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A Systematic Review: Early Warning System for Hospital Wards

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ABSTRACT

An Early Warning System (EWS) is a system created to identify worsening patients outside the Intensive Care Unit (ICU). EWS is one of the requirements that must be met to get hospital accreditation. Hospitals have to choose the appropriate EWS to get optimal outcomes. This study aims to describe some of the EWS in the wards that have been researched and developed, as well as their performance in predicting severe adverse events (SAE). This study is a literature review design, conducting a systematic review by selecting relevant articles on Pub Med and Science Direct using the keyword "Early Warning Systems" in the 2018-2023 period. Out of 269 articles, only 12 articles that met the criteria. The selected articles are then systematically reviewed and analyzed. Based on the extraction results of 12 articles, 9 EWS were grouped into National Early Warning Score (NEWS) and its variants, Modified Early Warning Score (MEWS) and its variants, and EWS integrated with Electronic Medical Record (EMR). In choosing an EWS, hospitals must consider the complexity of the cases being managed and the capabilities of existing resources. The recommended EWS in hospital wards with limited resources is weighted EWS or EWS with combinations, such as NEWS and MEWS with variants. Meanwhile, hospitals that have used EMR can choose EWS integrated with EMR to increase their predictive value for SAE, as well as improve protocol compliance.

Keywords:

Early Warning Systems, hospital ward, in-hospital mortality, severe adverse events, unplanned ICU admission

1. INTRODUCTION

About ten percent of hospitalized patients are at risk of adverse events. About 30% of them can cause fatality. Most of the unexpected events occur in the hospital wards. Where more than 50% can be prevented. One of the influencing factors is the failure of hospital staff to detect patients at risk of worsening. Other factors include failure to take precautions before further deterioration occurs, and even untoward events [1], [2], [3].

Before the onset of deterioration, the patient will show changes in vital signs that can be detected. Around 1997 the Early Warning System (EWS) was first introduced to detect changes in these vital signs. This system is designed by assessing the patient's vital signs and assessing them using scores. It is this score that describes the clinical condition of the patient. The higher the score, the worse the condition [1]. A certain score activates a series of measures to prevent further worsening[2]. EWS is growing at a rapid pace. Since becoming part of patient safety in hospitals, various centers around the world have researched and developed EWS [4], [5], [6], [7], [8].

Since 2015, the Indonesian Hospital Accreditation Commission has developed the National Standard of Hospital Accreditation. EWS is one of the requirements that must be met to get hospital accreditation. The large number of EWS that is growing is a good potential for hospitals to choose the appropriate EWS to get optimal results. But on the contrary, it is also a challenge for hospitals to learn more deeply about each potential EWS. EWS that is too simple in complex hospitals certainly does not produce the expected outcomes in reducing hospital mortality. Conversely, EWS that is too complex without adequate resource support will become a workload for hospital staff and result in low compliance with protocols [9], [10], [11].

This study aims to describe some of the EWS that have been researched and developed, as well as their performance in predicting severe adverse events (SAE), like hospital mortality, and unplanned ICU admissions. In this review, we focus EWS on medical and surgical cases in the wards. The results of this review are expected to help clinicians and hospital managers in determining the most appropriate EWS to be used in detecting worsening patients in hospital wards.

2. METHOD

This study is a literature review design, conducting a systematic review by selecting relevant articles aligned with the research objectives. Research begins by identifying the purpose and question of the study. The research question in this study is "Which EWS can be used to predict the occurrence of severe adverse events (SAE) in hospital wards?"

The next step is to identify the literature that fits the research question. We searched for literature from the internet on 2 search engines, namely Pub Med and Science Direct using the keyword "Early Warning Systems" in the 2018-2023 period and was a research or original article. As many as 269 articles are identified. Articles that are not in English, incomplete, do not contain full text, research for certain conditions (including pregnant women, children, and emergencies), out-of-hospital settings, and article reviews are excluded (Figure 1). A total of 15 articles that met the criteria were included in the study. The selected articles are then systematically reviewed and analyzed (Table 1).

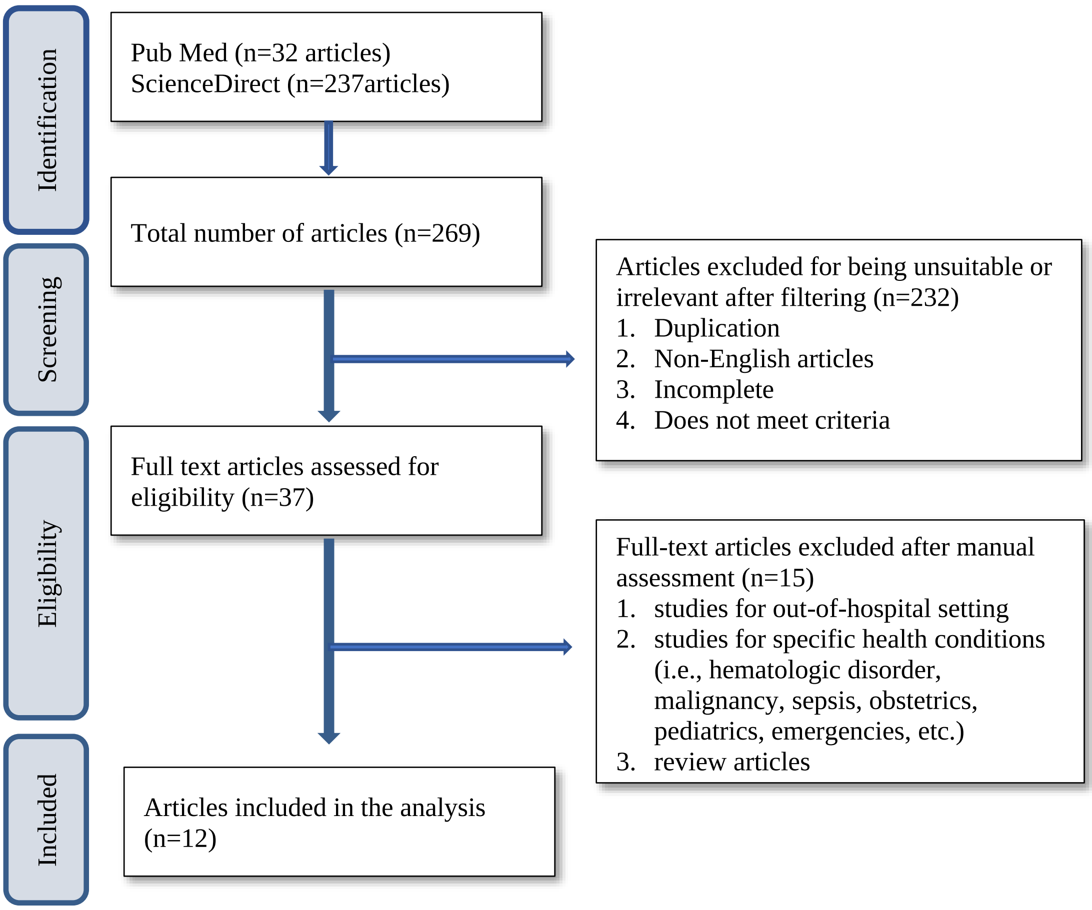

Figure 1. Flowchart of identified relevant literature

3. RESULTS AND DISCUSSION

RESULT

Twelve articles are included in the study. Data extraction according to the inclusion criteria is presented in Table 1. Articles are extracted based on title and author, purpose, method, and results.

Table 1. Data extraction

Article title and authors	Purpose	Methods	Results
Evaluating the performance of the National Early Warning Score in different diagnostic groups, Price (2023)	Evaluate the best EWS for various patients' condition	Retrospective single-center cohort study.	The NEWS has the best performance to predict unplanned ICU admission.
Low Compliance to a Vital Sign Safety Protocol on general hospital wards: A retrospective cohort study, Eddahchouri (2021)	To evaluate the quality of recorded MEWS, and evaluate the protocol compliance	Retrospective single-center cohort study.	The measurement of MEWS assessments was incomplete in one-quarter. The MEWS compliance with the protocol was generally low, especially in high score MEWS.
A multicenter validation study of the deep learning-based early warning score for predicting in-hospital cardiac arrest in patients admitted to general wards, Yeon Joo Lee (2021)	To validate DEWS and to compare DEWS performance with MEWS	Retrospective cohort study	DEWS is better than MEWS in IHCA predictive, alarming, and timeliness performance
The efficacy of twelve early warning systems for potential use in regional medical facilities in Queensland, Australia, Le Lagadec (2019)	To evaluate 12 EWSs used in regional subcritical hospitals	Retrospective case-control study, multicenter	lack of conclusive evidence of the efficacy of the 12 EWSs tested.
The implementation of a real-time early warning system using machine learning in an Australian hospital to improve patient outcomes, Bassin (2023)	To investigate Deterioration Index (DI) performance in conjunction with Between the Flags (BTF) compared with BTF alone.	pre-post study, single center.	DI performance in conjunction with BTF is associated with lower unexpected deaths, unplanned ICU admission, MET activation, and reduced length of stay in the hospital.
The predictive power of the National Early Warning Score (NEWS) 2, as compared to NEWS, among patients assessed by a Rapid response team: A prospective multi-center trial, Anna Thoren (2022)	To examine the predictive power of National Early Warning Score (NEWS) 2 compared with NEWS.	Prospective observational cohort study, multicenter	No differences between NEWS 2 and NEWS in predicting severe adverse events. NEWS2 and NEWS have acceptable prognostic accuracy to predict mortality within 24 hours, relatively weak to predict unanticipated ICU admission, and poor prognostic accuracy to predict IHCA.

Testing the effectiveness of the revised Cape Town modified early warning and SBAR systems: a pilot pragmatic parallel group randomized controlled trial, Kyriacos (2019)	To examine the effectiveness of the Cape Town (CT) MEWS observation chart and SBAR communication guide	Pragmatic, parallel-group RCT with two arms, multi-center	The revised CT MEWS observation chart improved the recording of certain parameters but did not improve nurses' ability to identify patient deterioration.
Trends in the national early warning score are associated with subsequent mortality – A prospective three-center observational study with 11,331 general ward patients, Loisa (2022)	To investigate whether trends in the NEWS values are associated with patient mortality in general ward patients.	prospective observational study, multi-center	NEWS score trajectory in the first three days of admission is associated with patient outcome.
Clinical assessment as a part of an early warning score—a Danish cluster-randomized, multicenter study of an individual early warning score, Nielsen (2022)	To investigate the implementation of Individual EWS (I-EWS) compared with NEWS.	Cluster-randomized, crossover, non-inferiority study, multi-center.	The implementation of I-EWS was feasible and non-inferior to the NEWS to predict 30-day mortality. I-EWS also reduced the number of routine measurements.
Capillary Refill Time as Part of an Early Warning Score for Rapid Response Team Activation is an Independent Predictor of Outcomes, Sebat (2020)	To evaluate Capillary Refill Time (CRT) performance combined with EWS (10SOV, 10 Sign of Vitality) in predicting adverse outcomes.	Prospective observational study, single-center	Prolonged CRT is associated with increased hospital mortality, transfer to higher levels of care, and length of stay than normal CRT. CRT should be considered as a principal assessment for critically ill patients.
Effect of continuous wireless vital sign monitoring on unplanned ICU admissions and rapid response team calls: a before-and-after study, Eddahchouri (2022)	To investigate the impact of continuous wireless vital sign (VS) monitoring on unplanned ICU admission and rapid response team activation compared with MEWS protocol alone.	The before-after study, single-center	The intervention group had lower unplanned ICU admission and rapid response team calls than the control group, but no differences in hospital length of stay and in-hospital death.
An intervention including the national early warning score improves patient monitoring practice and reduces mortality: A cluster randomized controlled trial, Haegdorens (2019)	To investigate RRS and NEWS implementation quality and examine the association between protocol compliance and patient mortality.	RCT, multi-center	An RRS and NEWS implementation improved patient monitoring practice and reduced mortality.

Abbreviations: EWS, Early Warning Systems; NEWS, National Early Warning Score; MEWS, Modified Early Warning Score; CT MEWS, Cape Town Modified Early Warning Score; Cont VS, Continuous Vital Sign; I-EWS, Individual Early Warning Score; DEWS, Deep-learning Early Warning Score; DI, Deterioration Index; BTF, Between the Flag; CRT, Capillary Refill Time; 10 SOV, 10 Signs of Vitality; ICU, Intensive Care Unit; RRS, Rapid Response System; RCT, Randomized Controlled Trial; MET, Medical Emergency Team

Based on the extraction results of 12 articles, 9 EWS were obtained for our analysis. These EWS are NEWS, NEWS 2, I-EWS, MEWS, CT MEWS, MEWS with continuous Vital Sign, DEWS, DI and BTF, and 10 SOV. Each EWS has different parameters used to detect worsening in patients. When compared to the original version, in general, the EWS that is currently developing is divided into simplified EWS and enriched EWS. In this study, the 9 EWS we analyzed were enriched EWS. Six EWS use vital signs and clinical tests only, 3 EWS add laboratory tests, and 3 are added with technology. The technology added starts from the use of wireless vital sign monitors, integrated with Electronic Medical Records (EMR), and the use of Artificial Intelligence (AI). The specifications of each EWS are described in Table 2.

Table 2. EWS parameter specification

Early Warning Systems	Parameter Specification											Tech. added
	RR	SpO2	BT	HR	AVPU	SBP	DBP	O2 +	CVPU	Lab	Clin	
NEWS	√	√	√	√	√	√						No
NEWS 2/Compass/ NHS NEWS	√	√	√	√	√	√		√	√			No
I-EWS	√	√	√	√	√	√					√	No
MEWS	√	√	√	√	√	√	√				√	No
CT MEWS	√	√	√	√	√	√	√			√	√	No
MEWS+Cont VS	√	√	√	√	√	√	√	√				Yes
DEWS	√		√	√		√	√				√	Yes
DI + BTF	√	√		√		√	√	√		√		Yes
CRT + EWS (10 SOV)	√	√	√	√	√	√	√			√	√	No

Abbreviations: EWS, Early Warning Systems; NEWS, National Early Warning Score; MEWS, Modified Early Warning Score; CT MEWS, Cape Town Modified Early Warning Score; Cont VS, Continuous Vital Sign; I-EWS, Individual Early Warning Score; DEWS, Deep-learning Early Warning Score; DI, Deterioration Index; BTF, Between the Flag; CRT, Capillary Refill Time; 10 SOV, 10 Signs of Vitality; RR, Respiratory Rate; SpO2, Oxygen saturation; BT, Body Temperature; HR, Heart Rate; AVPU, Alert/Voice/Pain/Unresponsive; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; O2 +, supplementary oxygen; CVPU, new confusion/Voice/Pain/Unresponsive; UO, urine output; Hb, Hemoglobin; WBC, White Blood Count; Ur, Ureum; Cr, Creatinin; EMR, Electronic Medical Record; AI, Artificial Intelligence. The yellow color indicates the original parameter used in EWS.

Following the purpose of the study, researchers analyzed the performance of 9 EWS. In general, EWS performance is assessed by looking at its ability to predict SAE and other performance. The severe adverse events we recorded from these 12 articles were mortality in hospitals, unplanned ICU admission or transfer to other rooms with higher levels of care, activation of the rapid response system (RRS), occurrence of in-hospital cardiac arrest (IHCA), and its effect on hospitals Length of Stay (LOS). Included in other performances in this review are protocol compliance and frequency of measurements. The performance of each EWS is summarized in the form of a narrative table in Table 3 based on the best performance we found in the literature.

Table 3. Summarize of various EWS performances

EWS	Mortality	Unplanned ICU admission	RRS activation	IHCA	LOS	Protocol compliance	Freq. of measurement
NEWS	Good predict	Good predict	N/A	Poor predict	N/A	N/A	Not reduced
NEWS 2/ NHS NEWS	Good predict	Good predict	N/A	Poor predict	N/A	N/A	Not reduced
I-EWS	Good predict	Good predict	N/A	Poor predict	N/A	N/A	Reduced
MEWS	Fairly	Fairly	N/A	Weak	Not reduced	Poor	N/A
CT MEWS	Fairly	Fairly	N/A	Weak	Not reduced	Good	Not reduced
MEWS + Cont. VS	Reduced	Reduced	Reduced	Weak	Not reduced	Good	Reduced

DEWS	Good predict	N/A	Reduced	Good predict	N/A	Good	Reduced
DI + BTF	Reduced	Reduced	N/A	N/A	Reduced	Good	N/A
CRT + EWS (10 SOV)	Good predict	Good predict	N/A	N/A	Reduced	Poor	Not Reduced

Abbreviations: EWS, Early Warning Systems; NEWS, National Early Warning Score; MEWS, Modified Early Warning Score; CT MEWS, Cape Town Modified Early Warning Score; Cont VS, Continuous Vital Sign; I-EWS, Individual Early Warning Score; DEWS, Deep-learning Early Warning Score; DI, Deterioration Index; BTF, Between the Flag; CRT, Capillary Refill Time; 10 SOV, 10 Signs of Vitality; ICU, Intensive Care Unit; RRS, Rapid Response System; IHCA, Intra Hospital Cardiac Arrest; LOS, Length of Stay.

DISCUSSION

This study aims to describe several EWS that can be used in inpatient rooms in various hospital settings. In this study, researchers focused on EWS used in adult cases in general wards, both medical and surgical. We separated the use of EWS for obstetric, pediatric, and emergency cases to increase data validity. When compared to EWS in its original form, there are two major groups of EWS developing today, namely weighted EWS, and simplified EWS. Both have their advantages and disadvantages. Its use depends on the hospital's ability to accommodate the implementation of EWS and the outcomes to be achieved

We identified 9 types of EWS from the 12 articles. Under the research objectives, we describe the specifications and performance of 9 EWS in 3 themes, namely NEWS and its variations, MEWS and its variations, and EWS integrated with EMR.

NEWS and its variations

NEWS is the most widely used and researched EWS compared to other types of EWS. First introduced in the UK in 2012 by the Royal College of Physicians, NEWS has performed well in reducing the occurrence of SAE. The parameters used are 5 vital signs consisting of respiratory rate, Oxygen saturation, Body Temperature, heart rate, consciousness level using Alert / Verbal / Pain, Unresponsive (AVPU) systems, and Systolic Blood pressure (SBP). In 2020 NEWS was then developed by adding an assessment of oxygen saturation with supplementary oxygen, and changes in mental status that occur. This modified NEWS is called NEWS 2 or National Health Service (NHS) NEWS [12]. NEWS 2 and NEWS have sufficient potential to predict SAE which is AUROC 0.75 and 0.74 [13]. NEWS and NEWS 2 also performed differently in predicting mortality. NEWS2 is at an AUROC between 0.67 to 0.88, while NEWS2 is at an AUROC of 0.69 to 0.74. Although NEWS has almost the same performance as NEWS 2 in predicting SAE, NEWS 2 has higher diagnostic accuracy than NEWS in predicting mortality in 24 hours. However, the NEWS score trajectory in the first three days of admission is associated with patient outcomes [14]. In their research, Thoren et al reported that both NEWS and NEWS 2 had poor performance in predicting the occurrence of IHCA. In predicting unplanned ICU admission, NEWS 2 is at AUROC 0.60-0.83, while NEWS is at AUROC 0.59 [8], [15]. From the gathered data, it is shown that NEWS and NEWS 2 have inconsistent performance.

Although the NEWS and NEWS 2 protocols are theoretically quite easy and simple, they have low compliance. This is due to the high frequency of monitoring that must be done when the score reaches the trigger. For hospitals with adequate resources and established RRS, this is not a problem. However, for hospitals with limited resources, increasing the frequency of monitoring will cause staff fatigue [10], [11], [12], [16]. So, another variation of NEWS called I-EWS emerged. I-EWS is NEWS that is added with clinical assessment and judgment so that authorized staff can upgrade or downgrade the score according to the clinical assessment carried out. I-EWS has a performance that is not much different from NEWS but can reduce the frequency of measurements that must be done. With I-EWS, it is expected that staff fatigue can be reduced, and compliance with protocols can increase [10].

In line with Nielsen, in 2019 Haegdorens reported that adding RRS to the implementation of NEWS can improve patient observation and reduce mortality [6]. Even the addition of RRS will be an additional burden for hospitals, for complex hospitals with sufficient resources, the addition of RRS is one step worth considering [17]. However, for hospitals with limited human resources, I-EWS can be an option.

MEWS and its variations

Modified EWS (MEWS) is another EWS that is frequently adapted. This is because the protocol is easy and not money-consuming, but quite reliable. In its original form, the parameters used by MEWS to predict patient deterioration were HR, RR, BT, AVPU, SBP, and urine output (UO) [18]. MEWS has sufficient performance in predicting mortality at AUROC 0.75. However, just like NEWS, MEWS protocol compliance is also low [9]

Over time, MEWS is increasingly developed and modified according to the needs and capabilities of hospitals. Cape Town MEWS (CT MEWS) is one of them. CT MEWS modifies MEWS by adding vital signs such as oxygen saturation, and Diastolic Blood pressure (DBP). In addition, it also adds laboratory tests and other clinical examinations consisting of perfusion, skin color, pain, sweating, pedal pulse, glucose, Hb, and the appearance of pain. CT MEWS is said to have a good performance in predicting SAE (AUROC 0.86) compared to MEWS. In overcoming the low compliance of MEWS as reported by the researchers, in 2019 a revision was made to the MEWS CT observation sheet integrated with SBAR. This revised CT MEWS chart is reported to significantly improve protocol compliance [19]. The CT MEWS protocol and its revised observation sheet can be an option for hospitals with limited resources if they want to improve their EWS performance in predicting SAE. Although there are additional laboratory tests, namely glucose and Hb, these two tests are fairly simple, cheap, and can be done with point-of-care examinations in the wards. Additional clinical assessments such as perfusion assessment, skin color, sweating, pedal pulse, and pain appearance assessment can be said to be simple examinations even though they are more time-consuming than NEWS.

In 2022, Eddahchouri modified the MEWS with a vital sign monitor for continuous monitoring. This is to reduce staff workload due to increased monitoring frequency in cases with high MEWS values. Compared to MEWS, it turns out that the use of vital sign monitors on MEWS can reduce unplanned ICU admissions and RRS calls. It also means lowering hospital staff workload. However, there was no difference in the length of stay and in-hospital mortality. This strategy can be done by hospitals that have enough vital sign monitors to be used in the wards [20], [21].

The last variant of MEWS is 10 SOV. 10 SOV is one of the EWS developed in a hospital in America. The examination component in 10 SOV consists of 10 vital signs, namely RR, SpO2, BT, HR, mental state, BP (SBP and DBP), CRT, pain, urine output, and between lactic acid or base deficit. This component is similar to MEWS which is modified with the addition of clinical examination of CRT and pain, as well as laboratory tests in the form of lactic acid or base deficit. Its overall performance compared to other EWS remains unreported. Sebat reported the ability of CRT examination in 10SOV to predict mortality. They said that CRT > 3 seconds has a 2-fold tendency to cause mortality compared to the group with CRT < 3 seconds. The 3-second > CRT group also showed longer hospitalizations than the 3-second < CRT [7]. In his research, Sebat emphasized the addition of CRT testing to existing EWS to improve predictive ability against mortality

EWS integrated EMR

DEWS is an EWS developed in Korea in 2018 by utilizing AI integrated into EMR in calculating scores. The components contained in DEWS are RR, BT, HR, BP, as well as the age of the patient. All these components are then scored using AI. DEWS is said to perform well with an AUROC of 0.86 in predicting mortality compared to MEWS (AUROC of 0.75). DEWS is also better at predicting IHCA, and signaling danger, and has good compliance than MEWS. DEWS is a good choice for hospitals that already use EMR and have the compatible resources to use AI [22].

BTF is one of the EWS that is frequently used in Australia. When used alone, BTF has the lowest potential to predict SAE (AUROC 0.63) compared to the other 9 EWS in this review [5], [13]. In 2023, a study combined BTF with Deterioration Index (DI) and calculated using AI to improve their performance. The sensitivity of DI and BTF alone was considered sufficient in predicting mortality at 77.0% and 69.0% respectively when compared to NEWS 2 and NEWS (77.4% and 63.5%). The examination components in DI and BTF are RR, SpO2, HR, BP, supplementary oxygen, and laboratory (Hb, WBC, Ureum, and Creatinin). Compared to BTF itself, DI performance along with BTF is associated with lower mortality and unplanned ICU admission. In addition, it also reduces Medical Emergency Team (MET) activation and reduces LOS in hospitals [5]. In DI and BTF there is no body temperature monitoring. As some research said, body temperature is one of the most missing components in the NEWS implementation [9]. However, in BTF there is a DBP examination. EWS that uses DBP parameters has a high sensitivity. However high false positives in this parameter examination can also add to the workload of hospital staff. This is why EWS with DBP examination is less practical in implementation despite this parameter having a high sensitivity [13]. Nevertheless, BTF combined with DI and AI can be one alternative EWS strategy that can be done by hospitals with EMR systems.

Using technology-assisted EWS that automatically screens for abnormal vital signs is associated with increased protocol and timeliness compliance in large hospitals with extensive RRS activation, as well as reduced in-hospital resuscitation and in-hospital deaths. Compared to traditional EWS, technology-assisted EWS performs better [5], [22], [23].

4. CONCLUSION

Based on the extraction results of 12 articles, 9 EWS were obtained for our analysis. Each EWS has different parameters that are used in detecting worsening in patients. In choosing an EWS in the wards, hospitals must consider the complexity of the cases being managed and the capabilities of existing resources. The recommended EWS in hospital wards with limited resources are weighted EWS or EWS with combinations, such as NEWS and their variants (NEWS 2, I-EWS, or combined with RRS), or MEWS with their variants (CT MEWS, Continuous vital sign MEWS, and 10 SOV). Meanwhile, hospitals that have used EMR can choose EWS integrated with EMR such as DEWS or BTF combined with DI. Integration of EWS with technology and/or RRS can improve protocol compliance, predictive value for SAE, and positive effect on patient outcomes.

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