Online Supplementary Appendix 1: Population, Intervention, Comparison, Outcomes, Study Design

PICO	Indicative Terms
Population	▪ Newborn/neonate/infant/child/adolescent/young person patient ▪ Newborn/neonate/child/adolescent/young person acute patient ▪ Critically ill/deteriorating paediatric/pediatric patient ▪ Sepsis/septic infection/shock in newborn/neonate/infant/child/adolescent/young person patient
Intervention	▪ Neonatal/Paediatric/Pediatric Early Warning Score/System/Tool/Chart ▪ Neonatal/Paediatric/Pediatric Modified Early Warning Score/System/Tool/Chart ▪ Bedside PEWS/BPEWS ▪ Parent Activated Early Warning Systems ▪ Sepsis Six ▪ Track and Trigger Systems/Tools ▪ Instrument Validity/Reliability/Evaluation ▪ Calling Criteria/Rapid Response/Escalation Protocols/ Communication Tools/Situation Awareness ▪ Education/Training/ALERT™/COMPASS©
Comparison#	▪ Neonatal/Paediatric/Pediatric Early Warning Score/System/Tool/Chart ▪ Neonatal/Paediatric/Pediatric Modified Early Warning Score/System/Tool/Chart ▪ Bedside PEWS/BPEWS ▪ Parent Activated Early Warning Systems ▪ Sepsis Six ▪ Track and Trigger Systems/Tools ▪ Validity/Reliability/Evaluation ▪ Alert/Calling Criteria/Rapid Response/Escalation Protocols/ Communication Tools/Situation Awareness ▪ Education/Training/ALERT™/COMPASS© (comparison against each other or with no intervention)
Outcome	***Clinical outcomes*** Detection, and/or timely identification, of clinical deterioration of the newborn/neonate/child/adolescent/young person patient and all relevant *sequalae*; and diagnostic accuracy Instrument sensitivity/specificity ***Economic outcomes*** Costs and results ▪ Healthcare resource use ▪ Training/Education costs ▪ Staff time costs ▪ ICU outreach costs/additional referrals ▪ Results e.g. number of unplanned ICU admissions; number of cardio-pulmonary arrests; ongoing care costs, hospital mortality ▪ Immediate call to resuscitation team/MET (medical emergency team) team/CCRT (Critical Care Response Team) ▪ Cost savings ▪ Cost-effectiveness measures (e.g. ICER)
Study Design	Not specified as no limits were applied to study type/designs

Online Supplementary Appendix 2: Characteristics of included studies

Table 1: PEW detection systems (n=45)

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes/findings	Level of evidence & rationale for judgement
Agulnik et al. (2016) [14]	Boston Children's Hospital, Boston (USA)	Evaluate correlation of a PEW Score with unplanned PICU transfer in hospitalized oncology & hematopoietic stem cell transplant (HSCT) patients	Case–control Retrospective	All unplanned PICU transfers among hospitalized oncology & HSCT patients 110 paediatric oncology patients (42 oncology, 68 HSCT) 220 matched controls (not require PICU transfer)	Children's Hospital Early Warning Score, Boston Children's Hospital (adapted a modified PEWS-Brighton PEWS)	PEW Score highly correlated with need for PICU transfer overall (AUROC = 0.96) & in oncology & hematopoietic stem cell transplant groups (AUROC = 0.95 & 0.96 respectively) Among cases, average max PEWS 24-hour pre transfer 4.6 for oncology & 5.7 for HSCT patients (p = 0.002) Patients with higher PEW scores pre transfer had increased PICU mortality (p = 0.028) & length of stay (p = 0.004)	2+ Well-conducted case control study Retrospective, controls matched to cases 2:1 using 4 developmental ages (<1yr, 1-6yr, 7-11yr, ≥12yr), 2 hospital services (oncology & HSCT) and length of stay (i.e. time from admission to PICU transfer)
Akre et al. (2010) [15]	Children's Hospitals & Clinics of Minnesota (USA)	Evaluate sensitivity of PEWS	Chart review Retrospective	170 RRT calls & 16 code blue events for 186 patients on medical surgical units	Adapted the Brighton PEWS	Sensitivity of PEWS 85.5% Median time from first critical PEWS to RRT or code event 11h 36min & latest critical score 30min For 97.3% of patients earliest median time to consult was 80min Oximetry monitoring added at median time of 6.9h for 43.5% of patients 7% of patients had increased nursing assessment. Sub-group of patients had critical PEWS, consult & addition of monitor. Median time for earliest critical PEWS for these patients was significant (p <0.001)	3 Non-analytic, case reviews Retrospective, descriptive
Bell et al. (2013) [16]	Texas Children's Hospital Houston (USA)	Examine psychometric properties of PAWS	Chart review Retrospective	150 infant & child charts randomly selected from 3 units; included if length of stay > 48 hours (general medicine, transplant; pulmonary, adolescent, endocrine; & cardiology units)	Texas Children's Hospital Paediatric Advanced Warning Score (PAWS) (adapted a modified PEWS-Tucker at al. who had adapted the Brighton PEWS)	Cronbach's alpha reliability co-efficient for PAWS score at final measurement was 0.75 (adequate instrument reliability)	3 Non-analytic, case reviews Retrospective, descriptive, 6 month period, 150 charts (reflected 0.7% of population)

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Bolger et al. (2015) [17]	National Children's Hospital, Tallaght (Republic of Ireland)	Determine if time taken to maximise clinical input into deteriorating children would reduce following introduction of PEWT	Before & after Retrospective	All charts of patients whose clinical condition resulted in a CRA, PEWT call or a critical illness transfer to another centre (included paediatric wards and emergency department)	Paediatric Early Warning Trigger (PEWT) (based on modified Bristol PEWS)	9/89 PEWTs resulted in patients remaining on ward; 48/89 patients had care escalated to HDU; 9 patients required transfer to PICU; 1 patient died Time from deterioration to senior clinician involvement reduced from 312min to 166min Rate of transfers to PICU (among triage category 1&2 patients – i.e. all patients who require assessment by a doctor within 10min of arrival to ED) reduced from 1:50 pre the study to 1:29, 1: 118, 1:131 during the 3 years of the study Rate of CA reduced from 1:100 pre the study to 1:129, 1:216, 1:542 during the 3 years of the study	2- High risk of confounding or bias Retrospective, no control, audits of patient charts, 12mths pre & 3yrs post PEWT
Bradman & Maconochie (2008) [18]	St Marys Hospital London (UK)	Determine if PEWS can detect patients who need hospital admission or discharge home	Chart review Retrospective	424 patients who visited paediatric A&E	Brighton PEWS	PEWS ≥4; sensitivity 24%, specificity 96% PEWS ≥2; sensitivity 37%, specificity 88% Score had low sensitivity therefore limited value in predicting need for admission	3 Non-analytic, case reviews Retrospective audit of patients who attended ED over 2 week period
Bradman et al. (2014) [19]	Princess Margaret Hospital, Perth (Australia)	Compare published prediction tools (PRISA, PRISA II, PEWS, triage category) with triage nurse (TN) predictions	Chart review Prospective	All patients who presented to emergency department over 1 week study period (except patients presenting with psychiatric, dental, child protection concerns or non-medical presentations)	Comparing TN predictions for admission to PRISA (paediatric risk of admission score) ≥9 PRISA II (refined score) ≥2 Brighton PEWS ≥4 Triage category 1,2, 3	Of 1223 patients, 946 (83.6%) included (as had TN predictions) TNs had highest prediction accuracy (87.7%), followed by elevated PEWS (82.9%), triage category 1, 2, or 3 (82.9%) PRISA & PRISA II score had accuracy of 80.1% & 79.7% respectively	3 Non-analytic, case reviews Prospective, patients who attended ED over 1 week period, potential selection bias as not all patients had TN predictions performed
Breslin et al. (2014) [20]	Emergency department of urban tertiary care children's hospital (USA)	Determine association between PEWS at time of emergency department disposition & level of care	Chart review Prospective	383 patients; 239 discharged (62%); 126 admitted to acute care (33%); 18 admitted to ICU (5%)	Brighton PEWS	PEWS ≥ 1 = maximum discriminant ability for admission (sensitivity 63%; specificity 68%) PEWS ≥3 = maximum discriminant ability for ICU admission (sensitivity 56%; specificity 72%) Respiratory patients (n=97): PEWS >=3 had maximum discriminant ability to distinguish admission from discharge with sensitivity 60% specificity 83%	3 Non-analytic, case reviews Prospective data, 10 month period, convenient sample (based on availability of study team member)
Chaiyakulsil & Pandee (2015) [21]	Ramathibodi Hospital, Mahidol University, Bangkok (Thailand)	Validate PEWS in predicting hospitalisation in children <15 years presenting in emergency department (ED)	Chart review Prospective	All consecutive children aged > 15 years who presented to ED at time of study (except patients presenting with trauma, psychiatric, dental	PAWS (Egdell)	Of 1136 patients,168 (14.8%) were admitted (162 to general ward & 6 to ICU) For overall admission, PEWS ≥1 sensitivity 78%, specificity 59.6%, PPV 27.7%, NPV 94.8%, AUC 0.71 For ICU admission, PEWS ≥3 sensitivity 100%, specificity 90.5%, PPV 4.8%, NPV 100%, AUC 0.98	3 Non-analytic, case reviews Prospective, descriptive, patients who attended ED over 3 month period

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				and surgical concerns)		For general ward admission, PEWS ≥1, sensitivity 77.2%, specificity 59.1%, PPV 23.5%, NPV 93.8%, AUC 0.71	
Chapman et al. (2010) [7]	Great Ormond Street Hospital for Children NHS Trust, London (UK)	Identify number and nature of PAC & evaluate their validity, reliability, clinical effectiveness and clinical utility	Review	Included 11 publications describing 10 PAC	Paediatric alert criteria (PAC)	Number of PAC small & diverse in purpose, content & thresholds for activation Potential of PACs to improve care of hospitalised children (i.e. early identification of those at risk of clinical deterioration) has not yet been demonstrated Evidence lacking/weak in support of PACs validity, reliability & utility	2++ High quality systematic review of observational/quasi-experimental studies Detailed description of search strategy/evidence reviewed; quality assessment in line with research design criteria; results summarised narratively
Chapman et al. (2016) [22]	Great Ormond Street Hospital for Children NHS Trust, London (UK)	Examine key characteristics of paediatric track and trigger systems (PTTS) Appraise evidence on PTTS validity, calibration, & clinical utility	Review (updated from Chapman et al. 2010)	33 PTTS identified from 55 studies	Paediatric Track & Trigger Systems	Considerable variety in number & type of parameters; all contained one or more vital signs. Low evidence to support PTTS implementation as a single intervention Majority of outcomes did not achieve statistical significance Moderate evidence of impact of PTTS on mortality & cardiac and respiratory arrests when delivered as a care package High (and increasing) number of systems, outcomes and metrics is a significant confounder	2++ High quality systematic review of observational/quasi-experimental studies Detailed description of search strategy/evidence reviewed; quality assessment in line with GRADE methodology; results summarised narratively
Duncan et al. (2006) [23]	Hospital for Sick Children, Toronto, Ontario (Canada)	Develop bedside score to identify children requiring resuscitation to treat actual or impending CPA	Case control Retrospective	Case patients: (n=87) had code blue calls made as part of care Control patients: (n=128) had no code blue event	Paediatric Early Warning System (PEWS) score	PEWS sensitivity 78%, specificity 95% @ threshold score of 5 Score greater in case than control patients (mean max score 7.9 vs 3.2; $P < 0.0001$) & within each age category Score could discriminate between cases & controls & within each age category (AUROC 0.83-1.0) PEWS score identifies patients with at least 1-hour warning before code blue event	2+ Well-conducted case control study Frequency matched case control design, retrospective, 87 cases/128 controls
Ennis (2014) [24]	University Hospital Waterford (Republic of Ireland)	Support staff to recognise physiological changes & make appropriate decisions for early proactive intervention; & evaluate clinical utility & effectiveness (PEWS)	Quality Improvement Initiative Prospective	30 bed acute children's ward All children triggering PEWS of ≥3 during inpatient stay	PEWS track & trigger system; & ISBAR (Identify, Situation, Background, Assessment & Recommendation) (NHS Institute's PEWS Charts)	72 instances of PEWS ≥3 (35 children) 97% (34/35) with PEWS ≥3 had additional medical intervention following first PEWS alert review 82% (59/72) resulted in specific intervention or change to treatment plan Medical responses to 18% of all PEWS alerts (n=13) was 'continue to monitor'; 12/13 were for children with an earlier PEWS review/intervention 85% (n=30) with PEWS ≥3 improved within 24h following initial rapid medical review/interventions Low (0.3%) incidence of ICU level care (n=5); emergency resuscitations or unpredicted ICU referrals	3 Non-analytic, case review Prospective, descriptive, cohort, chart review/audit 18 month period

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						3 children electively transferred to ICU for a higher level of care & 2 children received ICU-level monitoring and non-invasive respiratory support on the children's ward Presence of experienced senior clinicians (registrars/consultants) at PEWS-triggered review was 82% of all PEWS reviews	
Edwards et al. (2009) [25]	Paediatric wards at University Hospital of Wales (UK)	Develop & evaluate predictability of PEWS (C&VPEWS)	Cohort Prospective	n=1000 patients 9075 observation sets	Cardiff &Vale PEWS (C&VPEWS)	As a single parameter: for threshold score of 1: 89.0% sensitivity, 63.9% specificity, 2.2% PPV, 99.8% NPV, AUROC 0.86 As a multiple parameter: 69.5% sensitivity, 89.9% specificity, 5.9% PPV, 99.7% NPV Tool is sensitive but not specific with low PPV (positive predictive value) - high number of false positives	2+ Well-conducted cohort study Prospective, to test predictability of PEW system, all children admitted in a time period were eligible to participate, data collected on 1,000 children; follow-up across admission
Edwards et al. (2011) [26]	Paediatric wards at University Hospital of Wales (UK)	Test predictability of MAC of medical emergency team (MET)	Cohort Prospective	n=1000 patients 9075 observation sets Data set from Edwards et al. (2009)	Melbourne criteria for activation (MAC) of MET (as described by Tibballs & Kinney)	MAC as single parameter: 68.3% sensitivity, 83.2% specificity, 3.6% PPV, 99.7% NPV, AUROC 0.79 Criteria had reasonable sensitivity but at cost of low specificity and low PPV which could result in high number of false positive triggers	2+ Well-conducted cohort study Prospective, to test predictability of activation system, all admissions to paediatric wards over 12 month period
Egdell et al. (2008) [27]	James Cook University Hospital, Middlesbrough (UK)	Design & validate physiology-based scoring system for assessment of children attending emergency department (ED)	Case control Retrospective	Case: (n=46) children admitted directly from ED to PICU Control: (n=49) children admitted from ED to paediatric ward	Paediatric Advanced Warning Score (PAWS) Chart	PAWS score could discriminate between cases and controls, with AUROC curve of 0.86 ($p<0.0001$) At threshold trigger score of 3, PAWS able to identify children requiring admission to PICU with sensitivity 70% & specificity 90%	2- High risk of confounding or bias Retrospective, pilot, 50 consecutive control patients
Fenix et al. (2015) [28]	Large tertiary children's hospital, Washington (USA)	Compare a prospectively validated PEWS to physician opinion in identifying patients at risk of deterioration	Chart Review Retrospective	All patient non-electively transferred to PICU	PEWS (modified Brighton)	97 patients non-elective transfer to ICU (also eligible for placement on SSO (assignment to institutional senior sign-out) lists before PICU transfer) – 51 experienced deteriorating events Patients experiencing a deterioration event in 12h after ICU transfer had max mean PEWS of 3.9 before PICU transfer compared with max mean PEWS of 2.9 in patients not experiencing a deterioration event ($p = .01$) Patients experiencing deterioration within 12 hours of PICU transfer were assigned to SSO lists 43% of the time, whereas patients without a deterioration event were assigned to SSO lists 30% of the time; this difference not statistically significant ($p = .2$) PEWS was significantly associated with ICU	3 Non-analytic, case review Retrospective, descriptive, chart review, single center, limited sample size, limited time period (9months)

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						deterioration whereas physician opinion was not	
Fuijkschot et al. (2015) [29]	Radboudumc Amalia Children's Hospital (Netherlands)	Design & implementation of a PEWS system	Cohort 1: Retrospective case review Cohort 2: Retrospective case review Cohort 3: Prospective cohort study	Case cohort 1: All patients admitted to 20 bed oncology ward over 3 month period Focus was clinical condition of patients with high scores (>8) Case cohort 2: Patients whose clinical course during admission (general ward) had deteriorated (i.e. cardiopulmonary arrest & unplanned PICU admission) Case cohort 3: All patients receiving emergency medical interventions	Modified Bedside PEWS	Case cohort 1: PEWS≥8 scored 56 times in 15/118 admissions (13%); specificity 88% (taking unplanned PICU admission as end point); sensitivity calculated as 100% (however this parameter is not reliable as only one unplanned PICU admission); n=15 (27%) false-positive scores; PPV 0.73. Case cohort 2: Of 24 patients, 16 scored PEWS of ≥8 at 2–6h pre PICU admission. Sensitivity 0.67 (threshold score ≥8 endpoint 2-6h pre unplanned PICU admission) Case cohort 3: 17 cases received emergency medical interventions); median PEWS 10 (range 8–15) at time of intervention; threshold score 8, no falsely negative scores detected (high sensitivity)	2+ Well-conducted case/cohort study Three case/cohort studies, appropriate sample and follow-up duration – two described as retrospective, one prospective
Gold et al. (2014) [30]	Nationwide Children's Hospital, Ohio (USA)	Explore if PEWS assigned in ED predicts need for ICU admission or clinical deterioration in admitted patients	Chart Review Prospective	Patients presenting to ED at time of study <u>2 outcome groups</u> Patients admitted to ICU (initially from the ED or subsequently from the floor) Patients admitted to the floor (with no ICU transfer)	Monaghan PEWS *P0* PEWS at initial assessment *P1*PEWS at time of admission	12,306 consecutively admitted patients, with 98.9% having a PEWS documented PEWS scores higher for patients in ICU group (P02.8& P13.2, $p < 0.0001$) vs floor (P00.7& P10.5, $p < 0.0001$) To predict need for ICU admission, optimal cut-off points on ROC are P0 =1 & P1 =2, with AUROC 0.79 & 0.86 respectively For every unit increase in P0 & P1, the odds of admission to ICU were 1.9 times greater ($p < 0.0001$) & 2.9 times greater ($p < 0.0001$) than to the floor	3 Non-analytic, case review Prospective, 12-month study period
Haines et al. (2006) [10]	Bristol Royal Hospital for Children (UK)	Develop & evaluate clinical & physiological tool for identifying acutely ill children	Cohort Prospective	Case: Children (*n* = 360) who triggered tool over a 6-month period Control: (*n* = 180) 5	Bristol PEWS	Of case (n=360) patients 73 (20%) required paediatric intensive or high dependency care. All fulfilled trigger criteria thus tool 100% sensitive for identification of patients requiring HDU/PICU; 63% specificity Modified tool (post research): 99% sensitivity &	2- High risk of confounding or bias Prospective, with a random control sample on day of data collection. Sample generated by nurse identification of previous

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes/findings	Level of evidence & rationale for judgement
		in hospital ward areas		random bed space numbers generated on each day of data collection		66% specificity	high-dependency nursing needs
Holme et al. (2013) [31]	Neonatal Unit Whittington Health (UK)	Design & validation of objective clinical scoring system to identify unwell neonates	Case cohort Retrospective	Group 1: n=193 (classed as 'unwell') All neonates born in study period admitted to NICU from labour or postnatal wards Group 2: n= 292 (classed as 'well') Neonates born during same study period not admitted to NICU	Neonatal Trigger Score (NTS)	AUROC 0.924 threshold score ≥2 predicting need for admission to NICU 79.3% sensitivity & 93.5% specificity; mean NTS significantly higher for neonates in group 1 (2.8 vs 0.35, p<.001) NTS out-performed PEWS, with significantly better sensitivity, particularly in neonates who deteriorated within the first 12 hours after birth (P <.001) or in neonates with sepsis or respiratory symptoms (P <.001).	2+ Well-conducted case cohort study Retrospective, 2 groups - 1 classed as 'unwell' and 1 class as 'well'
Kaul et al. (2014) [32]	Children's Hospital of Wisconsin (USA)	Determine if Bedside PEWS impacts on nurses ability to identify patients' at risk of CPA & enables nurses to share assessments & effectively manage deteriorating patients'	Cross-sectional survey	2 acute care medical units (1 with, & 1 without, Bedside PEWS) n=35 nurses (RR 46%) n=17 physicians (RR 81%)	Bedside PEWS	Nurses using Bedside PEWS significantly more likely to recognize risk for deterioration ($p < .04$) & significantly greater ability to initiate escalation of care when a patient was at risk for deterioration ($p < .01$) Physicians on the Bedside PEWS unit significantly more likely to indicate nurses able to effectively communicate concerns about deterioration in patient status ($p < .05$)	4 Expert opinion Electronic descriptive cross-section survey; small sample; one centre; self-report data
Mandell et al. (2015) [33]	Children's Hospital Los Angeles, CA (USA)	Evaluate association between PEWS at PICU discharge & 1st PEWS on paediatric ward with risk of early unplanned PICU readmission	Case-control Retrospective	Cases: 38 children readmitted to PICU within 48 hours after transfer to paediatric ward Control: 151 age-matched controls (not readmitted to PICU within 48 hours after transfer to paediatric ward)	PEWS (modified version of Brighton tool)	PEWS score pre PICU discharge higher for readmitted vs non-readmitted children p = .0003 First PEWS score on paediatric ward higher for readmitted vs non-readmitted children p<.0001 Higher PEWS scores pre PICU discharge & on paediatric ward associated with increased risk of PICU readmission p=.001 & p<.001 respectively No threshold score had adequate sensitivity and specificity to definitively identify children requiring PICU readmission within 48 hours of discharge	2+ Well-conducted case control study Age matched controls, retrospective, 38 cases/151 controls, controls randomly chosen by computer 1 case/3 control
McLellan et al. (2013) [3]	Boston Children's Hospital (USA)	Validation of Cardiac Children's Hospital Early	Cohort Retrospective	*Case:* All patients on inpatient cardiac unit experiencing a CPA or unplanned	C-CHEWS tool Comparison: Paediatric Early	For threshold score ≥3, PEWS sensitivity 54.7% vs 95.3% C-CHEWS; PEWS specificity 86.3% vs 76.2% C-CHEWS; PPV for PEWS 50.7% vs C-CHEWS 50.8%; NPV for PEWS 88.1% vs	2+ Well-conducted cohort study Retrospective, a specific high risk population, convenient comparison group

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		Warning Score (C-CHEWS) tool and its related three-tiered algorithm		ICU transfer (n = 64 with 10 arrests, 54 transfers) *Comparison:* 248 patients admitted to inpatient cardiac unit that did not experience CPA or unplanned ICU transfer	Warning Score (Monaghan 2005; Tucker et al 2008)	C-CHEWS 98.4% For threshold score ≥ 5, PEWS sensitivity 23.4% vs 67.2% C-CHEWS; PEWS specificity 97.6% vs 93.6% C-CHEWS; PPV for PEWS 71.4% vs C-CHEWS 72.9%; NPV or PEWS 83.2% vs C-CHEWS 91.7% C-CHEWS higher AUROC (0.917) compared with PEWS (0.785) ($p < .001$) Lead-time: for cut point ≥ 3, median for C-CHEWS 9.25h vs 2.25h for PEWS & for cut point ≥ 5, C-CHEWS median approx. 2h vs PEWS of 0h C-CHEWS achieved statistically significant higher discrimination than PEWS in identifying cardiovascular patients who may experience an arrest or ICU transfer	
Miranda et al. (2016) [34]	Federal University of Bahia, Salvador, Brazil (South America)	Review literature on use of Brighton PEWS as an instrument to identify signs of clinical deterioration in hospitalised children & possibilities of its application in a Brazilian context	Review	Included 11 research papers (using the Brighton PEWS)	Brighton PEWS	The Brighton PEWS was used, in most studies, as a tool to measure warning signs of clinical deterioration in hospitalized children Although some studies show limitations, the Brighton PEWS proved to be easy to apply & user-friendly & was regarded as low complexity, short time & wider feasibility of application, since its use is quick & monitoring equipment is not required; The Brighton PEWS may be regarded as a scoring option to be used in Brazil	2+ Integrative review of 11 studies specifically focused on the validity & reliability of 1 PEWS; 2 databases searched with limited search terms; quality assessment not reported; results reported narratively/descriptively on non-controlled non-randomised studies; included English, Portuguese & Spanish language
Monaghan (2005) [35	Royal Alexandra Children's Hospital Brighton (UK)	Development of a PEWS to detect children at risk of deterioration	Chart review Retrospective	n=30 patients scored 4 on PEWS	Brighton PEWS	96% of patients seen within 15min of applying the Brighton PEWS 83% of patients improved following intervention 17% of patients deteriorated requiring PICU admission	3 Non-analytic, case review Descriptive pilot (of PEWS for 3 month period), followed by patient audit – retrospective
Murray et al. (2015) [36]	Boston Children's Hospital (USA)	Explore literature about the use of early warning system scores with paediatric patients	Review	Included 28 publications; 13 data/research based, 10 clinical practice articles & 5 conference abstracts	PEWS	Greater psychometric testing of tools is needed before any recommendations can be made regarding extensive implementation with paediatric population	2+ Integrative review of 28 publications of which 13 were research based and the remainder grey literature; search terms and databases outlined and acknowledged that due to limited search terms publications may have been missed; quality appraisal included ranking level of evidence; narrative/descriptive

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							presentation of findings
Nielsen et al. (2015) [37]	Seattle Children's Hospital (USA)	Determine association between MPEWS in the emergency department (ED) and inpatient ward-to-PICU transfer within 24 hours of admission	Case-control Retrospective	Cases: 50 children transferred to PICU within 24 hours Controls: 575 children remaining hospitalised on inpatient ward	Modified paediatric EWS (MPEWS) (modified from Duncan)	Children with MPEWS > 7 in ED more likely to experience ward-to-PICU transfer; sensitivity 18%, specificity 97.4%, AUROC 0.691 (using this threshold would have led to 167 unnecessary PICU admissions & identified only 9/50 patients requiring PICU care)	2+ Well-conducted case control study Retrospective, control-case ratio 5:1, 18-month study period
Niu et al. (2016) [38]	Children's Hospital of Michigan, Detroit (USA)	Assess feasibility & reliability of PEW scores in paediatric emergency department setting	Feasibility & reliability testing study Prospective	Emergency department patients aged 18 years or younger n=56 ED nurses	Modified PEWS (from Skaletzky et al. who modified Brighton PEWS)	PEW scores demonstrated high inter-rater reliability (intra-class correlation coefficient = 0.91) and intra-rater reliability (intra-class correlation coefficient = 0.90)	3 Non-analytic, case review Descriptive prospective reporting of feasibility and reliability testing in a small sample in one emergency department
Parshuram at al. (2009) [39]	Hospital for Sick Children Toronto (Canada)	Develop & validate a simple bedside score to quantify severity of illness in hospitalized children	Case control Prospective	Case: (n=60) patients admitted urgently to PICU from inpatient ward (not following a 'code-blue' call) Control: (n=120) patients admitted to inpatient ward (not PICU, NICU, OPD, ED) (no 'code-blue' call & not admitted to PICU)	Bedside PEWS score	AUROC 0.91; sensitivity 82%; specificity 93% at threshold score 8 Score increased over 24h pre-urgent PICU admission ($P < 0.0001$) & score higher in patients admitted to ICU ($P < 0.0001$) Bedside PEWS Score can differentiate sick patients & identify >80% of patients with at least 1h notice before urgent ICU admission	2+ Well-conducted case control study Prospective, frequency matched case control design (+ retrospective survey interview), risk recall bias, data abstraction not verified
Parshuram et al. (2011a) [40]	4 participating hospitals - Montreal, Edmonton, Toronto & Birmingham (Canada & UK)	Evaluate performance of Bedside PEWS score in large population at multiple hospitals	Case control Prospective Multicentre	4 hospitals Case: (n= 686) patients experiencing a clinical deterioration event resulting in immediate resuscitation team call or urgent ICU admission Control: (n=1388) patients cared for in an inpatient unit without resuscitation	Bedside PEWS scoring system	Threshold 7, sensitivity 64% & specificity 91% Threshold 8, sensitivity 57% & specificity 94% AUROC 0.87 with scores maintained across age groups, diagnoses and hospitals After inclusion of data from the hour immediately before near or actual CPA, AUROC increased from 0.87 to 0.88	2++ High quality case control study. Large multi-centre international, prospective, 1:2 frequency matched case control design (acc. to clusters of similar inpatient units and stratified patient age categorises), clinical data abstraction + nurse interview/recall of observations (+ retrospective survey global rating); missing data was a limiting factor

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				team call or urgent ICU admission			
Parshuram et al. (2011b) [41]	Community hospital (Canada)	Evaluate effect of implementation of Bedside PEWS in 22-bed community paediatric hospital	Before-and-after Prospective	1274 patient admissions Care provided for 842 patient-days before & 2350 patient-days after implementation	Bedside PEWS	Reduction from 2.4 to 0.43 significant clinical deterioration events per 1000 patient-days (P=0.013) Fewer stat calls to respiratory therapists per 1000 patient-days (9.5 vs 3.4; P<0.0001) & to paediatricians per 1000 patient-days (22.6 vs 5.1; P<0.0001) Increase in overall number of transfers per 1000 patient-days (5.9 vs 8.1; P=0.041)	2- High risk of confounding or bias No control group, prospective, 9-month period, small number of events, self-report subjective responses
Parashuram et al. (2015) [42]	Hospital for Sick Children Toronto (Canada)	Evaluate impact of Bedside PEWS on early identification of children at risk for near and actual CPA, hospital mortality, processes of care & ICU resource utilization	Protocol (for 22 hospital cluster randomised trial) EPOCH (evaluating processes & outcomes of children in hospital)	Randomization unit is participating hospitals with a PICU Eligible inpatient wards providing care to children other than NICU, PICU, operating rooms & other areas where anaesthetist-supervised procedures are performed Eligible patients >37 weeks gestational age & <18 years	Bedside PEWS vs standard care (no severity of illness score) Bedside PEWS 4 elements: Bedside PEW score, Bedside PEW documentation record, score-matched care recommendations & education program	Primary outcome: all-cause hospital mortality Secondary outcomes: (i) clinical outcomes: clinical deterioration, severity of illness at and during ICU admission & potentially preventable cardiac arrest; (ii) processes of care outcomes: immediate calls for assistance, hospital and ICU readmission & perceptions of healthcare professionals; (iii) resource utilization: ICU days and use of ICU therapies	NA
Rahman et al. (2016) [43]	New York-Presbyterian/Weill Cornell Medical Center (USA)	Investigation of the external validity of Burn PEWS	Chart review Retrospective	All patients aged 0-15.9 years admitted to the burn center for ≥3 days for treatment of a burn injury, inhalation injury, or toxic epidermal necrolysis syndrome n=50 charts	NewYork-Presybterian/Weill Cornell Medical Center burn center pediatric early warning score (PEWS) - modified a general PEWS system to a burn specific PEWS	1612 PEWS from 1745 opportunities documented (92.4%); mean overall PEWS 0.9 ± 1.2 (0–10) From 1612 scores, PEWS were elevated greater than 0 for a total of 912 events (56.6%); mean elevated PEWS value greater than 0 was 1.61 ± 1.23 (1–10); parameters most frequently elevated were intake (95.6%) and output (7.9%) 129 PEWS increases (79.6%) were followed by an intervention that most commonly included text notation of score increase (93.7%), physician/physician assistant notification (70.5%), and feeding-tube insertion (25.6%)	3 Non-analytic, case review Retrospective, cohort small sample, single site, 12 month period
Robson et al. (2013) [2]	Children's Hospital in California (USA)	Validate & compare sensitivity & specificity of 3 previously	Case control Retrospective	Cases: n=96 triggered EMRT call due to critical illness with impending or actual CPA	Comparison of 3 PEWS PEW Tool (Haines); Bedside	PEW Tool: PEWS ≥1sensitivity 76.3%, specificity 61.5%, AUROC 0.75 Bedside PEW System Score: PEWS ≥7 sensitivity 56.3%, specificity 78.1%, AUROC 0.73	2+ Well-conducted case control Matched case control, on age, diagnosis and gender; retrospective

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes/findings	Level of evidence & rationale for judgement
		validated PEW scoring systems in predicting acute care patients at risk for impending or actual CPA		Controls: n=96 selected from internal database; matched to cases	PEW System Score (Parshuram); PEW System Score (Duncan)	PEW System Score: PEWS ≥5 sensitivity 86.6%, specificity 72.2%; demonstrated significantly greater accuracy ($p<0.05$) with AUROC of 0.85	
Roland et al. (2010) [44]	Neonatal Unit, Derriford hospital, Plymouth (UK)	Describes development, and assessment of effectiveness, of a Newborn Early Warning (NEW) system	Chart reviews x 2 Retrospective x 1 Prospective x 1	<u>Retrospective</u> Term infants > 2.5kg presenting to neonatal unit from either postnatal wards or transition care ward <u>Prospective</u> 117 at risk newborn infants (ARNI) - 84 charts available for review (71.2%).	Newborn Early Warning (NEW) System	<u>Retrospective</u> 122 term infants, 51% fulfilled ARNI criteria (84% were correctly identified as such) Only 48% (25/52) of infants recognised as ARNI had observations recorded, but half would have been reviewed earlier (13/25) by a neonatal doctor or nurse practitioner if their observations had been charted on the NEW chart <u>Prospective</u> Increase in retrievable observations to 72% NEW chart threshold criteria prompted management decisions in 9 (47.3%) of 19 infants who required intervention	3 Non-analytic, case reviews 2 chart review audits, 1 retrospective and 1 prospective (+ qualitative survey)
Roland et al. (2014) [45]	Paediatric Emergency Medicine Leicester Academic (PEMLA) Group, University of Leicester (UK)	Determine use of PEWS & RRT in paediatric units in Great Britain	Cross sectional survey	All hospitals with inpatient paediatric services in GB (n=157) 126 hospitals classified as district general hospital (DGH) & 31 tertiary children's hospitals		85% of units using PEWS & 18% had RRT (in 2005 <25% of UK hospitals used PEWS) Tertiary units more likely than district to have PEWS 90% vs 83%, & RRT 52% vs 10%. Large no. of PEWS in use, majority unpublished & invalidated systems; respiratory and heart rates most common criterion used in PEWS with > 50% of respondents using these and oxygen saturations, abnormal consciousness and effort of breathing Implementation of PEWS inconsistent with large variation in the PEWS used, activation criteria used, availability of RRT & membership of RRT	4 Expert opinion Electronic survey based on 2005 PEWS survey (+ follow up telephone survey for non-responders) of identified hospitals providing inpatient paediatric services in Great Britain, self-report data
Roland et al. (2016) [46]	Children's Emergency Department. Leicester Royal Infirmary (UK)	Validate/analysis performance of Paediatric Observation Priority Score (POPS)	Database Review Prospective	Convenience sample of 936 children 0-15 years presented to ED over 2 year period	Paediatric Observation Priority Score (POPS)	Majority of presentations were children of low clinical acuity when analysed by POPS. 69% of all attendees had total POPS of 2 or less. Inclusion of gut instinct and appearance factors into scoring of patients helped contextualise physiological parameter scoring i.e. additional 261 patients identified of lowest acuity & potentially suitable for discharge Those with total POPS score of 2 – 7 appear to stay in ED for longer than average waiting time & those with higher total POPS scores of 8 -10 stay in ED for less time than average	3 Non-analytic, case reviews Prospective data, convenient sample, patients who attended ED over 2 year period 2009-2011

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes/findings	Level of evidence & rationale for judgement
						Patients discharged from ED consume fewer resources than those admitted Average number of investigations or interventions per person increases with increasing clinical acuity on presentation POPS shows promise in assessing children presenting to EDs	
Sefton et al. (2015) [47]	Alder Hey Children's NHS Foundation Trust (UK)	Explore how introducing PEWS at a tertiary children's hospital affects emergency admissions to PICU	Before and after Prospective	In-house cohort of emergency admissions to PICU External cohort of emergency admissions transferred to PICU from wards at District General Hospitals (without PEWs in place) 958 unplanned PICU admissions over 2 years reviewed (1 year before and 1 year after PEWS)	Modified Bristol PEW	<u>In-house cohort</u> Median Paediatric Index of Mortality (PIM2) reduced from 0.60 to 0.44 ($p < 0.001$) Fewer admissions required invasive ventilation 62% vs75% ($p = 0.015$) for a shorter median duration, dropping from 4 to 2 days Median length of PICU stay reduced from 5 to 3 days ($p = 0.002$) Non-significant reduction in mortality ($p = 0.47$) <u>External cohort</u> No comparable improvements in outcomes <u>Impact on service delivery</u> 39% overall reduction in total number of bed days used for emergency PICU admissions which resulted in reduced cancellation of major elective surgical cases by 90% & 79% reduction in number of refused regional PICU referrals	2- High risk of confounding or bias Cohort, prospective, before 12 month period and after 12 month period, 'in-house' cohort emergency admissions to PICU, comparative group 'external' admissions transferred from DGH (without PEWS)
Seiger et al. (2013) [48]	Erasmus MC - Sophia Children's Hospital, Rotterdam, (Netherlands)	Compare validity of 10 different PEWS to predict ICU admission or hospitalization in large population of children visiting a paediatric emergency department (ED)	Cohort Prospective	n= 17,943 ED patients; 16% (n=2828) admitted to hospital and 2% (n=373) admitted to ICU or died in ED	10 different PEWS (Monaghan; Akre; Skaletzky; Duncan; Parshuram; Egdell; Tibballs; Edwards; Haines; Brilli)	For ICU admission range for the 10 PEWS: sensitivity 61.3-94.4% & specificity 25.2-86.7% For hospitalization range for the 10 PEWS: sensitivity 36.4-85.7% & specificity 27.1-90.5% Discriminative ability of PEWS (AUROC) moderate-to-good for ICU admission (range: 0.60-0.82); poor-to-moderate for admission to the hospital (range: 0.56-0.68). None of PEWS showed both high sensitivity & specificity	2+ Well-conducted cohort study Prospective collected data during triage assessments, all admissions to ED, 10 different PEWS evaluated
Sinitsky & Reece (2016) [49]	Royal Free London NHS Foundation Trust & West Hertfordshire	In paediatric patients can a PEW trigger or scoring system predict serious clinical deterioration?	Review	Included one systematic review & 12 research papers validating PEWS in paediatric inpatient settings	PEWS	No evidence to recommend the use of any one specific PEWS in paediatric inpatient settings No PEWS yet validated in large multi-centre RCT; although results are awaited from 1st international cluster RCT for Bedside PEWS (EPOCH study)	2- Commentary review of validation of PEWS; unsure risk of bias Search terms delineated, search restricted to specific databases & limited reporting of methodology (i.e. selection & screening

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes/findings	Level of evidence & rationale for judgement
	Hospitals NHS Trust (UK)						process, quality assessment, data synthesis etc.) underpinning the review
Skaletzky et al. (2012) [50]	Miami Children's Hospital (USA)	Validate modified version of Brighton PEWS tool for assessment of at-risk children in less acute care hospital areas	Case control Retrospective	Case: (n=100) all patients admitted to medical–surgical wards & transferred to PICU Controls: (n=250) patients admitted to medical–surgical wards but not transferred to the PICU	Modified Brighton PEWS score	Max PEWS score significantly higher $p < .0001$ for cases; AUROC 0.81; sensitivity & specificity of PEWS score 2.5 for transfer to higher level of care was 62% & 89%, respectively	2+ Well-conducted case control study Retrospective, 1:3 matching controls for each case, matched for age, ward of admission, month of admission, admitting diagnosis
Solevag et al. (2013) [51]	Akershus University Hospital (Norway)	Assess correlation of modified version of Brighton PEWS with other indictors of severe illness/patient characteristics	Chart review Retrospective	n=761 patients (PEWS forms collected)	Modified and translated version of Brighton PEWS	16.2% patients PEWS ≥ 3 & 83.8% PEWS ≤ 2 Transfer to higher level of care was significantly ($p = 0.04$) more frequent among patients with PEWS ≥3 (4.9%) as compared to PEWS 0-2 (1.4%) Patients with PEWS ≥3 had a higher proportion of admissions compared to patients with PEWS 0-2 Children with PEWS ≥3 received fluid resuscitation, oxygen supplementation & IV antibiotics significantly more often than those with PEWS 0-2	3 Non-analytic, case review Quality improvement project, retrospective data (3 month period – 761 PEWS forms)
Tucker et al. (2009) [6]	Cincinnati Children's Hospital (USA)	Evaluate use of PEWS for detecting clinical deterioration among hospitalised children	Chart review Prospective	n=2979; all patients admitted to a medical unit	Adapted Brighton PEWS tool	n=51 transferred to PICU (1.8%); PEWS discriminated between children who required transfer to PICU (AUCROC = 0.89, $p< .001$) For PEWS of 3 (lowest score requiring additional intervention) sensitivity 90.2%, specificity 74.4%, PPV 5.8%, NPV 99.8%. For PEWS of 9, sensitivity 7.8%, specificity 99.9%, PPV 80%, NPV 98.4% Inter-rater reliability high (intra-class correlation coefficient = 0.92, $p<.001$)	3 Non-analytic, case review Prospective, descriptive, all patients admitted to one unit over 12 month period, data recorded by charge nurse using localised tool
Tume (2007) [52]	Large specialist children's hospital based in North West of England (UK)	Examine extent of inpatient deterioration & critical care unit admission	Chart review Prospective	n=341 children admitted to PICU (65 children (19%) were unplanned admissions from wards); 346 children admitted to HDU, 16% (n = 52) unplanned admissions from wards	Bristol Children's PEWS Melbourne Activation Criteria (MAC)	121 children required unplanned HDU or ICU admission; mostly (55%) for respiratory distress (predominantly (59%) occurred out of office hours) When matched, 88% (n = 29) of ICU-admitted children would have triggered the Bristol PEW tool & 88% (n = 29) would have also triggered MAC 83% (n =27) of HDU admitted patients would have triggered the Bristol Children's tool & 89% (n = 28) would have also triggered MAC	3 Non-analytic, case review Prospective audit, 4 month period, descriptive analysis, child physiological data retrospectively matched against two PEW tools

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes/findings	Level of evidence & rationale for judgement
Zhai et al. (2014) [53]	Cincinnati Children's Hospital (USA)	Develop & evaluate performance of an EHR-based automated algorithm to predict need for PICU transfer & compare effectiveness of this new algorithm with 2 published PEWS	Case control Retrospective	Cases: n=526 patients admitted to PICU within 24 hours of admission Control: n=6772 patients never transferred to PICU	EHR-based automated prediction algorithm for PICU transfer Comparison: Monaghan PEWS tool & Bedside PEWS	Algorithm achieved 0.849 sensitivity, 0.859 specificity & 0.912 AUC; the algorithm's AUC was significantly higher by 11.8 and 22.6%, than two published PEWS Bedside PEWS (sensitivity 0.736, specificity 0.717, AUC 0.816) & Monaghan's PEWS (sensitivity 0.684, specificity 0.816, AUC 0.744)	2- High risk of confounding or bias Retrospective, to test algorithm

Table 2: PEWS response mechanisms (n=29)

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
Bonafide et al. (2014a) [54]	Children's Hospital of Philadelphia (USA)	Evaluate impact of paediatric RRS implementation on critical deterioration	Interrupted time series Retrospective	1810 unplanned transfers from medical/surgical wards to PICU/NICU	Hospital-wide RRS inclusive of MET and an early warning score	Absolute reductions in ward cardiac arrests (from 0.03 to 0.01 per 1000 non–intensive care patient-days) and deaths during ward emergencies (from 0.01 to 0.00 per 1000 non–intensive care patient-days), but these were not statistically significant ($p = 0.21$ and $p = 0.99$, respectively) Among all unplanned transfers, critical deterioration was associated with a 4.97-fold increased risk of death ($p < .001$)	2- High risk of non-causal relationships Retrospective, historical records, potential exposure to unmeasured confounding
Bonafide et al. (2012) [55]	Children's Hospital of Philadelphia (USA)	Develop a valid pragmatic measure for evaluating & optimizing RRSs over shorter periods of time	Cohort Retrospective .	724 medical emergency team (MET) & 56 code-blue team (CBT) activations	Rapid Response System including an early warning score & a MET	Critical deterioration (1.52 per 1000 non-ICU patient-days) >8 times more frequent than CHCA (Child Health Corporation of America) metric & associated with >13-fold increased risk of death among patients who received treatment from MET & CBT Critical deterioration metric sensitivity 76.0%; specificity 83.1%; PPV 16.7%; NPV 98.7%; relative risk of death 13.1 (95% CI:5.4–32.1) vs CHCA metric sensitivity 20.0%; specificity 98.8% ; PPV 41.7%; NPV 96.5%; relative risk of death 12.0 (95% CI:5.4–26.6)	2- High risk of confounding or bias Retrospective, review of MET activations, chart and unit review
Brilli et al.	Free standing	Implement & evaluate	Chart review	Hospital medical	Medical Emergency	Code rate (respiratory + cardiopulmonary	3 Non-analytic, case

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
(2007) [56]	children's hospital (USA)	effectiveness of MET & develop a 'trigger tool' (like PEWS)	Retrospective	records 44 patients who had CRA (cardiac respiratory arrest)	Team (MET)	arrests) post-MET 0.11 per 1,000 patient days compared with baseline 0.27 (p=.03) For codes outside ICU, pre-MET mortality rate 0.12 per 1,000 days compared with 0.06 post-MET (p =.13); overall mortality rate for outside ICU codes 42%	reviews Described as a performance improvement project, pre-post chart review + a staff performance assessment survey
Chan et al. (2010) [57]	Dept. of Internal Medicine, Mid America Heart Institute at St Luke's Hospital, University of Missouri–Kansas City (USA)	Assess effect of RRT implementation in reducing rates of CPA & hospital mortality; examine cumulative temporal trend on outcomes of RRTs & evaluate degree to which mortality reductions are explained by lower rates of CPA	Review	17 articles identified 5 child specific studies	Rapid Response Team (RRT)	37.7% reduction in rates of CPA outside ICU & 21.4% reduction in hospital mortality rates (pooled analysis); however this pooled mortality estimate in children was not robust to sensitivity analyses Although RRTs have broad appeal, robust evidence to support their effectiveness in reducing hospital mortality is lacking	2++ High quality systematic review of observational/quasi-experimental studies Search strategy detailed, 5 child specific studies of varying quality; all before/after studies with one time series study; results analysed at study not patient-level data; meta-analysis limited by extensive heterogeneity in reported outcomes and variation in research designs
Chen et al. (2014) [58]	Adult and children's hospitals with PICUs (USA)	Determine prevalence, characteristics & opinions of RRTs in hospitals with PICUs	Cross sectional survey	Survey sent to 210 US hospitals, 130 included - 103 completed by PICU medical directors Response rate 64%	Rapid Response Teams	103 (79%) had an RRT (most implemented in last 5 years); all available 7 days a week, 24 hours a day. 80% of institutions had RRT separate from cardiopulmonary resuscitation team Family activations present in 69% of hospitals Composition: median of 3 members composed of physicians in 77%; nurses in 100% and respiratory therapists in 89% of institutions Respondents with RRTs more likely to agree RRTs improve patient safety than respondents from institutions without RRTS (76% vs 52%) & more likely to disagree that RRTs are not worth the money invested (82% vs 63%)	4 Expert opinion Surveys (designed by investigators & piloted) distributed online and via mail, targeted selected US hospitals with PICU only, surveyed PICU physicians – data self-reported practices and beliefs, potential for non-response bias
Dean et al. (2008) [59]	Children's Hospital of Pittsburgh of the University of Pittsburgh	Develop paediatric patient safety program to give families a voice in their child's medical care	Quality Improvement Initiative	42 calls from patients/parents to Condition HELP team over 24 month study	Condition Help Call	Main reason for each call - communication breakdown between patient/parents & clinical staff (physician/nurse)	4 Expert opinion Descriptive account of 2 year analysis of Condition Help

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
	Medical Center (USA)			period			
Hanson et al. (2010) [60]	North Carolina (USA)	Determine effects of multifaceted paediatric RRS on duration of predefined clinical instability & subsequent rate of cardiac arrests	Interrupted time series Retrospective	All patients in the hospital during the study period	Paediatric Rapid Response Team (PRRT)	Increase in mean time interval between cardiac arrests from 2512 to 9418 patient days Median duration of clinical instability decreased from 9h 55min to 4h 15min in unplanned PICU admissions (p=0.028) Ward cardiac arrest rate/1000 ward admissions 1.27 before & 0.45 after PRRS (p=0.126) Ward death rate/1000 ward admissions 1.5 before & 0.45 after PRRS (p=0.070)	2- High risk of non-causal relationships Retrospective (+ chart review); potential exposure to unmeasured confounding
Haque et al. (2010) [61]	Aga Khan tertiary care University Hospital (Pakistan)	Report before & after implementation of a PRRT in paediatric wards to determine effect & outcome of the intervention	Chart review Retrospective	All paediatric admissions pre & post intervention	Paediatric rapid response team (RRT)	Code rate per 1000 admissions outside the PICU decreased from 5.2 to 2.7 (p=0.004) Mortality rate of patients admitted in PICU from wards decreased from 50% to 15% (p=0.001)	3 Non-analytic case review Audit, retrospective data, before and after, 9 month post-implementation period, all children admitted, data form completed by RRT and later collected by one investigator for review
Heath et al. (2016) [62]	Birmingham Children's Hospital (UK)	Development, and pilot of, a tool to support parents in communicating & escalating concerns about their child's clinical condition when in hospital	Quality improvement initiative	51 parents & 49 staff completed evaluation questionnaire	'Listening to You' communication bundle (poster, booklets, planning care together sheet) for parents and staff	<u>Implementation</u> 24/51 parents reported seeing the poster & 20/51 the booklet; only 3 parents reported using these resources; reasons for non-usage were-lack of awareness or lack of need 38/49 staff reported being aware of the project & 4 reported been involved in parent-initiated discussions using the resources <u>User feedback</u> Of the 3 parents who used the 'Listening to You' resources, 2 felt the materials led to increased confidence in raising concerns & having them listened to Of the staff who had seen or used the staff resources, approximately half reported they were easy to use, gave them confidence to elicit & discuss parental concerns & helped with parent-professional communication	4 Expert opinion Outlines local quality improvement initiative including a purposive national survey of current practice (31 wards 14 hospitals contacted over 1 month period via telephone/email), a literature review (30 papers mainly adult focused), semi-structured interviews (10 parents, 14 health professionals); describes intervention development & local user feedback

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
						Incidents and complaints Prior to implementation of 'Listening to You', two SIRIs relating to staff not listening to parent concerns were recorded. No incidents or complaints had been reported at the end of the pilot. PEW Scores (parental concerns box) On two cardiac wards reviewed, 81% of parental/nurse concern boxes were completed & of the completed boxes, 4% had documented a parental concern	
Hueckel et al. (2012) [63]	Duke University Hospital - Children's Health Center (USA)	Increase nursing & family awareness about Condition H	Quality improvement initiative	PBMTU n=38 families eligible for teaching Those who received teaching ranged from 64-90% monthly with mean of 80% n=32 eligible to complete survey on family understanding Intermediate ward n=159 patients admitted during study period; n=107 families received Condition H teaching – weekly range 53% - 85% (mean 68%)	Condition Help .	PBMTU 88% completed survey – all indicated they had heard about Condition H and could provide reason for calling Condition H; only 1 family needed additional instruction on how to call Condition H Intermediate ward n=81 (81%) participated - all but 2 families (98%) heard about Condition H; 64 (74%) could describe reason for calling Condition H and 66 (76%) answered correctly when asked how to call a Condition help. Rapid response and Condition H Activations 2 family initiated calls - in both cases parents were following up on signs & symptoms they had been told by medical staff to watch for; both appropriate & did not need higher level of care	4 Expert opinion Describes education process for teaching families about Condition Help & follow up survey to evaluate family understanding
Humphreys & Totapally (2016) [64]	Miami Children's Hospital, Florida (USA)	Evaluate times & disposition of rapid response alerts & outcomes for children transferred from acute care to intensive care	Cohort Retrospective	542 rapid response calls	Rapid response (RR) calls	321/542 (59.2%) RR calls were during daytime 323 children (59.6%) transferred to PICU 164 (30.3%) remained on acute care unit 19 (3.5%) required resuscitation (and were eventually transferred to PICU) More children transferred to PICU after rapid response alerts (p = .048) during day (66%) than night (59%) time	2- High risk of confounding or bias Retrospective, RR calls reviewed

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
						Mortality rate among children transferred from acute care units (3.8%) to PICU significantly higher ($p < .001$) than other PICU admissions (1.4%)	
Hunt et al. (2008) [65]	Johns Hopkins Children's Medical and Surgical Center (USA)	Effect of a PMET intervention on prevention of respiratory arrest & cardiopulmonary arrest	Before-and-after Retrospective & Prospective	Admitted patients who had either code team or PMET called or who had a CRA	Paediatric medical emergency team (PMET)	No change in the rate of CPAs Respiratory arrests decreased by 73% (0.23 to 0.06 per 1000 patient-days p=.03) Combined rate of respiratory and CPAs on the wards decreased 51% after transition to the PMET, but not significantly Consistent decrease (not statistically significant) in survival of patients who had a respiratory or CPA after the intervention	2- High risk of confounding or bias No control group, retrospective & prospective
Kotsakis et al. (2011) [66]	4 academic paediatric hospitals in Ontario (Canada)	Examine effectiveness of a paediatric rapid response system (PRRS)	Before-and-after Retrospective & Prospective	Data extracted from hospital administrative databases for 2 years before & after PRRS implementation	Rapid Response System using a physician led MET	No difference in rate of actual CPA 1.9 vs 1.8 per 1000 hospital admissions (p =.68) No change in rate of PICU mortality after urgent PICU admission 1.3 vs 1.1 per 1000 hospital admissions (p =.25) There was reduction in PICU mortality rate after PICU readmission 0.3 vs 0.1 death per 1000 hospital admissions (p <.05)	2- High risk of confounding or bias Interdisciplinary multi-centre study, no control group; retrospective & prospective
Lobos et al. (2014) [67]	Children's Hospital, of Eastern Ontario, Ottawa (Canada)	Explore whether health care staff activate MET differently and if so whether the difference was associated with patient disposition	Cohort Retrospective	Patients < 18 years who received MET activation during hospitalisation	Rapid Response System using a physician led MET	Physicians were most common MET activators 53.3% vs 47.7% generated by nurses Physicians had statistically significant higher PICU admission rates when compared with nurses (25.2% vs 15.0%, p =.001).	2- High risk of confounding or bias Retrospective, MET activations reviewed
Lobos et al. (2015) [68]	Children's Hospital, of Eastern Ontario, Ottawa (Canada)	Describe MET activity in follow-up program of all patients discharged from PICU	Cohort Retrospective	Discharged paediatric patients from PICU	Rapid Response System using a physician led MET – follow-up program of 2 planned MET visits within 48 hours post PICU discharge	1,805 patients followed after PICU discharge 36 patients (2%) readmitted at some point during follow-up period of which 11 (30%) occurred at time of 1st planned MET visit As comparison to 2 years preceding RRS the PICU readmission rate was significantly higher 6.8 vs 2% p=0.0001) Interrupted time-series analysis demonstrated a statistically significant immediate change in PICU readmission rate (–5.5%, p = 0.0001) During the 48-hour planned follow-up period,	2- High risk of confounding or bias Data from prospectively maintained rapid-response system database over 41-month period

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
						4% (64) of patients received an unplanned MET visit & 13% received an active intervention Multiple diseased organs were associated with major MET support after initial visit for recent surgical patients (p = 0.03)	
Paciotti et al. (2014) [69]	Children's Hospital of Philadelphia (USA)	Explore physician views on families facilitating identifying deteriorating children & possible options of enabling families to independently activate MET	Qualitative - interviews	30 physicians (21 medical & 9 surgical)	FAMET (family activated medical emergency team).	Physicians depend on families to explain child's baseline condition & identify changes; 63% (n=19) Families should not be able to directly activate an MET; 93% (n=28) Reasons why not; Family activation would lead to misuse of resources (64%, n=18) Families lack training & clinical knowledge to determine when MET call is indicated (43%, n=12) Family activation would undermine therapeutic relationship between clinicians & families (25%, n=7) Availability of Family Activation burdens families/increases anxiety (18%, n=5) Evidence demonstrating a relationship between FAMET implementation & improved patient outcome is needed (18% n=5) One FAMET call activated by family member - primary reason for call = communication breakdown between family & staff	4 Expert opinion Semi-structured interviews based on expert opinions of 30 physicians selected purposively, single site, constant comparative analysis
Panesar et al. (2014) [70]	Stony Brook Long Island Children's Hospital (USA)	Examine changes in characteristics of RRT calls before & after implementation of mandatory hospital policy	Database review Retrospective	Before mandatory triggering: 44 RRT calls (40 patients) After mandatory triggering: 69 RRT calls (63 patients)	Paediatric RRT	Number of night time events increased by 17.5% (p =.07) Main trigger for activations was tachycardia - an increase of 26.1% (p =.004). Reduction of 22.9% (p =.009) in RRTs called due to acute change in mental status/agitation Increase of 15.1% of RRTs required no intervention with mandatory triggering Trend toward decreased frequency of PICU transfers in post group by 17.5% (p = .06) with no change in number of code blue calls or mortality	3 Non-analytic, case review Quality assessment project, retrospective RRT database review, > 2 year period, before and after implementation

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
Ray et al. (2009) [71]	North Carolina Children's Hospital (USA)	Implementation of family-activated paediatric RRS; issues that arise during process and strategies for overcoming challenges	Quality improvement initiative	140 bed hospital	Family activation RRT	Random in-person surveys of 276 families show on average only 27% of families understand when and how to activate RRT. Family awareness has been as high as 58% and as low as 6% Family concern was noted as a reason for activation in 5% of calls; 2 calls directly activated by families Insufficient data to evaluate impact of family activation on cardiac arrests	4 Expert opinion Descriptive localised account of implementing a family activated Paediatric RRS, random in-person surveys with families
Sen et al. (2013) [72]	30 academic US paediatric hospitals (USA)	Examination of standard paediatric RRT practice, focusing on large US academic institutions	Cross-sectional survey	34 hospitals (identified using top US News & World Report rankings) Response rate 88% (n=30) Respondents were arrest committee chairpersons or PICU medical directors		All responding hospitals maintained 24 hour/day-7 day/week arrest teams and RRTs RRTs vary in terms of triggers, composition, response time and follow-up 33% of hospitals had a dedicated emergency team nurse; none had a dedicated physician Only 73% RRT had physician member 23% provide additional support (e.g. salary) 60% received family-activated calls 52% of RRT calls led to PICU transfer 73% of hospitals track RRT call times with 82% reporting majority of calls occur in daytime Limited standardisation (incl. definition) of outcome measures Best outcome measure for determining effectiveness of paediatric RRTs is unclear	4 Expert opinion Telephone survey, focused on prominent academic paediatric hospitals in US, self-report data
Sharek et al. (2007) [73]	Lucile Packard Children's Hospital (LPCH) (USA)	Evaluate effect of RRT implementation on hospital-wide mortality rates and code (respiratory & cardiopulmonary arrests) rates outside ICU in paediatric inpatients	Cohort Retrospective & Prospective	Patients admitted to LPCH during the study period; spent at least 1 day on the non-obstetric, non-nursery-based, non-ICU medical or surgical wards	Paediatric RRT	After RRT implementation, mean monthly mortality rate decreased by 18% (1.01 to 0.83 deaths per 100 discharges; p=.007) Mean monthly code rate per 1000 admissions decreased by 71.7% (2.45 to 0.69) & mean monthly code rate per 1000 patient-days decreased by 71.2% (0.52 to 0.15) Estimated code rate per 1000 admissions for post-intervention group 0.29 times that for pre-intervention group (p=.008) Estimated code rate per 1000 patient-days for post-intervention group 0.28 times that for pre-intervention group (p=.007)	2+ Well-conducted cohort study Described as before and after, uses historic data as 'control', cannot definitively say clinical outcome changes result of RRT intervention potential variance between pre and post intervention populations
Theilen et al. (2013) [74]	Royal Hospital for Sick	Evaluate impact of regular team training on hospital response to	Cohort Prospective	All deteriorating in-patients requiring	Paediatric Medical Emergency Team (pMET)	Deteriorating patients recognised more promptly (before/after pMET: median time 4/1.5h, $p < 0.001$); more often reviewed by	2+ Well-conducted cohort study Prospective, audit, all

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
	Children, Edinburgh (UK)	deteriorating in-patients with evolving critical illness and subsequent patient outcome		admission to PICU the year before & after introduction of pMET & concurrent team training	Concurrent with weekly in situ simulation team training	consultants (45%/76%, p = 0.004); more often transferred to high dependency care (18%/37%, p = 0.021) & more rapidly escalated to intensive care (median time 10.5/5h, p = 0.024) (improvements most marked in out-of-hours) Trend towards fewer PICU admissions, reduced level of sickness at time of PICU admission, reduced length of PICU stay & reduced PICU mortality Introduction of pMET coincided with significantly reduced hospital mortality (p < 0.001)	admissions to ICU, 1 year period, before & after MET & concurrent team training, uncontrolled, Hawthorne effect bias
Tibballs et al. (2005) [75]	Royal Children's Hospital, Melbourne (Australia)	Determine impact of MET on cardiac arrest, mortality, and unplanned admission to intensive care in a paediatric tertiary care hospital.	Chart review Comparison of retrospective & prospective data	Cardiac arrest & death incidences pre & post intervention (excluded non-inpatients, infants in N/PICU, patients with DNR decisions or receiving palliative care & arrests under anaesthesia)	MET .	Risk of cardiac arrest 0.19/1000 admissions before MET; reduced to 0.11/1000 admissions with MET (p=0.32) Risk of death 0.12/1000 admissions before MET; reduced to 0.06/1000 admissions with MET (p=0.28) Incidence of transgression of MET call criteria in patients who arrested decreased from 17 to 0 (risk difference 0.16/1000, p=0.0158) & in those who died, decreased from 12 to 0 (risk difference 0.11/1000, p=0.0426) after introduction of MET Unplanned admissions to ICU from wards increased from mean of 20 to 24 per month (p=0.074), representing increase from 17.3% to 21.3% of total ICU admissions	3 Non-analytic, case review Quality assurance exercise, preliminary results, before & after, compared retrospective data pre-MET (41 month period) with prospective data post-MET (12 month period)
Tibballs & Kinney (2009) [76]	Royal Children's Hospital Melbourne (Australia)	Determine effect of MET service on incidence of unexpected cardiac arrest and death in a paediatric hospital	Chart review Comparison of retrospective & prospective data	104780 admissions during a 41 month period pre-MET 138424 admissions during a 48 month period post-MET	Paediatric MET	Incidence of hospital deaths decreased from 4.38 to 2.87/1000 admissions ($p < 0.0001$) Incidence of unexpected in-hospital ward deaths decreased from 0.12 to 0.04/1000 (p=0.03) Incidence of total unexpected ward cardiac arrest did not change from 0.19 to 0.17/1000 (p=0.75)	3 Non-analytic, case review Before & after, compared retrospective data pre-MET (41 month period) with prospective data post-MET (48 month period)

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
						Among patients whose condition fulfilled MET calling criteria (preventable cardiac arrest), incidence of arrest decreased from 0.16 to 0.07 (p=0.04) & incidence of subsequent death decreased from 0.11 to 0.01/1000 admissions (p=0.001) Among patients whose condition did not fulfil MET calling criteria (non-preventable cardiac arrest), incidence of arrest increased from 0.03 to 0.10/1000 (p=0.03) but incidence of subsequent death did not increase. Survival from cardiac arrest increased from 7 of 20 patients to 17 of 23 (p=0.01)	
VandenBerg et al. (2007) [77]	Canadian and American hospitals with >=50 paediatric acute care beds or >=2 paediatric wards (Canada)	Describe levels of care, frequency of near or actual cardiopulmonary arrest (code-blue events), identification mechanisms & responses to evolving critical illness in hospitalized children	Cross-sectional survey	964 health care professionals from 388 hospitals (response rate 84%); of responding hospitals 181 (47%) met inclusion criteria; 16 (8%) were Canadian hospitals; 165 (92%) were American; 85 (47%) were freestanding paediatric acute care hospital		All responding hospitals had immediate-response teams; they were activated 4676 times in previous 12 months 24% of hospitals had activation criteria for immediate-response teams Urgent-response teams to treat clinically deteriorating children (not at immediate risk of cardiopulmonary arrest) were available in 75% hospitals; 17% had formal METs and 51% consulted PICU Code-blue events were more common in hospitals with extracorporeal membrane oxygenation therapy, cardiopulmonary bypass, and larger PICU size.	4 Expert opinion Telephone survey (designed by investigators), of selected Canadian/American hospitals ≥50 paediatric acute care beds or ≥2 paediatric wards, self-report data – accuracy not verified
Jagt (2013) [8]	Dept. of Paediatrics, University of Rochester (USA)	Identify what is known about use & organization of paediatric resuscitation teams (code teams) & PRRS	Review	Search strategy, screening process and number of eligible papers included in the review not specified	Paediatric rapid response team (PRRT)	Exact details of RRT implementation varies among paediatric institutions Critical that data is collected in a standardised fashion across institutions so that best possible RRS can be designed	2- Narrative review of components of RRS; unsure risk of bias Methodology (i.e. search strategy, screening process, quality assessment, data synthesis) underpinning the review not reported
VanVoorhis & Willis (2009)	North Carolina	Highlight process of developing a	Case examples x 2	*Case example 1* North Carolina	Paediatric rapid response system (PRRS)	Case example 1: Mean time interval between cardiac arrests increased from 2512 to 9418	3 Non-analytic, case review

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main outcomes	Level of evidence and rationale for judgement
[78]	Children's Hospital & Levine Children's Hospital (LCH), North Carolina (USA)	paediatric rapid response system (PRRS) & measuring its effects on patient safety		Children's Hospital *Case example 2* Levine Children's Hospital	Institution-wide/Paediatric Early Response Team (PERT)	days, indicating a decrease in non-ICU cardiac arrests. Median duration of predefined clinical instability before assessment by ICU personnel decreased from 9h 55min to 4h 15min post intervention (p = .028) Case example 2: Mean rate of non-ICU codes decreased from 4 to 1.5/1000 discharges	Descriptive presentation of case examples from 2 US hospitals
Wang et al. (2011) [79]	Children's hospital Denvor (USA)	Describe demographic & clinical variables including outcomes of emergency response team (ERT) activations	Database review Retrospective	n=1334 ERT activations analysed	Emergency Response Team (ERT)	A total of 39% (511) of all ERT activations occurred in patients under the age of 1 year Statistically, there were significantly more ERT activations during day as compared to night shifts (P < 0.001); no statistical significance between summer and winter months Most common admission diagnosis category was cardiac disease Survival rate after an ERT itself was 90%, with an overall survival rate to discharge of 78%	3 Non-analytic, case review Descriptive retrospective, database of ERT activations, 13 year period
Winberg et al. (2008) [80]	Queen Silvia Children's Hospital, Gothenburg (Sweden)	Evaluate & summarise current knowledge about paediatric RRSs	Review	Included 8 articles published in peer-reviewed journals	Paediatric Rapid Response System (PRRS)	PRRSs are used extensively internationally 1 study reported a statistically significant decrease in mortality rate after implementation; 2 studies showed a non-significant association with decreased mortality rate Cardiac and/or respiratory arrest rates decreased in 4 before-after studies with statistical significance in 2 studies Concluded that existing data supports effectiveness of paediatric RRS; however limited guidance on most optimal system	2+ Review reporting on observational / quasi-experimental studies Outline of search strategy provided; quality assessment not reported; results reported narratively on non-controlled non-randomised studies
Zenker et al. (2007) [81]	Children's Hospitals and Clinics of Minnesota (USA)	Evaluate effectiveness & impact of implementing RRT	Pre-post design Retrospective & Prospective	Post-RRT implementation 150 activations (2 requested by parents) Rates of 12.84 RRT activations per 1000 discharges & 3.06 per 1000 patient-days	Paediatric Rapid Response Team	Mortality rate unchanged from 22561 discharges pre-implementation to 11682 discharges during implementation phase (4.3 vs 4.5 per 1000 discharges p=.57) Incidence of arrests both cardiac and respiratory decreased from 8 to 5.1 per 1000 discharges a decrease of 36% (p=.19)	2- High risk of confounding or bias No control group, retrospective & prospective

Table 3: PEWS implementation strategies (n=16)

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main Outcomes	Level of evidence and rationale for judgement
Azzopardi et al. (2011) [82]	Royal Children's Hospital Melbourne (Australia)	Assess value/attitudes placed on MET by clinical staff & identify barriers to activation of MET	Cross-sectional survey	n=407 (280 nurses & 127 doctors) Of the 407 participants, 305 were MET callers & 102 were MET responders	MET	MET highly valued for obtaining urgent assistance for seriously ill patients by 85% nurses & 83% doctors Amongst MET callers more nurses than doctors ($p = 0.01$) disagreed that MET reduces their skills in managing sick patients and agreed that MET teaches them how to better manage severely ill patients ($p = 0.09$) Doctors who were MET responders agreed that MET increases their workload when caring for sick patients compared to MET callers ($p < 0.01$) Amongst nurses, MET responders were more likely to agree that MET was overused compared to MET callers ($p < 0.01$) Amongst MET callers, medical staff were more likely to agree that MET was overused compared to nurses ($p < 0.01$)	4 Expert opinion Electronic survey, modified version of a previously developed & validated questionnaire, all clinical staff (medical and nursing) invited to complete; 1 month time-period; self-report expert opinion, potential for non-response bias
Bonafide et al. (2013a) [83]	Children's Hospital of Philadelphia (USA)	Identify mechanisms beyond statistics to predict clinical deterioration by which physicians and nurses use EWS to support their decision making	Qualitative - interviews	n=57 (27 nurses & 30 physicians) General medical & surgical wards	Rapid Response System (EWS based on Bedside Paediatric Early Warning System + MET)	EWS facilitates safety by alerting physicians & nurses to concerning vital sign changes & prompting critical thinking about possible deterioration EWS provides less-experienced nurses with age-based vital sign reference ranges Having concrete evidence of clinical changes in form of an EWS empowers nurses to escalate care & communicate their concerns For patients who are stable; patients with abnormal physiology baselines who consistently have high EWSs & patients experiencing neurologic deterioration EWS may not help with decision-making	4 Expert opinion Semi-structured interviews, expert opinion of nurses and physicians in one context, potential social desirability response bias
Bonafide et al (2014b) [84]	Children's Hospital of Philadelphia (USA)	Model the financial costs & benefits of operating a MET & determine annual reduction in critical deterioration (CD) events required to off-set MET costs	Cohort Retrospective	Unplanned transfer of child classified as CD if any life-sustaining interventions (ventilation or vasopressor infusion) were required within 12 hours of ICU	MET team	Patients who had CD cost \$99,773 ($p < .001$) more during their post-event hospital stay than transfers to ICU that did not meet CD criteria Annual MET operating costs ranged from \$287,145 for a nurse & respiratory therapist team with concurrent responsibilities to \$2,358,112 for a nurse, respiratory therapist, & ICU attending physician freestanding team	2- High risk of confounding or bias Retrospective review

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main Outcomes	Level of evidence and rationale for judgement
				transfer. 1,759 unplanned transfers occurred during study period; 1,396 patients met inclusion criteria; 378 (27.1%) met CD criteria		In base-case analysis, a nurse, respiratory therapist, & ICU fellow team with concurrent responsibilities cost $350,698 per year, equivalent to a reduction of 3.5 CD events	
Brady & Goldenhar (2013) [85]	Cincinnati Children's Hospital Medical Center (USA)	Learn about factors that influence front-line healthcare providers' ability to achieve and maintain SA	Qualitative – focus group interviews	n=3 focus groups with charge nurses (n=3,3,4) n=3 focus groups bedside nurse/RT groups (n=3,3,5) n=1 resident focus group (n=10)	NA	**Team based care (social system input)** *Family empowerment* – listening to, engaging & giving families power to escalate their concerns *Nurse empowerment* - having a powerful, equal and welcomed voice in huddles and within patient care team *Unit culture that supports teamwork, accountability & safety* - support trusting relationships, encourage communication & willingness to ask for second opinions **Availability of standardised data (technological system input)** *Standardised data elements/score*s e.g. objective algorithms (e.g. PEWS) + gut feeling *Tools for entering, displaying and monitoring data and data trend*s e.g. electronic health record & its ability to display data over time **Standardised processes and procedures (organisational system input)** *Shared training and language regarding patient risk* - e.g. watcher - having a gut feeling about a patient that is at risk for deterioration or close to the edge; having experienced providers; peer coaching & debriefing *Structure to proactively identify and plan for risk* e.g. huddles, frequent scheduled assessments, check-ins by charge nurses & physicians, MRT calling criteria, planning tools and explicit contingency planning *Structure to support handoffs and continuity of care* e.g. clear and standardised handoff practices and knowledge of the patient's initial and current status and the patient's family *Structure that supports adequate workload/staffing* e.g. improved staff-to-patient ratio; experienced &	4 Expert opinion Localised focus group interviews with nurses, respiratory therapists and physician, potential for group think bias & presentation of beliefs and opinions rather than actual behaviours/actions

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main Outcomes	Level of evidence and rationale for judgement
						diverse team of providers available on all shifts; extra resources available	
Brady et al. (2013) [86]	Cincinnati Children's Hospital Centre (USA)	Design a system to identify, mitigate, & escalate patient risk by using principles of high-reliability organizations	Time series	Checklist-based form followed flow of situation awareness algorithm; completed by charge nurse (collected from each unit on each nursing shift)	Situation Awareness intervention	Rate of UNSAFE (unrecognized situation awareness failures events) transfers/10000 non-ICU inpatient days were significantly reduced from 4.4 to 2.4; days between inpatient SSEs (serious safety events) also increased significantly	2- High risk of non-causal relationships Retrospective, potential exposure to unmeasured confounding, no measure for situation awareness
Demmel et al. (2010) [87]	Cincinnati Children's Hospital Medical Center (USA)	Implement PEW Scoring System on a Paediatric Haematology/Oncology	Chart review Quality improvement initiative (PDSA cycles)	Haematology/ oncology/bone marrow transplant unit PEWS team & historical data (unplanned ICU transfers from oncology unit)	PEWS scoring process & 'watchful eye' action algorithm	Immediately prior to implementation of PEWS, no. of days between CPA on unit = 299; Post-implementation, days between CPA on unit increased to 1053; sustained at that level for nearly 2 years Staff evaluation: PEWS scoring process improved multidisciplinary team communication & defined clear actions for new, less experienced staff High level of charge nurse involvement helped keep the initiative going	3 Non-analytic, case reviews Describes implementation of PEWS tool & action algorithm, prospective and retrospective data, ongoing cycles using plan-do-study-act
Duncan & Frew (2009) [88]	Teaching specialist children's hospital (UK)	Determine additional short-term health service costs of in-hospital acute life threatening events in children to inform a cost-effectiveness analysis of prevention strategies	Cost-analysis exercise	All life-threatening event calls over a 27 month period Control group of age and specialty matched patients	Cardio-pulmonary resuscitation attempts	120 acute life-threatening event calls (36 cardiac & 80 respiratory arrest; 4 for another event); average 12.8 staff members attended each call Total cost of a CPR attempt (actual attempt & preparedness) £3,663/attempt Mean cost of post-event length of stay in hospital was £22,562for cardiac arrest, £26,335 for other acute life-threatening events, and £26,138 for urgent PIC admissions. Cost per survivor to hospital discharge £53,289	3 Non-analytic, case reviews Prospective
Hayes et al. (2012) [89]	20 Child Health Corporation of America (CHCA) hospitals (USA)	Implement suite of prevention, detection & correction strategies to reduce number of inpatient paediatric cardiopulmonary arrests and improve patient safety culture	Quality improvement initiative	Ward areas: each team identified target units from noncritical care inpatient units, ED, operating rooms, and ICUs.	Foundational changes e.g. SBAR Midlevel changes e.g. RRT Advanced changes e.g. FARRT	PEWS implemented in 92% of hospitals within 12months of end of collaborative period Code rate for collaborative did not decrease significantly (3% decrease) 12 hospitals reported additional data after collaborative & saw significant improvement in code rates (24% decrease) Patient safety culture scores improved by 4.5% to 8.5%.; the only statistically significant improvement was seen in "non-punitive response to error" (P = .02)	4 Expert opinion Multi-centre multi-disciplinary collaborative based on Model for Improvement (plan-do-study-act); monthly data submissions over 12 month study period and preceding 12 month period as baseline data, + safety culture survey at 3 time points
Kukreti et	Hospital for	Implementation &	Quality	4 Paediatric	Paediatric MET	>95% satisfied with quality & timeliness of MET	4 Expert opinion

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main Outcomes	Level of evidence and rationale for judgement
al. (2014) [90]	Sick Children in Toronto (Canada)	evolution of a paediatric rapid response team; process, barriers, and ongoing challenges	improvement initiative	Academic Health Science Centres, Ontario granted funding to initiate paediatric Program introduced in 3 phases at Hospital for Sick Children, Toronto	program	>90% MET had positive impact on patient care <u>3 perceived benefits of MET were:</u> Education provided on hospital floors/clinics Satisfaction of service users (patients, nurses & physicians) Empowerment of bedside staff No significant reduction in code blue rate or readmission rate to CCU	Describes local experience of implementing RRT, presented some data on pre-post implementation survey and MET activity
Lobos et al (2010) [91]	Toronto & Children's Hospital of Eastern Ontario; McMaster Children's Hospital, Hamilton; Children's Hospital London (Canada)	Describe standardised implementation of RRS using a MET across 4 paediatric hospitals .	Quality improvement initiative	2 free-standing paediatric hospitals & 2 paediatric units in adult hospitals	Paediatric RRS using physician-led MET	44 activations/1000 admissions during 1st 2 years with respiratory concerns most common activation reason (46%) Resulted in significant reductions in total code blue events & PICU mortality following unplanned PICU admissions and PICU readmissions from the ward	4 Expert opinion Multi-centre study on standardised implementation of RRS, based on Social Marketing principles, phases of implementation described
McCrory et al. (2012) [92]	John Hopkins University Hospital Simulation Center (USA)	Evaluate education intervention of teaching ABC-SBAR to paediatric interns	Pre-post design	n=27 paediatric interns 26 (96%) of 27 interns agreed to have their pre-and post-intervention video-recorded hand-off data included 52 total hand-offs included for analysis	Education session: Rapid Response: why, when and how (incl. ABC-SBAR training) Video-recorded mock patient hand-off (before & after education session)	After training: Mean score of hand-offs improved significantly (3.1/10 pre- vs 7.8/10, P<0.001) Hand-offs including airway or breathing assessment improved (9/26 [35%] to 22/26 [85%], p = 0.001) & this information was stated earlier (25 vs 5 seconds, p<0.001) Hand-offs including an assessment or recommendation by interns significantly increased (1/26 [4%] vs 22/26 [85%], p<0.001). Hand-offs with ABCs or situation prioritized before background increased (≤5% vs ≥77%) Elapsed time to stated essential content items significantly decreased (19 vs 7 seconds, p<0.001) Total hand-off duration increased (29 vs 36 seconds, P = 0.004)	2- High risk of confounding or bias No control group, simulated environment not patient care environment
McKay et al. (2013) [93]	Tertiary hospital providing regional paediatric care (Australia)	Evaluate impact of newly designed PEWS & accompanying education package COMPASS	Before & after study	2 inpatient paediatric wards Pre-intervention n=1059 Post-intervention	Education package: COMPASS (e-learning package and a 3-hour face-to-face low-	<u>Patient outcomes</u> Reduction in the number of patients requiring unplanned admission to paediatric HDU (3.8% vs. 2.7%, *P* = 0.22) <u>Vital sign documentation</u> Significant improvement in daily documentation of vital signs including: level of consciousness (0 vs.	2- High risk of confounding or bias Prospective, controlled, potential selection bias at one site and potential for Hawthorne effect (sustainability unknown)

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main Outcomes	Level of evidence and rationale for judgement
				n=899 <u>Random subgroup</u> Pre-intervention n=262 Post-intervention n=221	fidelity simulation)	7.8, p < 0.001), respiratory effort (0.0 vs. 7.8 p < 0.001), capillary refill (0 to 1.1 p < 0.001) and blood pressure (0.0 vs. 0.0), p = 0.007) Fewer children breached MET criteria (38.9% (*n* =102) vs. 20.4% (*n* = 45)) <u>Communication and medical review</u> Significant improvement in number of documented communication episodes (8.5% vs. 40.9%, *P* < 0.001)	
McLellan & Connors (2013) [94]	Children's Hospital Boston (USA)	Implementation & modifications of CHEWS & its companion Escalation of Care Algorithm for paediatric cardiovascular patients	Chart reviews 3 pilot studies	Inpatient paediatric cardiovascular unit Pilot 1: 27 patients & 157 observations Pilot 2: 33 patients & 312 observations Pilot 3: 20 patients & 119 observations	Children's Hospital Early Warning Score (CHEWS) & Escalation of Care Algorithm	Pilot 1: 29.6% of patients had lower CHEWS scores than the acuity severity of their clinical presentation Pilot 2: 7.5% of patients' C-CHEWS scores did not correlate with acuity of their clinical picture Pilot 3: 100% of C-CHEWS scores matched the acuity of patients' clinical presentations <u>Unplanned CICU transfers after C-CHEWS implementation</u> Chart review of patients who had an unplanned transfer to the CICU or experienced an arrest on the cardiac unit typically had elevated C-CHEWS scores with exception to sudden onset of compromising arrhythmia; in comparing rate (transfers per 1000 patient days) of these events 1 year pre- and 1 year post- C-CHEWS implementation, there was a reduction in unplanned transfers	3 Non-analytic, case reviews Describes modification and implementation of a PEWS tools and escalation of care algorithm for cardiac patients, processes implemented over course of 3 pilot studies which incorporated retrospective chart reviews/audits + clinician interviews
Randhawa et al. (2011) [95]	Children's National Medical Center, Division of Nursing, Washington (USA)	Describe process & outcomes of implementing & sustaining use of PEWS at unit & organizational level to reduce paediatric cardiopulmonary arrest	Quality improvement initiative - cycles of change	First cycle: 15-bed cardiology & nephrology unit Second cycle: 39-bed general medical unit Third cycle: All acute care areas (additional 136 beds, including haematology/oncology, surgical, respiratory, short stay &	PEWS & escalation algorithm	First cycle: Frequency of codes of CPA's reduced from 0.98/1000 to 0.62/1000 patient-days Second cycle: Frequency of codes/1,000 patient-days reduced from 0.65/1000 to 0.49/1000 patient-days Third cycle: CPA reduced from 0.15/1000 patient-days to 0.12/1000 patient-days 23.4% reduction in CPA organizationally (0.21 codes/1000 patient days) 19.4% reduction in CAT Team activations across all acute units	4 Expert opinion Single site, description of 3 cycles of change related to the process and outcome implementation of PEWS, underpinned by plan-do-check-act methodology

Author(s); Date	Setting	Aim	Design	Sample	Intervention	Main Outcomes	Level of evidence and rationale for judgement
				neurosciences units)			
Roberts et al. (2014) [96]	Children's Hospital of Philadelphia (USA)	Identify & understand barriers to calling for urgent assistance in a children's hospital where an rapid response system (RRS) was implemented	Qualitative - interviews	n=57 (27 nurses & 30 physicians) General medical/surgical wards	RRS consisting of calling criteria, EWS & MET	Nurses & physicians valued RRS; believed it enhanced patient safety & improved relationships between clinicians in general care and ICU areas Reported on barriers that shaped decision to activate MET see Table 4	4 Expert opinion Semi-structured interviews, based on expert opinion of select nurse (n=27) and physician (n=30) participants in single setting, modified grounded theory approach used to analyse data
Tume et al. (2013) [97]	Large children's hospital in the North West of England (UK)	Describe development of the RESPOND course, including preliminary evaluation of 1st 4 courses	Course evaluation survey	Course participants over 4 separate days n=65 (multi-professional) 63 of 65 (97% response rate) paper evaluations of 4 RESPOND courses completed	RESPOND (Recognising Signs of Paediatric hOspital iNpatients Deterioration) (1-day course)	<u>Most useful aspects of RESPOND:</u> Discussion/review of real life cases Learning to use SBAR - improved communication between doctors & nurses & working more as a team Multi-professional approach improved understanding among each professional group when dealing with deterioration cases Stated that in-hospital cardiac arrests had reduced from mean of 21.3 to 13 post introduction of RESPOND course	4 Expert opinion Small preliminary evaluation of a training course, post-course paper evaluation form and 3-month post-course electronic survey (low response rate – non-response bias); descriptive

Online Supplementary Appendix 3: Original PEWS Tools

PEWS Tool	Origin	Development
Brighton-Paediatric Early Warning Score (Monaghan 2005) [35]	Royal Alexandra Hospital for Sick Children (UK)	Multidisciplinary working group; developed on available adult systems (not specified)
Pediatric Early Warning System score (Duncan et al. 2006) [23]	Hospital for Sick Children Toronto (Canada)	Expert group of nurses utilised a modified Delphi approach to achieve consensus on parameters and ranges
Paediatric Early Warning (PEW) Tool (Haines et al. 2006) [10]	Bristol Royal Hospital for Children (UK)	Expert group; pilot tool based on un-validated tool developed at Derriford Hospital Plymouth with modifications from criteria developed at Melbourne Children's Hospital Australia & similar adult systems. Modifications made by expert opinion of investigating team including study research nurse, two supervisors, a PICU intensivist & PICU consultant nurse
Paediatric Advanced Warning Score (Edgell et al 2008) [27]	James Cook University Hospital (UK)	Not reported
Bedside Paediatric Early Warning System Score (Parshuram et al. 2009) [39]	Hospital for Sick Children Toronto (Canada)	Expert group & statistical methods (evaluated alongside score comparison & score progression)
Cardiff & Vale Paediatric Early Warning System (Edwards et al. 2009) [25]	University Hospital of Wales (UK)	Developed using physiological parameters based on 2005 advanced paediatric life support guidelines for recognition of sick child Expert group - general paediatricians, regional nurse educator & paediatric intensivist –reviewed other EWS to modify age-related normal ranges & identify other parameters for inclusion; the group reached a consensus opinion to agree 8 parameters & trigger criteria
Newborn Early Warning System (Roland et al 2010) [44]	Neonatal Unit, Derriford Hospital, Plymouth (UK)	Not reported
Cardiac Children's Hospital Early Warning Score (McLellan et al. 2013) [3]	Boston Children's Hospital (USA)	Expert group; developed from CHEWS - a multidisciplinary panel assessed which risk factors were unique to cardiovascular patients & incorporated these risks into new tool
Neonatal Trigger Score (Holme et al 2013) [31]	Neonatal Unit London (UK)	Developed by expert group (5 consultant neonatologists, NICU nurses & midwives) consensus & guidance from Neonatal Life Support, National Institute for Clinical Excellence Postnatal Care & a neonatal scoring chart
Paediatric Observation Priority Score (POPS) (Roland et al. 2016) [46]	Children's Emergency Department Leicester Royal Infirmary (UK)	POPS was developed locally using current evidence and the experience of senior paediatric emergency clinicians; the physiological parameters were chosen based on APLS guidance and their utilisation in other scoring systems. The visual style was based on feedback from nurses over a 1 month period which was constantly refined based on feedback. A small pilot phase in 100 patients (presented at a regional paediatric meeting) demonstrated acceptability and feasibility.