ELECTRONIC MEDICAL RECORD BASED AUTOMATED PATIENT DETERIORATION IDENTIFICATION

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Please find following a summary of a literature search and relevant results. All articles can be provided in full - email library@monashhealth.org for a list of the articles you require.

QUESTION

What is the utility of real-time digital or EMR monitoring and intervention of inpatients clinical deterioration?

SEARCH LIMITS

English-language, last 10 years

SEARCH METHODOLOGY

A systematic search was conducted for literature. The results were screened by two librarians using Covidence. See the Appendix for the PRISMA chart, search terms, and Medline search strategy.

DATABASES SEARCHED

- Medline – index of peer reviewed articles across health sciences and medicine.
- Embase – index of biomed and pharmacological peer reviewed journal articles.
- Emcare – index of nursing, allied health, critical-care medicine and more.
- CINAHL – index of nursing, allied health, critical-care medicine and more.
- Computer Science Database – index of computing, information technology and information science.
- Grey literature – Google, Google Scholar, Trip database, Biomed Central Proceedings.

LITERATURE RESULTS

All articles can be provided in full text - email library@monashhealth.org a list of articles you require.

GENERAL RESOURCES

ONLINE RESOURCES (GREY LITERATURE)

Government documents & health guidelines:

Australian Commission on Safety and Quality in Healthcare. (2021). **Review of trigger tools to support the early identification of sepsis in healthcare settings.** Link.

- Tools and triggers for early identification of sepsis (p.23)
- Appendix 7: Description and components of tools and triggers (p.81)

Canberra Hospital and Health Services. (2018). **Canberra Hospital and Health Services Clinical Procedure Vital Signs & Early Warning Scores.** Link.

- Implementation, Related Policies, Procedures, Guidelines and Legislation. (p.42)

Centers for Disease Control and Prevention. (2018). **Hospital Toolkit for Adult Sepsis Surveillance.** Link.

- Electronic Case Finding – data points used for electronic health record monitoring (p.13)

Western Australia Department of Health. (2017). **Recognising and Responding to Acute Deterioration Guideline.** Link.

- Section 16: Technical Systems and Solutions (p.12)

Relevant theses and dissertations:

- Alhmoud, B. (2022). **Digital early warning scores in cardiac care settings: Mixed-methods research.** Link.
  Implementation of the digital NEWS2 in two healthcare settings and the evaluation of EHR-integrated dashboard for auditing NEWS2 and clinicians' performance.

- Le Lagadec, M. (2021). **Identification and management of patient deterioration—Comparing the afferent limb of early warning systems.** Link.
  Comparing the uses of twelve early warning systems in Australian hospitals, in both regional and metropolitan areas.

- Malycha, J. (2021). **Predicting Clinical Deterioration.** Link.
  Evaluation of Hospital-wide Alerts Via Electronic Noticeboard (HAVEN) system in the ward environment.

PEER-REVIEWED LITERATURE - IN REVERSE CHRONOLOGICAL ORDER

Articles are grouped by theme:

- Disseminating Alerts
- Evaluation of Early Warning Systems
- Implementation
- Monitoring Technology
  - Artificial Intelligence
  - Machine Learning
  - Prediction
- Patient Contexts
  - Cardiac Arrest
  - Paediatrics
  - Racial Bias
  - Sepsis

Each article summary contains excerpts from the abstract and an online link.

DISSEMINATING ALERTS

Fletcher, G. S., et al. (2017). **Effect of a Real-Time Electronic Dashboard on a Rapid Response System.** *Journal of medical systems,* 42(1), 5. Full text
A rapid response system (RRS) may have limited effectiveness when inpatient providers fail to recognize signs of early patient decompensation. We evaluated the impact of an electronic medical record (EMR)-based alerting dashboard on outcomes associated with RRS activation. The introduction of the RRT dashboard was associated with increased initial RRT activations but not overall activations, unexpected ICU transfers, cardiopulmonary arrests, or death. The RRT dashboard is a novel tool to help providers recognize patient decompensation and may improve initial RRT notification.

Scott Evans, R., et al. (2015). **Automated detection of physiologic deterioration in hospitalized patients.** *Journal of the American Medical Informatics Association,* 22(2), 350-360. Full text
Develop and evaluate an automated case detection and response triggering system to monitor patients every 5 min and identify early signs of physiologic deterioration. We monitored patients every 5 min and provided automated pages of early physiologic deterioration. This before-after study found a significant increase in MET calls and a significant decrease in mortality only in the unit with older patients with multiple comorbidities, and thus further study is warranted to detect potential confounding. Moreover, nurses reported the graphical alerts provided information needed to quickly evaluate patients, and they felt more confident about their assessment and more comfortable requesting help.

Kollef, M. H., et al. (2014). **A randomized trial of real-time automated clinical deterioration alerts sent to a rapid response team.** *Journal of Hospital Medicine,* 9(7), 424-429. Full text
Episodes of patient deterioration on hospital units are expected to increasingly contribute to morbidity and healthcare costs. Real-time alerts sent to the RRT did not reduce ICU transfers, hospital mortality, or the need for subsequent long term care. However, hospital length of stay was modestly reduced.

EVALUATION OF EARLY WARNING SYSTEMS

Esmaeilzadeh, S., et al. (2022). **Improving In-Hospital Patient Rescue: What Are Studies on Early Warning Scores Missing? A Scoping Review.** *Critical care explorations,* 4(2), e0644. Full text
Administrative and clinical efforts to improve hospital mortality and intensive care utilization commonly focus on patient rescue, where deteriorating patients are systematically identified and intervened upon. Despite hundreds of EWS-related publications, most do not report details of hospital context that would inform decisions about real-world EWS adoption. To make informed decisions about whether EWS implementation improves hospital quality, decision-makers may require alternatives such as peer networks and implementation pilots nested within local health systems.

Blythe, R., et al. (2022). **A scoping review of real-time automated clinical deterioration alerts and evidence of impacts on hospitalised patient outcomes.** *BMJ Quality & Safety,* 31(10), 725-734. Full text
Hospital patients experiencing clinical deterioration are at greater risk of adverse events. Monitoring patients through early warning systems is widespread, despite limited published evidence that they improve patient outcomes. Current limitations including infrequent or incorrect risk calculations may be mitigated by integration into electronic medical records. Most studies in this review did not detect improvements in patient outcomes following the implementation of real-time deterioration alerts. Future implementation studies should consider: directly involving the patient's physician or a dedicated surveillance nurse in structured response protocols for deteriorating patients; the workflow of alert recipients; and incorporating model features into the decision process to improve clinical utility.

Fang, A. H. S., et al. (2020). **Early warning score validation methodologies and performance metrics: a systematic review.** *BMC Medical Informatics & Decision Making,* 20(1), 1-7. Full text
Early warning scores (EWS) have been developed as clinical prognostication tools to identify acutely deteriorating patients. In the past few years, there has been a proliferation of studies that describe the development and validation of novel machine learning-based EWS. Methodologies and performance metrics used in studies performing validation on EWS were heterogeneous hence making it difficult to interpret and compare EWS performance. Standardizing EWS validation methodology and reporting can potentially address this issue.

Bedoya, A. D., et al. (2019). **Minimal Impact of Implemented Early Warning Score and Best Practice Alert for Patient Deterioration.** *Critical Care Medicine,* 47(1), 49-55. Full text
Previous studies have looked at National Early Warning Score performance in predicting in-hospital deterioration and death, but data are lacking with respect to patient outcomes following implementation of National Early Warning Score. We sought to determine the effectiveness of National Early Warning Score implementation on predicting and preventing patient deterioration in a clinical setting. At both our academic and community hospital, National Early Warning Score had poor performance characteristics and was generally ignored by frontline nursing staff. As a result, National Early Warning Score implementation had no appreciable impact on defined clinical outcomes. Refitting of the model using site-specific data improved performance and supports validating predictive models on local data.

Kipnis, P., et al. (2016). **Development and validation of an electronic medical record-based alert score for detection of inpatient deterioration outside of the ICU.** *Journal of Biomedical Informatics,* 64, 10-19. Full text
Patients in general medical-surgical wards who experience unplanned transfer to the intensive care unit (ICU) show evidence of physiologic derangement 6–24 h prior to their deterioration. With

increasing availability of electronic medical records (EMRs), automated early warning scores (EWSs) are becoming feasible. The AAM score is an example of a score that takes advantage of multiple data streams now available in modern EMRs. It highlights the ability to harness complex algorithms to maximize signal extraction.

IMPLEMENTATION

Tseng, T.-W., et al. (2022). **Fast Healthcare Interoperability Resources for Inpatient Deterioration Detection With Time-Series Vital Signs: Design and Implementation Study.** *JMIR medical informatics,* 10(10), e42429. Full text
Vital signs have been widely adopted in in-hospital cardiac arrest (IHCA) assessment, which plays an important role in inpatient deterioration detection. As the number of early warning systems and artificial intelligence applications increases, health care information exchange and interoperability are becoming more complex and difficult. We also proposed a clarifying system architecture and possible workflows. Based on FHIR, we integrated the 3 different systems in 1 dashboard system, which can effectively solve the complexity of the system in the medical staff workflow.

Paulson, S. S., et al. (2020). **What Do We Do After the Pilot Is Done? Implementation of a Hospital Early Warning System at Scale.** *Joint Commission Journal on Quality & Patient Safety,* 46(4), 207-216. Full text
Adults who deteriorate outside the ICU have high mortality. Most rapid response systems (RRSs) have employed manual detection processes that rapid response teams (RRTs) use to identify patients at risk. This project piloted the use of an automated early warning system (EWS), based on a very large database, that provides RRTs with 12 hours lead time to mount a response. Its implementation has resulted in standardization of RRT staffing, clinical rescue workflows, and in-hospital palliative care.

MONITORING TECHNOLOGY – ARTIFICIAL INTELLIGENCE

Malycha, J., et al. (2022). **Artificial intelligence and clinical deterioration.** *Current Opinion in Critical Care,* 28(3), 315-321. Full text
To provide an overview of the systems being used to identify and predict clinical deterioration in hospitalised patients, with focus on the current and future role of artificial intelligence (AI). Escobar et al. (AAM) provide the current gold standard for robust model development and implementation methodology. Multiple technologies show promise, however, the pathway to meaningfully affect patient outcomes remains challenging.

Martinez, V. A., et al. (2022). **The Kaiser Permanente Northern California Advance Alert Monitor Program: An Automated Early Warning System for Adults at Risk for In-Hospital Clinical Deterioration.** *Joint Commission Journal on Quality & Patient Safety,* 48(8), 370-375. Full text
In-hospital deterioration among ward patients is associated with substantially increased adverse outcome rates. In 2013 Kaiser Permanente Northern California (KPNC) developed and implemented an Artificial Intelligence–driven program, Advance Alert Monitor (AAM), to improve early detection and intervention for in-hospital deterioration. The AAM predictive model is designed to give clinicians 12 hours of lead time before clinical deterioration, permitting early detection and a patient goals–concordant response to prevent worsening. The AAM program leveraged predictive analytics to produce highly reliable care by identifying at-risk patients, preventing deterioration, and reducing adverse outcomes and can be used as a model for how clinical decision support and inpatient population management can effectively improve care.

MONITORING TECHNOLOGY – MACHINE LEARNING

Rust, L. O. H., et al. (2023). **The Deterioration Risk Index: Developing and Piloting a Machine Learning Algorithm to Reduce Pediatric Inpatient Deterioration.** *Pediatric Critical Care Medicine,* 24(4), 322-333. Full text
Develop and deploy a disease cohort-based machine learning algorithm for timely identification of hospitalized pediatric patients at risk for clinical deterioration that outperforms our existing situational awareness program. The etiology of pediatric inpatient deterioration requires acknowledgement of the unique pathophysiology among patients. Selection and weighting of diverse candidate risk factors via machine learning can produce a more sensitive early warning system for clinical deterioration. Leveraging preexisting situational awareness platforms and accounting for operational impacts of model implementation are key aspects to successful bedside translation.

Winslow, C. J., et al. (2022). **The Impact of a Machine Learning Early Warning Score on Hospital Mortality: A Multicenter Clinical Intervention Trial.** *Critical Care Medicine,* 50(9), 1339-1347. Full text
To determine the impact of a machine learning early warning risk score, electronic Cardiac Arrest Risk Triage (eCART), on mortality for elevated-risk adult inpatients. A pragmatic pre- A nd post-intervention study conducted over the same 10-month period in 2 consecutive years. The intervention period was also associated with a significant increase in ICU transfers, decrease in time to ICU transfer, and increase in vital sign reassessment within 2 hours. Implementation of a machine learning early warning score-driven protocol was associated with reduced inhospital mortality, likely driven by earlier and more frequent ICU transfer.

Ginestra, J. C., et al. (2019). **Clinician Perception of a Machine Learning-Based Early Warning System Designed to Predict Severe Sepsis and Septic Shock.** *Critical Care Medicine,* 47(11), 1477-1484. Full text
To assess clinician perceptions of a machine learning-based early warning system to predict severe sepsis and septic shock (Early Warning System 2.0). In general, clinical perceptions of Early Warning System 2.0 were poor. Nurses and providers differed in their perceptions of sepsis and alert benefits. These findings highlight the challenges of achieving acceptance of predictive and machine learning-based sepsis alerts.

MONITORING TECHNOLOGY - PREDICTION

Cummings, B. C., et al. (2023). **External Validation and Comparison of a General Ward Deterioration Index between Diversely Different Health Systems.** *Critical Care Medicine,* 51(6), 775-786. Full text
Implementing a predictive analytic model in a new clinical environment is fraught with challenges. Dataset shifts such as differences in clinical practice, new data acquisition devices, or changes in the electronic health record (EHR) implementation mean that the input data seen by a model can differ significantly from the data it was trained on. Validating models at multiple institutions is therefore critical. Here, using retrospective data, we demonstrate how Predicting Intensive Care Transfers and other UnfoReseen Events (PICTURE), a deterioration index developed at a single academic medical center, generalizes to a second institution with significantly different patient population. Important differences were observed between the two institutions, including data availability and demographic makeup. PICTURE was able to identify general ward patients at risk of deterioration at both hospitals with consistent performance (AUROC and AUPRC) and compared

favorably to existing metrics.

Escobar, G. J., et al. (2020). **Automated Identification of Adults at Risk for In-Hospital Clinical Deterioration.** *New England Journal of Medicine,* 383(20), 1951-1960. Full text
Hospitalized adults whose condition deteriorates while they are in wards (outside the intensive care unit [ICU]) have considerable morbidity and mortality. Early identification of patients at risk for clinical deterioration has relied on manually calculated scores. Outcomes after an automated detection of impending clinical deterioration have not been widely reported. The use of an automated predictive model to identify high-risk patients for whom interventions by rapid-response teams could be implemented was associated with decreased mortality.

Churpek, M. M., et al. (2019). **Validation of early warning scores at two long-term acute care hospitals.** *American Journal of Respiratory and Critical Care Medicine,* 199(9), e962-e965. Full text
Early warning scores (EWSs) were developed to identify high-risk patients on the hospital wards to allow for earlier, life-saving treatment. Although research on EWSs has focused on ward patients in short-term acute hospitals, there are other settings, such as long-term acute care hospitals (LTACHs), where these tools could be useful. However, the accuracy of EWSs in LTACHs for predicting the need for acute hospital transfers and mortality is currently unknown. Therefore, we aimed to evaluate the accuracy of the commonly used Modified Early Warning Score (MEWS) and our previously developed eCART score in the LTACH setting. In this retrospective cohort study in two LTACHs, we found that eCART was significantly more accurate than MEWS for predicting acute hospital transfer and mortality without any modification to the original score. Because laboratory values were more predictive than vital signs and the average length of stay in an LTACH is much longer than short-term acute hospitals, developing a score specific to the LTAC population would likely further improve accuracy, thus allowing earlier identification of high-risk patients for potentially life-saving interventions.

Escobar, G. J., et al. (2016). **Piloting electronic medical record-based early detection of inpatient deterioration in community hospitals.** *Journal of Hospital Medicine,* 11, S18-S24. Full text
Patients who deteriorate in the hospital outside the intensive care unit (ICU) have higher mortality and morbidity than those admitted directly to the ICU. As more hospitals deploy comprehensive inpatient electronic medical records (EMRs), attempts to support rapid response teams with automated early detection systems are becoming more frequent. We aimed to describe some of the technical and operational challenges involved in the deployment of an early detection system. We then demonstrated that EMR data could be employed to predict deteriorations. After addressing specific organizational mandates (eg, defining the clinical response to a probability estimate), we instantiated a set of equations into a Java application that transmits scores and probability estimates so that they are visible in a commercially available EMR every 6 hours. The pilot has been successful and deployment to the remaining hospitals has begun.

PATIENT CONTEXT – CARDIAC ARREST

Bartkowiak, B., et al. (2019). **Validating the Electronic Cardiac Arrest Risk Triage (eCART) Score for Risk Stratification of Surgical Inpatients in the Postoperative Setting: Retrospective Cohort Study.** *Annals of surgery,* 269(6), 1059-1063. Full text
Postoperative clinical deterioration on inpatient hospital services is associated with increased morbidity, mortality, and cost. Early warning scores have been developed to detect inpatient clinical deterioration and trigger rapid response activation, but knowledge regarding the application of early warning scores to postoperative inpatients is limited. Early warning scores are predictive of severe adverse events in postoperative patients. eCART is significantly more accurate in this patient population than both NEWS and MEWS.

Green, M., et al. (2018). **Comparison of the Between the Flags calling criteria to the MEWS, NEWS and the electronic Cardiac Arrest Risk Triage (eCART) score for the identification of deteriorating ward patients.** *Resuscitation,* 123.86-91. Full text
Traditionally, paper based observation charts have been used to identify deteriorating patients, with emerging recent electronic medical records allowing electronic algorithms to risk stratify and help direct the response to deterioration. An electronically generated eCART score was more accurate than commonly used paper based observation tools for predicting the composite outcome of in-hospital cardiac arrest, ICU transfer and death within 24h of observation. The outcomes of this analysis lend weight for a move towards an algorithm based electronic risk identification tool for deteriorating patients to ensure earlier detection and prevent adverse events in the hospital.

Kang, M. A., et al. (2016). **Real-Time Risk Prediction on the Wards: A Feasibility Study.** *Critical Care Medicine,* 44(8), 1468-1473. Full text
Failure to detect clinical deterioration in the hospital is common and associated with poor patient outcomes and increased healthcare costs. Our objective was to evaluate the feasibility and accuracy of real-time risk stratification using the electronic Cardiac Arrest Risk Triage score, an electronic health record-based early warning score. Patients met the high-risk electronic Cardiac Arrest Risk Triage score threshold a median of 30 hours prior to cardiac arrest or ICU transfer versus 1.7 hours for standard Rapid Response Team activation. Electronic Cardiac Arrest Risk Triage score identified significantly more cardiac arrests and ICU transfers than standard Rapid Response Team activation and did so many hours in advance.

PATIENT CONTEXT - PAEDIATRIC

Kartika, L., et al. (2021). **The Modified Pediatric Early Warning Score Innovation Project (mPEWS-InPro) Mobile-Based Application Development: Another Way of Monitoring a Child's Clinical Deterioration.** *Pediatric Nursing,* 47(1), 38-44. Full text
Children who are hospitalized have the potential for experiencing clinical deterioration during the treatment period. Nurses who recognize abnormal physiological parameters and implement appropriate, integrated, multidisciplinary interventions can prevent a child's condition from worsening. However, communication problems may delay the required decision-making. The present study assessed the effectiveness of monitoring physiological changes in children via the modified Pediatric Early Warning System (mPEWS)-InPro mobile-based application in determining the risk of clinical deterioration and in providing appropriate intervention. The mPEWS-InPro mobilebased application is effective for predicting and monitoring a child's clinical deterioration. Its application can be integrated with any hospital's electronic health record system. This form of nursing informatics can be considered a strategy for detecting the clinical deterioration of pediatric patients. Its user-friendly application and automatic parameter scoring allow nurses to take care the patients while maintaining the human touch, which is essential in nursing care.

Rivero-Martin, M. J., et al. (2016). **Results of applying a paediatric early warning score system as a healthcare quality improvement plan.** *Revista de Calidad Asistencial,* 31, 11-19. Request article
The aims of this study were to introduce a paediatric early warning score (PEWS) into our daily clinical practice, as well as to evaluate its ability to detect clinical deterioration in children admitted, and to train nursing staff to communicate the information and response effectively. PEWS are useful to provide a standardised assessment of clinical status in the inpatient setting, using a unique scale and implementing data capture. Because of the lack of severe complications requiring PICU admission and deaths, we will have to use other data to evaluate these scales.

PATIENT CONTEXT – RACIAL BIAS

Pirret, A. M., et al. (2022). **Removing modifications to the New Zealand Early Warning Score- does ethnicity matter? A multimethod research design.** *Intensive & Critical Care Nursing,* 68 103141. Full text
Previous research on a modified New Zealand Early Warning Score (M-NZEWS) used in predominately medical ward patients identified removing the modifications would significantly reduce the number of M-NZEWSs triggering the medical emergency team (MET), particularly in Māori patients. To firstly, explore the impact of removing the modifications from the M-NZEWS on medical and surgical ward patients' early warning score MET triggers and secondly, determine if the M-NZEWS MET triggers resulted in MET activations and if the MET activations were a result of M-NZEWS MET triggers. Removing the modifications would significantly reduce the number of MET triggers, particularly in Māori patients. Analysing solely electronic vital sign data may not reflect the number of medical emergency team triggers or activations.

PATIENT CONTEXT - SEPSIS

Honeyford, K., et al. (2020). **Evaluating a digital sepsis alert in a London multisite hospital network: a natural experiment using electronic health record data.** *Journal of the American Medical Informatics Association,* 27(2), 274-283. Full text
The study sought to determine the impact of a digital sepsis alert on patient outcomes in a UK multisite hospital network. A natural experiment utilizing the phased introduction (without randomization) of a digital sepsis alert into a multisite hospital network. : These findings strongly suggest that the introduction of a network-wide digital sepsis alert is associated with improvements in patient outcomes, demonstrating that digital based interventions can be successfully introduced and readily evaluated.

Giannini, H. M., et al. (2019). **A Machine Learning Algorithm to Predict Severe Sepsis and Septic Shock: Development, Implementation, and Impact on Clinical Practice.** *Critical Care Medicine,* 47(11), 1485-1492. Full text
Develop and implement a machine learning algorithm to predict severe sepsis and septic shock and evaluate the impact on clinical practice and patient outcomes. Our machine learning algorithm can predict, with low sensitivity but high specificity, the impending occurrence of severe sepsis and septic shock. Algorithm-generated predictive alerts modestly impacted clinical measures. Next steps include describing clinical perception of this tool and optimizing algorithm design and delivery.

Austrian, J. S., et al. (2018). **Impact of an emergency department electronic sepsis surveillance system on patient mortality and length of stay.** *Journal of the American Medical Informatics Association,* 25(5), 523-529. Full text
The purpose of this study was to determine whether an electronic health record-based sepsis alert system could improve quality of care and clinical outcomes for patients with sepsis.Materials and

Methods: We performed a patient-level interrupted time series study of emergency department patients with severe sepsis or septic shock between January 2013 and April 2015. The intervention, introduced in February 2014, was a system of interruptive sepsis alerts triggered by abnormal vital signs or laboratory results. Alerting based on simple laboratory and vital sign criteria was insufficient to improve sepsis outcomes. Alert fatigue due to the low PPV is likely the primary contributor to these results. A more sophisticated algorithm for sepsis identification is needed to improve outcomes.

Umscheid, C. A., et al. (2015). **Development, implementation, and impact of an automated early warning and response system for sepsis.** *Journal of hospital medicine,* 10(1), 26-31. Full text
Early recognition and timely intervention significantly reduce sepsis-related mortality. Describe the development, implementation, and impact of an early warning and response system (EWRS) for sepsis. The EWRS resulted in a statistically significant increase in early sepsis care, ICU transfer, and sepsis documentation, and decreased sepsis mortality and increased discharge to home, although neither of these latter 2 findings reached statistical significance. An automated prediction tool identified at-risk patients and prompted a bedside evaluation resulting in more timely sepsis care, improved documentation, and a suggestion of reduced mortality.

SEARCH TERMS

Concept	MeSH headings	Keywords
Inpatient	Hospitalization or Inpatients or Hospitals	Hospital or inpatient hospital or ward *near* patient
Electronic Health Record	Electronic Health Records or Software or Artificial Intelligence or Telemetry	electronic medical or electronic health or digital health *near* record EMR or EHR or DHR or machine learning or ai or artificial intelligence
Clinical Deterioration	Clinical Deterioration or Monitoring, Physiologic or Early Warning Score	detect or identify or prevent or predict *near* deteriorate or met call or code blue or adverse outcome* or at risk
Communication	Communication	Messaging or alert or warning

MEDLINE SEARCH STRATEGY

Ovid MEDLINE(R) ALL <1946 to June 28, 2023>

1	Hospitalization/ or Inpatients/ or Hospitals/	254240
2	hospitali*.tw.	337114
3	(in?patient* or ((hospital* or ward) adj patient*)).tw.	187716
4	1 or 2 or 3	599776
5	Electronic Health Records/ or Software/ or Artificial Intelligence/ or Telemetry/	196388
6	((electronic medical or electronic health or digital health) adj3 record*).tw.	51575
7	(EMR or EHR or DHR or machine learning or ai or artificial intelligence).tw.	152898
8	5 or 6 or 7	346585
9	Clinical Deterioration/ or Monitoring, Physiologic/ or Early Warning Score/	59630
10	((detect* or identif* or prevent* or predict*) adj5 (deteriorat* or met call or code blue or adverse outcome* or at?risk)).tw.	17003
11	9 or 10	76052
12	Communication/	100135
13	(messaging* or alert* or warning*).tw.	92806
14	12 or 13	191547
15	4 and 8 and 11 and 14	105
16	limit 15 to (yr="2013 -Current" and english)	96

APPENDIX

PRISMA CHART