, NEWS adds oxygen saturation and whether oxygen is administered, resulting in a total of seven scoring indicators [42]. However, research on NEWS and complications is still relatively limited. This study found that NEWS demonstrated the best discrimination ability for postoperative complications in gastric cancer patients (AUC 0.835, CI 0.785–0.884) and had the highest net benefits, indicating better safety and clinical applicability. Its calibration was also good (accompanying probability $0.283 < 0.05$), suggesting that its predicted values align well with the actual probability of outcomes occurring [30]. The Hosmer-Lemeshow test shows good calibration for all models. This strong calibration corresponds to the study's focus on patients in general wards, as it excluded those who required immediate transfer to the ICU for advanced life support due to critical postoperative conditions.It is worth noting that while NEWS has the best negative predictive value (0.946) and a better positive predictive value compared to MEWS and SEWS, its positive predictive value [38] is 0.625. This indicates that if NEWS scores identify patients with deteriorating conditions after gastrectomy, the actual probability of deterioration is 62.5%, leaving a 37.5% chance that the patients have not actually deteriorated. Among the three scoring systems, NEWS is the most suitable early warning scoring tool for the early postoperative stage in gastric cancer resection patients.

Limitation of this study

1. This study is a single-center study and has not been validated in other centers. Considering that surgical

techniques and ICU admission thresholds may vary significantly across different environments, the generalizability of the results of this study to other hospitals or regions should be considered;
2. This study is retrospective and has not undergone prospective validation;
3. The study subjects are inpatients from general wards and do not include patients who, due to critical conditions post-surgery, were directly transferred to the ICU for advanced life support without first entering the general wards; thus, this type of patient has not been validated;
4. The study employs mean imputation to handle missing data, this approach may not always be the most suitable for clinical data, particularly when data points are not missing at random;
5. This study only discusses the effectiveness of early warning scores in gastric cancer surgery and does not reference other surgical populations or diseases.

Conclusion

In summary, NEWS can be used to identify gastric cancer resection patients at risk of complications and can predict outcomes three days before deterioration, making it currently the most suitable early warning scoring model for observing early postoperative outcomes in gastric cancer resection patients.

Abbreviations

EWS	Early warning scores
NEWS	National Early Warning Score
MEWS	Modified Early Warning Score
SEWS	Standardized Early Warning Scoring
AUC	Area under Curve
ROC	Receiver operating curve
JCOG	The Japanese Clinical Oncology Group
ICD- 10	International Classification of disease-10
ICU	Intensive Care Unit

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Author contributions

Honglu, X, N, B, S and C wrote the main manuscript text; X, Huijuan, S and B prepared figures and table; N and B performed statistical data analysis; W participated in the design of the research plan; S, Y, Q, and Honglu collected data. Xinli Shi, Huijuan Jie, Naifa Li, Honglu Xu, Shurong Lai, Bolin Zhang contributed equally to this work. All the authors read and approved the manuscript.

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Data availability

Sequence data that support the findings of this study have been deposited in Sun Yat-sen University Thesis Data Repository Platform with the RDD code:RDDLC374546.

Declarations

Ethics approval and consent to participate

This study was conducted following the principles of the 1975 Declaration of Helsinki and was approved by the Ethics Committee of the General Hospital of The Seventh Affiliated Hospital (No: KY-2021-023-01). All study participants provided oral informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Nursing, The Seventh Affiliated Hospital, Sun Yat-sen University, Shenzhen 518107, China
[2]Department of Gastrointestinal Surgery, The First Affiliated Hospital, Sun Yat-sen University, Guangdong 510080, China
[3]Department of Information Management, The Seventh Affiliated Hospital, Sun Yat-sen University, Shenzhen 518107, China

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