PUMA

Paediatric early warning system - Utilisation and Mortality Avoidance

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General Information This protocol describes the PUMA study. The protocol should not be used as a guide, or as an aide-memoire for the treatment/care of other patients/participants. Every care has been taken in drafting this protocol; however, corrections or amendments may be necessary. These will be circulated to the known Investigators in the study, but centres participating for the first time are advised to contact the South East Wales Trials Unit (SEWTU) at Cardiff University to confirm that they have the most up-to-date version of the protocol in their possession. Problems relating to the study should be referred, in the first instance, to SEWTU.

Compliance This study will adhere to the conditions and principles outlined in the EU Directive 2001/20/EC, EU Directive 2005/28/EC and the ICH Harmonised Tripartite Guideline for Good Clinical Practice (CPMP/ICH/135/95). It will be conducted in compliance with the protocol, the Research Governance Framework for Health and Social Care (Welsh Assembly Government November 2001 and Department of Health 2nd July 2005), the Data Protection Act 1998, and other regulatory requirements as appropriate.

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Glossary of abbreviations

AE	Adverse Event
ANT	Actor Network Theory
CEMACH	Confidential Enquiry into Maternal and Child Health
CF	Consent Form
CI	Chief Investigator
CMO	Context-Mechanism-Outcome
CRF	Case Report Form
CTU	Clinical Trials Unit
CU	Cardiff University
DGH	District General Hospital
EUCTD	European Union Clinical Trials Directive
ICH	International Conference on Harmonization
GCP	Good Clinical Practice
IDMC	Independent Data Monitoring Committee
HB	Health Board
NHS	National Health Service
NPT	Normalisation Process Theory
NICE	National Institute for Clinical Excellence
NISCHR	National Institute for Social Care & Health Research
NPSA	National Patient Safety Agency
PEWS	Paediatric Early Warning System
PHDU	Paediatric High Dependency Unit
PI	Principal Investigator
PICU	Paediatric Intensive Care Unit
PIS	Patient Information Sheet
RCN	Royal College of Nursing
RCPCH	Royal College of Paediatrics and Child Health

R&D	Research and Development
REC	Research Ethics Committee
SAE	Serious Adverse Event
SEWTU	South East Wales Trials Unit
SMF	Study Master File
SMG	Study Management Group
SOP	Standard Operating Procedure
SSI	Site Specific Information
SSC	Study Steering Committee
STS	Science and Technology Studies

Definitions

1) A '**Track and Trigger tool'** (1) consists of sequential recording and monitoring of physiological, clinical and observational data (either by clinical staff or electronically). When a certain score or trigger is reached then a clinical action should occur including, but not limited to, altered frequency of observation, senior review or more appropriate treatment or management. Tools may be paper based or electronic and monitoring can be automated or undertaken manually by staff.

2) A **Paediatric Early Warning System** (PEWS) is a multi-faceted patient safety mechanism imbedded in an inpatient paediatric unit and may or may not include track and trigger tools.

3) **Outcomes**: Mortality and critical events including: unplanned admission to Paediatric Intensive Care (PICU) or Paediatric High Dependency Unit (PHDU), cardiac arrest, respiratory arrest, medical emergencies requiring immediate assistance (arrest calls that were not respiratory or cardiac arrests), Referrals for PICU review (in tertiary centres) or PICU retrieval (DGHs), Critical Deterioration (CD) metric. These may be reported individually or as composite outcomes.

1 Amendment History

Amendment No.	Protocol version no.	Date issued	Author(s) of changes	Details of changes made

2 Study Summary

In 2011 a research study (2) compared the child health outcomes and death rate in the UK with other European countries. It was worrying that UK measures of child health were amongst the worst in Europe. It is not clear why that is and further work needs to be done to understand this better. In hospital staff try to quickly identify the children who are seriously ill or getting sicker, so that they receive rapid treatment to improve their condition. Despite training, sometimes children become sicker in hospital without staff noticing or they underestimate the severity of illness, or do not treat deterioration quickly enough, or get extra help. In these cases the very sick child might require emergency transfer to intensive care, or stop breathing, or die unexpectedly.

This study aims to develop an understanding of a number of key pieces of information that could help to standardise monitoring of children in hospital, help to identify deterioration quickly so there is an urgent response to save the patient from harm and reduce premature death in hospitalised children across the United Kingdom.

This research study will be conducted in four hospitals and aims to examine what key components should be included in a track and trigger score and early warning system, to help identify the children who are sicker and prevent them becoming more unwell, having a serious complication or dying.

This will be the largest, most comprehensive study of PEW scores and systems, with the aim to improve paediatric patient safety and reduce mortality. Our findings inform recommendations about safety processes that should be established in every hospital treating paediatric in-patients across the NHS.

3 Introduction

3.1 Background

UK paediatric mortality is the highest in Europe (2). There is evidence suggesting that missed deterioration (3, 4) and difference in hospital performance contribute (5). Research in the adult care context identified that acute in-hospital deterioration is often preceded by a period of physiological instability which, when recognised, provides an opportunity for earlier intervention, and improved outcome (6, 7). The Royal College of Physicians endorsed the implementation of a National Early Warning track and trigger tool (8) to standardise the assessment of adult acute illness severity, predicting that 6000 lives will be saved annually. A similar intervention may save lives in hospitalised children (9, 10, 11) but the evidence base is uncertain. The alteration in accepted physiological norms for respiratory and heart rate across the age range, make it challenging to develop a standardised tool suitable for generic application for all hospitalized children. Some single site studies (12, 13, 14) reviewed the performance of individual track and trigger tools, with preliminary data on the sensitivity of different cut-offs for physiological measurements. However, it was difficult to prove an 'effect' based on the outcome measures described, since the event rate of in hospital cardiac arrest or death is low. Even if agreement existed on a particular track and trigger tool, this needs to be acted upon in everyday clinical practice and there is considerable variation in the systems and processes in place through which this is achieved and which may be consequential for effectiveness.

Track and trigger tools are always part of a wider Paediatric Early Warning System (PEWS), which in turn are always part of a wider clinical micro system (15,16,17) with a singular workplace history, culture, division of labour, skill-mix, infrastructure, workload, case-mix, leadership, resources, and specialist expertise which may be consequential for effectiveness. Furthermore, governance processes to objectively evaluate cases of missed deterioration and avoidable mortality are not well regulated for children in hospital. Mandatory Child Death Overview Panels have the responsibility to review all paediatric deaths in England to identify contributing factors, but recommendations have been largely public health focused. The narrative nature of data collected makes it difficult to identify hospital factors for individual cases. Feedback loops using quality improvement processes are required to ensure organisational accountability, compliance with and sustainability of initiatives to improve patient safety and reduce harm. Given this uncertainty, it is not surprising that there is currently wide variability in practice.

Recent work from this research team has reviewed PEWS throughout Great Britain (18). Out of a possible 157 in-patient units we obtained information from 149 (95%)

hospitals. 85% of units were using a track and trigger tool but there was huge variability in the tool being used and most of these were unpublished and un-validated. The current *ad hoc* utilisation of un-validated track and trigger tools and variance in organisational capacity to respond to a deteriorating child represents a serious clinical risk.

Over 700,000 children are admitted to hospital overnight in the UK annually with 8000 admitted to Paediatric Intensive Care Units (PICU) as an emergency (19). Half of these are from wards in the same hospital, suggesting that patients deteriorated acutely or had a cardiopulmonary arrest. Missed or delayed instances of deterioration identification in hospital are "failures in care" with a physiological, psychological and social cost to the child and family (20, 21). There is significant short-term added cost to the NHS (22) from rising cost of litigation (£1.1 billion) (23). In the current national and global financial climate the NHS is under severe pressure to make yearly cost savings (4% for 4 years running). For a society that values its NHS highly, this is widely recognised to be a situation that needs to be reversed. It is estimated that 1951 child deaths would need to be prevented to compare with the best performers in Europe (24). NHSLA recommends that Trusts in England use a PEWS to reduce harm to patients and avail of lower insurance premiums (25). The Confidential Enquiry into Maternal and Child Health (CEMACH) deaths (3) and NPSA (now NHS CBSHA) (26) also advocate the use of a track and trigger tool as part of an early warning system.

The CEMACH report (2008) highlighted the avoidable nature of many child deaths in the United Kingdom (3). By examining child death review panel reports it identified the need for all health care professionals to be able to recognise serious illness in children. It noted that not only did this involve good clinical skills and awareness of limitations but also good communication. The report highlighted identifiable failures in a child's direct care in "…just over a quarter of deaths, and potentially avoidable factors in a further 43% of deaths." (3). It was from this report that a recommendation for PEWS to be used in all hospitals was made. Recently the Royal College of Paediatrics and Child Health (RCPCH), National Children's Bureau and British Association for Child and Adolescent Public Health (Why Children Die 2014) (27) have examined data on childhood deaths and focused specifically on interventions which may have an effect through policy and practice changes. Although health care amenable deaths appear to have fallen since the CEMACH report they are still very prevalent. Data available up to early 2013 showed in 3,857 completed reviews 21% of the deaths had modifiable factors (DoE 2013) (28). Although these were not all as result of failure to recognise the deteriorating child, the scale of the problem, given the United Kingdom's poor record on childhood mortality, is significant. The report specifically concluded

"It is important that measures are taken to improve recognition and management of serious illness across the health service – both primary and secondary care; community and hospital; general practice, paediatrics, and mental health" [Why Children Die 2014] (27).

The report noted that comparative data between countries is extremely difficult to interpret but that significant discrepancies exist in the UK compared to the rest of Europe in respect of mortality. The large variation in management of common conditions such as epilepsy and asthma further evidences the avoidable nature of childhood mortality and morbidity (29).

There is, as yet, no consensus on the utility of the currently available track and trigger tools and there is variance in monitoring of patients (30), training to aid recognition and response to deterioration and mechanisms to ensure best practice. Patients admitted to hospital, and their families should have the expectation of excellent care. Therefore research that aims to reduce missed deterioration and prevent avoidable mortality, as well as limiting un-necessary NHS added cost and litigation (from failure to rescue), is both relevant and timely. There is an urgent national need to develop an evidence based PEWS for UK practice and produce guidance to inform National bodies (NICE, NHSLA, RCPCH, RCN) in order to standardise paediatric practice and improve patient safety within the NHS. The aim of this study is to develop an evidence based paediatric track and trigger tool, evaluate its feasibility and potential effectiveness in predicting deterioration and triggering timely interventions, identify the contextual features (i.e. micro, meso and macro (organisational)) consequential for success and factors necessary to ensure successful implementation and normalisation.

4 Research Plan

This study is a prospective, mixed methods, before and after study identifying the evidence base for the core components of an effective Paediatric Early Warning System (PEWS) and the development of an implementation package containing those core recommendations for use in the UK.

4.1 Research questions

- What is the evidence base for the core components of a national paediatric track and trigger tool?
- What is the evidence base that the implementation of a paediatric track and trigger tool in the UK NHS environment will reduce avoidable morbidity and mortality in hospitalised children?
- What are the contextual (micro, meso and macro) features consequential for its success?
- What factors are necessary to support successful implementation and normalisation?

4.2 Research Aims

A) To identify through a systematic review of the literature the evidence for the core components of a paediatric track and trigger tool.
B) To develop a track and trigger tool implementation package for prospective evaluation.
C) To evaluate the ability of the track and trigger tool to identify serious illness and reduce clinical events by examining core outcomes.
D) To identify the contextual factors that are consequential for tool effectiveness.
E) To identify the key ingredients of successful implementation and normalisation.

4.3 Study objectives

The study is split into two work streams, and the objectives for each work stream are described below:

Work stream 1:

- Identify through a systematic review of the literature the evidence for the core components of a paediatric track and trigger tool.
- Develop theories about the mechanisms by which the core components of track and trigger tools have their effects.

- Develop a track and trigger tool for use in different contexts.
- Develop an implementation package for prospective evaluation.

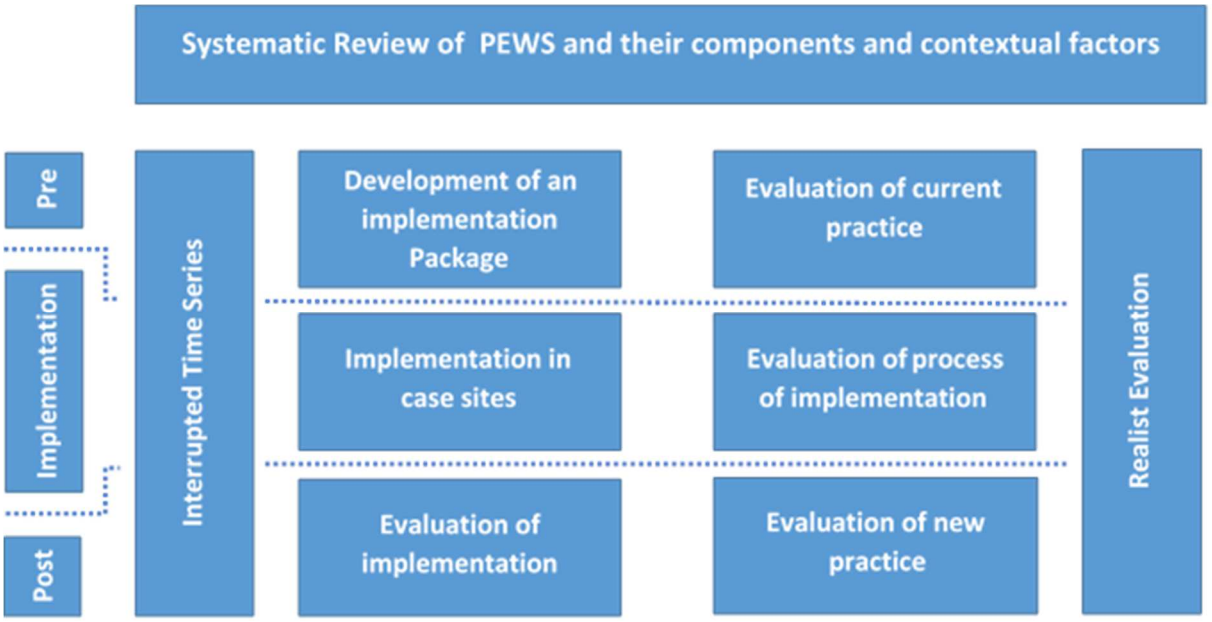
Work stream 2:

- Evaluate the ability of the track and trigger tool to impact on clinical outcomes.
- Identify the contextual factors that are consequential for tool effectiveness.
- Develop evidence-based recommendations for a national PEWS with underpinning programme theories.
- Identify the key ingredients of successful implementation and normalisation.

4.4 Work stream Overview

The following diagram (Figure 1) illustrates the phases within each work stream package.

Figure 1:



5 Study Design

The study aims to evaluate the effectiveness of a paediatric track and trigger tool in different contexts, the mechanisms by which it has its effects and factors necessary for successful implementation and normalisation.

Informed by the principles of realist evaluation (31,32,33), it is underpinned by the proposition that if we know and understand how different interventions produce varying impacts in different contexts then we are better able to decide what policies and interventions to implement under which conditions.

The interrupted time series design is an effective quasi-experimental design and an alternative to the randomized controlled trial. Because it avoids the potential biases in the estimation of intervention by considering the time series factors, such as seasonal trends and autocorrelation, it is increasingly adopted in the evaluation of health care interventions, where RCTs are not feasible.

5.1 Work stream 1

The development of a track and trigger tool and an implementation package based on systematic review and expert consultation. We will utilise our networks and the research group's national contacts (RCPCH, RCN, PICS, NHS England Deterioration in Children Advisory Group)to provide key stakeholder insight into the development of the tool and work with parent representatives, and local service providers to develop an implementation package based on effective implementation strategies identified in the SR.

5.2 Work stream 2

A prospective mixed method, before-and-after study design in four hospitals, with embedded case studies is proposed. These embedded case studies within the study at each phase will evaluate normal practice, the process of implementation and the use of the track and trigger tool post implementation.

Phase 1) Observe and record outcomes in current practice.

Phase 2) Implement the track and trigger tool and undertake a concurrent implementation process evaluation

Phase 3) Evaluate the system in use.

The effectiveness of the system will be assessed by examining the core outcomes defined above. The primary analysis of the outcomes will be an interrupted time series for each of the four hospitals. This aims to identify a change in the rate of outcomes that is potentially attributable to the introduction of the tool. The interrupted time series is adopted here for the main quantitative analysis. The interrupted time series design is an effective quasi-experimental design and strong alternative to the randomized controlled trial. Because it avoids the potential biases in the estimation of intervention by considering the time series factors, such as seasonal trends and autocorrelation, it is increasingly adopted in the evaluation of health care interventions.

5.3 Theoretical framework

The study design is informed by the principles of realist evaluation (33). Realist evaluation is one example of theory-driven approaches to evaluation which have emerged as an alternative to the RCT in health services research in recent years. A core assumption of a realist perspective is that service delivery programmes are complex interventions introduced into complex social-technical systems and that the latter are always changing. Thus in evaluating and implementing any intervention it is important to take into account relevant contextual features in order to establish the local modifications necessary to ensure sustainability and success, and to do this it is essential that an intervention's generative mechanisms are understood and can be articulated. This relationship is expressed in realist evaluation as a context-mechanism-outcome (CMO) configuration, where these terms take their meaning from their function in explanation, and where such explanations arise from empirical observation combined with high quality reasoning.

In addition in order to think systematically about PEWS and the socio-technical contexts into which it will be introduced, we will adopt a practice-based approach (34,35), particularly insights from activity theory (36), actor network theory (ANT) (37,38,39,40) and science and technology studies (STS) (41,42). For the purposes of the study, a paediatric track and trigger tool will be conceptualised as an artefact within an 'activity system'. An activity system is the basic unit of analysis in activity theory and refers to a constellation of inter-related practices and artefacts oriented towards a shared object: in this case the detection of physiological deterioration and timely intervention in the care of sick children. Activities are not regarded as belonging to an individual but are part of a collective endeavour with an associated division of labour, tools, technologies, norms, rules and conventions.

We will draw too on ANT because it affords an analytic sensitivity to the *relationships* between the diverse elements comprising a field of practice and a language with which

to describe these. This will provide a focus on the constellation of elements necessary for a track and trigger tool to function in different contexts and their inter-relations.

Finally insights from STS will ensure that we focus attention on the properties of the track and trigger tool and its inter-relationship with the wider activity system. Artefacts embody diverse assumptions or 'scripts' and are structured in different ways and these 'affordances' (43) shape the possibilities for action. Indeed materials do not just support human endeavour, they transform the nature of the task. Understanding the potential generative effects of artefacts for quality improvement purposes requires an understanding of their 'affordances' and how these relate to the socio-material infrastructure into which they are to be introduced, and/or the technologies they are designed to replace (44). Thus of particular interest is the relationship between tools and human action and how practice is distributed between them.

Normalisation process theory (NPT), which has a high degree of conceptual affinity with this underlying theoretical framework, will provide an additional theoretical lens to inform tool implementation and the evaluation of this process. NPT is concerned with 'how and why things become, or don't become, routine and normal components of everyday work' (45) and it defines four mechanisms that shape the social processes of implementation, embedding and integrating ensembles of social practices. These are interrelated and dynamic domains and include: 'coherence' (the extent to which an intervention is understood as meaningful, achievable and desirable); 'cognitive participation' (the enrolment of those actors necessary to deliver the intervention, which, for our purposes can be human and non-human); 'collective action' (the work that brings the intervention into use); and 'reflexive monitoring' (the ongoing process of adjusting the intervention to keep it in place). Within our overall practice-based approach we will use these domains as a framework to analyse the contextual factors necessary for integration into routine work organisation (normalisation). NPT is a relatively new theory and we will be open to the possibility of contributing to its refinement in the light of our findings.

6 Centre and Investigator Selection

The recent survey of paediatric units in Great Britain reported that 90% of tertiary units and 83% of DGH's already had a tack and trigger tool in place. A convenient sample of paediatric units was selected for the study to represent types of unit and units with and without a track and trigger tool in place. These four hospitals represent paediatric inpatient units of varying size; tertiary centres with PICUs and large DGH hospitals. No

studies so far have involved DGH environment. It is important if a track and trigger tool is going to be used throughout UK we can capture this environment. We have also chosen these hospitals for comparison as two of them do not have track and trigger tool in place currently. Two hospitals with no PEWS in place will be important to show a baseline of a system working initially without a score.

a) Alder Hey Hospital: very large tertiary centre with busy cardiac surgery intensive care with a track and trigger tool already in place.

b) Noah's Ark Children's Hospital for Wales, Cardiff – a smaller tertiary unit but similar with PICU and no track and trigger tool in place

c) Wirral – a large DGH with no PICU and with a track and trigger tool in place

d) Swansea- a large DGH with no PICU with no track and trigger tool in place

Further details of the 4 sites are detailed in Appendix 2.

7 Study Procedures

7.1 Work stream 1: Evidence review for tool and implementation package development

Aims:

A) To identify through systematic review of the literature the evidence for the core components of a paediatric track and trigger tool.

B) To develop an evidence based track and trigger tool and implementation package for prospective evaluation.

Objectives:

- Develop theories about the mechanisms by which the core components of track and trigger tools have their effects.
- Develop a track and trigger tool for use in different contexts.
- Develop an implementation package for prospective evaluation.

7.1.1 Systematic review to identify evidence of core components of a paediatric track and trigger tool (AIM A)

A systematic review will be conducted in order to answer three interlinked questions:

1. How well validated are existing track and trigger scores for PEWS and their component parts?
2. How effective are PEWS (with or without track and trigger scores) at reducing mortality and critical events?
3. What socio-technical and contextual factors are associated with successful or unsuccessful PEWS (with or without track and trigger scores)?

1) Validation of track and trigger scores

We will identify studies which development and/or valid track and trigger scores (or core items). These will allow us to identify a set of best items for a score and to guide trigger points for a score.

2) Effectiveness of PEWS

We will identify RCTs and quasi-experimental studies which have evaluated PEWS (with or without track and trigger scores). These will allow us to identify the potential effect of a successful PEWS and potential contextual factors.

3) Socio-technical and contextual factors

We will utilise studies included in questions 1 and 2 where relevant information on implementation factors are included and also either qualitative or quantitative studies of PEWS implementation. This will allow us to develop programme theories for PEWS and identify factors consequential for implementation and normalisation. If there are gaps in the literature relating to Paediatrics then this area may be extended to consider factors in adult implementation and other related literatures.

7.1.2 Search Methods

The Cardiff University Support Unit for Research will undertake the searches (Evidencehttp://www.cardiff.ac.uk/insrv/libraries/sure/index.html).

1) Literature searching

A comprehensive search will be conducted across a range of databases from the study's inception to identify relevant evidence/studies in the English language. Both published and unpublished literature that is publicly available, including studies in press will be considered. A preliminary search strategy has been developed using a set of key papers

known to the group for Ovid Medline using both text words and Medical subject headings (Appendix 1).

The search strategy will be translated for use in rest of the databases (Table 1).

Table 1. Databases to be used to identify relevant literature.

British Nursing Index
CINAHL (Cumulative Index of Nursing and Allied Health Literature)
Cochrane Central Register of Controlled Trials
Database of Abstracts of Reviews of Effectiveness
EMBASE
HMIC (Health Management Information Centre)
Medline
Web of Knowledge (Science Citation Indexes)
Scopus Trials Registers

2) Additional searches

To identify additional papers, information on studies in progress, unpublished research or research reported in the grey literature will be identified through searching a range of relevant websites and trial registers including Clinical Trials.gov. To identify published resources that have not yet been catalogued in the electronic databases, recent editions of key journals will be hand-searched.

3) Identify relevant studies

The search results would be imported into the reference management database Endnote. Duplicate references and clearly irrelevant citations will be removed. All remaining studies will then be sent to reviewers to screen for relevance and categorized according to which line of analysis they contribute to. We will adhere to the PRISMA flow diagram, in depicting the flow of information through the phases of the review. All identified titles and abstracts will be reviewed by two reviewers for inclusion and also which of the three questions they could contribute to. Studies considered potentially relevant by either reviewer will be retrieved in full. Full texts will be reviewed in full by two reviewers against the eligibility criteria and classification as to which questions they contribute to be re-assessed. Disagreement between reviewers will be resolved by consensus in the group, with reasons for exclusion recorded.

4) Data Extraction

The data extraction form will have some common elements (study design, country, setting, exact population, nature of the PEWS, outcomes assessed), then specific sections for each of the three questions. Data to be extracted:

- Question 1 – items in the PEWS, predictive ability of individual items and overall combination, sensitivity and specificity, inter and intra-rater reliability
- Question 2 – critical events, morbidity, mortality
- Question 3 – socio-technical features, factors consequential for implementation and normalisation

The question specific information will be extracted by members of the team focussed on that question.

5) Risk of Bias assessment

Studies will be quality appraised according to the purposes for which they will be used. For questions 1 and 2 we will utilise appropriate quality appraisal tools according to study type using the checklist suggested by Downs and Black (46). However, for the purposes of theory generation, it is evidential fragments or partial lines of inquiry rather than entire studies that form the unit of analysis. In such cases, the quality of each item will be appraised according to the contribution it makes to the developing analysis.

6) Data synthesis

Question 1 will combine information using the median ROC (if data is available) to identify the quality of prediction. The potential range of predictions of each item will be tabulated and associations between each item and the outcome will be summarised using OR and 95% confidence intervals.

Question 2 will use a random effect meta-analysis of the OR of mortality or critical event in the intervention group compared to control.

Question 3 will involve a qualitative synthesis of PEWS active ingredients, evidence of the mechanisms by which they have their effects in different contexts, and factors associated with implementation and normalisation in order to develop an indicative programme theory.

7.1.3 Development of an evidence based track and trigger tool and implementation package (AIM B).

Drawing on the evidence from the literature review, the PUMA study team will devise an optimal track and trigger tool, with the review informing the development of the items to be included in the score, the socio-technical features of the tool and the wider activity system features that will inform how the score is used. We will identify the core components of the intervention and those elements which can be adapted to fit the local context. The prototype and its associated programme theory will be considered by key expert stakeholders to assess face validity and feasibility. At all steps we will refer back to the systematic review and where there is discordance between the evidence and feasibility of a tool or system, consensus will be sought. After development, the new tool will be field tested for feasibility at one study site. Feasibility testing will involve feedback from medical, nursing and support staff who use the tool to assess clarity and utility. Throughout we will ensure transparency of process so that there is a clear audit trail between the decisions taken, the underlying rationale and agreement on the tool.

Each of the four centres will have a local PI acting as a champion for the implementation. Each champion will be provided with a comprehensive implementation package informed by the systematic review. In advance of the results of the literature review it would be premature to specify the details precisely, but it is likely to include an education programme for trainers, an end-user guide to the tool and system, and an organisational manual for trainers including, pre-prepared presentations, frequently asked questions and answers sheets to assist them cascade this information to their teams, evidence based resources and a self-assessment check list to identify wider contextual factors to be considered and how these might be addressed as part of the implementation process. Our approach will be informed by evidence of effective strategies for the implementation of new practices in systems and the factors necessary in ensuring the normalisation of the track and trigger tool in everyday practice.

7.1.3.1 Outputs

1) Systematic review of paediatric track and trigger tool development and validation.
2) Systematic review of PEWS effectiveness.
3) A narrative review of PEWS in different contexts.
4) The development of theories about the mechanisms by which track and trigger tool components have their effects in isolation, in combination and in different contexts and the factors consequential for implementation and normalisation.
5) PEW Tool and implementation package for both DGHs and specialist children's Hospitals.

7.2 Work stream 2: Prospective before and after evaluation with embedded case studies

Work stream 2 is a prospective before and after study evaluation with embedded case studies, with the following aims:

7.2.1 Aims

C) To evaluate the ability of the track and trigger tool to identify serious illness and reduce clinical events by examining core outcomes.
D) To identify the contextual factors that are consequential for tool effectiveness.
E) To identify the key ingredients of successful implementation and normalisation.

7.2.2 Design

A prospective mixed-method before and after study will be undertaken in four hospitals (as described in Section 6), with additional details of the individual hospital characteristics are contained in appendix 2.

7.2.3 Evaluation of core outcomes – Time Interrupted Series Analysis (AIM C)

This before and after study evaluation will be conducted in three phases:

Phase 1:

The baseline phase will be conducted to observe current practice and establish the foundations for the interrupted time series (ITS) analysis of the outcomes including mortality and the following critical events:

- cardiac arrest,
- respiratory arrest,
- unplanned admission to Paediatric Intensive Care (PICU) or Paediatric High Dependency Unit (PHDU),
- medical emergencies requiring immediate assistance (arrest calls that were not respiratory or cardiac arrests),
- referrals for PICU review (in tertiary centres) or PICU retrieval (DGHs),
- Critical Deterioration (CD) metric which is a composite measure of critical events defined as transfer to an intensive care unit followed by non-invasive or invasive mechanical ventilation or vasopressor infusion within 12 hours (47).

This phase will last 12 months for all four hospitals. A 12 month period has been chosen to give a reasonable number of data points (months) for the time series and to accommodate for seasonal differences in case mix.

Phase 2:

The implementation phase within each hospital will take up to three months. This will involve working with hospital management and multidisciplinary staff to implement and embed the PEW tool. Outcome data will continue to be collected during this phase to give an uninterrupted time series. We will also be conducted a concurrent process evaluation of the implementation phase (see section 7.2.4 for further detail).

Phase 3:

The post implementation phase will focus on the impact of the PEW tool on outcomes and will last a further 12 months to give an appropriate number of data points (months) for the time series and to accommodate for seasonal differences in case mix. Outcome data will be collected, which should also now include the track and trigger tool (where measured).

Overall for each hospital the study will last for 27 months, however each hospital will receive implementation in turn meaning the whole cohort study (starting the first hospital to finishing in the last hospital) takes 36 months to undertake all three phases.

For data collection sources, please refer to SECTION 7.3.

7.2.4 Embedded Case Studies: to identify the contextual factors that are consequential for tool effectiveness (AIM D).

Organisational case studies (one ward) will be undertaken in each hospital. Ethnographic methods will be deployed to explore the technical, social, and organisational factors consequential for PEW tool effectiveness at individual, team, unit and hospital level. Data will be generated pre-intervention and post-intervention in order to understand the impact of PEW tool implementation on practice and identify the micro, meso and macro contextual features consequential for effectiveness.

In each case we will undertake a pre and post intervention review of the local PEWS activity systems in the clinical settings prior to, and after implementation of the PEW tool, to assess the impact of implementation on practice. Data will be generated through non participant observation of everyday practice (by shadowing individuals – nurses, doctors, HCAs), attendance at, and, where possible, digital recording of, key meetings and events (handover, ward rounds, safety briefings), ethnographic interviews with

clinical team members, service managers and parents, and the analysis of relevant documents.

Our concern will be with understanding the network of actors: people, processes technologies and artefacts and their interrelationships in each PEWS activity system. Drawing on the literature review and our analysis of contextual features likely to be consequential for track and trigger tool effectiveness we will develop a template to guide our observations and interviews. Data generation will not be absolutely constrained by this however; rather in each case the strategy will be to 'follow the actors' (human and non-human). This will ensure that there is a consistent approach across case studies to facilitate comparative analyses, but flexibility to modify data generation in response to the singular features of each site. Adopting a practice-based approach, we will focus on what participants do, the tools they use, the concepts they deploy, and consider what these practices reveal about what they know and the factors that facilitate and constrain action (48). Adopting an ANT lens will direct attention to the relationships between the elements within each PEWS activity system including the relationships between artefacts. Thus, informed by STS, we will attend to the 'affordances' of tools and technologies, and how these are used to support practice.

Clinical observations will be undertaken over a 6 week period in each case, in order to give sites sufficient time to become accustomed to a researcher in their midst so we can develop an accurate understanding of normal routine practice.

We will also seek to observe relevant meso level events outside the immediate micro clinical activity systems such as the whole process of critical incident reporting and mortality review and feedback to the staff as part of the clinical governance management in each hospital.

In addition we will also undertake 6-8 interviews with parents/carers to explore their views and experiences (n=32) and semi-structured digitally-recorded interviews with a sample of clinical staff and relevant service managers (n=48) to explore each activity system at micro, meso and macro levels. The aim will be to develop a clear description and understanding of the local activity systems in each case. These will be presented to study participants to ensure accuracy and face validity and refined accordingly.

We will replicate this process 6 months following implementation of the PEW tool, modifying the interview content to explore staff experiences of tool use, factors consequential for impact, and unintended consequences. We will also reassess the activity system using the structured template as a guide to observation in order to analyse changes in these relationships brought about by the tool's introduction and the implications this has for normalisation.

Observations will be recorded contemporaneously as low inference-style field notes and later transcribed. Interviews will last approximately one hour and organised to take place either in private offices or by telephone. We will use critical incident techniques to explore the operation of the activity system pre and post intervention. Interviews will be digitally recorded and last approximately one hour. Interviews with a purposively selected sample of parents who have a physiologically unstable child will be undertaken when the child is still an in-patient, but at a time when their condition is considered by clinical staff to be stable. For the purposes of this study we will not include parents whose child has died but will interview parents whose (a) child has been monitored only (b) received intervention to prevent deterioration (c) had a critical event. Documents/records will be treated as both a resource and a topic. Their content will be analysed to inform our understanding of organisational processes and practices. Their form will be analysed in order to develop a better understanding of their design and affordances and inter-relationships.

7.2.5 PEW track and trigger tool Implementation and Evaluation (AIM E).

7.2.5.1 Background and Methodologies

An implementation strategy will be tailored to each organisation. Each of the four centres will have a local PI acting as a study champion for the implementation.

The systematic review will be used to identify those factors that appear to support the normalisation of PEW track and trigger tools in practice and we will draw on these materials to inform our implementation package. Guided by the normalisation process theory: we will attend to the factors indicated by the literature, the local stakeholders and base line case study work to be necessary for collective action, coherence, cognitive participation and reflexive monitoring (45) and build this into each implementation package.

We anticipate developing an implementation package adopting a train the trainers approach. The core of the implementation phase will focus on a train-the-trainers methodology, which has proven efficacy (49,50). In this process key personnel at each of the research sites will be identified as PEW tool champion to cascade a short training schedule to all staff. The training will involve bespoke workshops for the PEW tool champions/trainers in which they will be fully briefed on the system and how to teach it in the clinical workplace. There will be a locally focussed training program, informed by the literature view and the baseline case study data for the context in which they work. The PUMA implementation team are experienced in the delivery of this form of workshop and education.

7.2.5.2 Process Evaluation

Train the trainers

Observational methods will be employed to describe and understand the implementation of the train the trainers programme in each of the four study sites to identify any significant variation in the delivery of the intervention, local issues that may surface in relation to the challenges of implementation, and any proposed adaptations and solutions. Data will be recorded as low inference style field notes in a reporter's notebook and later word-processed. The PUMA training team will also undergo a formal debriefing in order to reflect on the process and their impressions about any barriers or facilitators to implementation in the case study site. This will be digitally recorded.

Local training

Group interviews will be undertaken with the local training team on two occasions. Group interview 1 will be undertaken within one month of the train the trainer event. The intention is to: explore their perceptions of the train the trainers programme, the PEW manual, the PEW tool, and the barriers and facilitators (clinical, management and organisational) to implementation in their local contexts and their plans for how these are to be overcome and any proposed modifications to the intervention. Group interviews will be undertaken at approximately 6 months after the local training team have experience of running the local training. The intention is to explore their experiences of implementation, any adaptations to the intervention made in the light of that experience, local receptiveness as well as barriers and facilitators. The interview schedules will be flexible to enable exploration of the issues arising in the group interviews, whilst maintaining consistency in the topics covered. They will take place in a private room in each of the 4 participating NHS Trusts, last up to one hour and be digitally recorded. Field notes will be completed after each interview to provide a debrief record and provisional analysis of main issues of interest. In each hospital, 2 local training events will be observed. The purpose will be to identify any issues that may surface in relation to the challenges of implementation, and any proposed adaptations and solutions. Data will be recorded as low inference style field notes in a reporter's notebook and later word-processed.

In addition, for each hospital we will evaluate service level implementation through interviews with a selection of staff that have undergone the training to explore their experiences, and views of the training (n=40). Interviews will be arranged to fit around the clinical responsibilities of service providers and can be undertaken either face to face or by telephone.

7.3 Data sources

7.3.1 Routine hospital level data.

We will collect audit data on mortality and specified morbidity (rates per 1000 non-ICU patient-days) before during and after intervention and fit a time series (36 time points) per hospital and test for changes in slope associated with time intervention. This will enable us to estimate the effect of intervention on mortality and significant morbidity.

7.3.2 Clinical Observations (unit and ward level)

We will collect 6 weeks of observation per site at two stages (pre and post intervention) and we will collect observations of training (during) including staff briefings and reviews. This will enable us to understand the initial activity systems in place and how staff interact around them (pre), to understand how implementation occurs (during) and to understand how the new activity systems operate (post).

7.3.3 Clinician interviews

We will complete 12 interviews with staff per site at pre and post stage and 10 interviews with staff per site (during). This will enable us to develop a description and understanding of the local activity systems in each site (pre), to explore each activity system at a micro, meso and macro level (pre), to understand how staff conceptualise & implement the new approach (during) and to explore changes in each activity system at a micro, meso and macro level (post).

7.3.4 Parent Carer's interviews

We will complete 8 interviews with parents/carers per site at pre and post stages. This will enable us to explore experiences and attitudes (pre and post) and to understand the activity systems from a parent/carer perspective (pre and post).

7.3.5 Medical record completion post-intervention

Patient documentation will also be accessed post-intervention to review the quality and completeness of recording vital signs in a random selection of medical records. The notes of patients who deteriorated will be compared to those patients who did not deteriorate. The access to these patient records by the research team will not be by explicit consent; instead, support from section 251 of the NHS Act 2006 will be sought. The data to be collected, the number of patients and how patients will be matched for a

case-control will be informed by the pre-intervention clinical observations [b) above] and details will be included as an amendment to this application.

7.3.6 Mapping of data source to aims

STUDY AIM / DATA SOURCE	A	B	C	D	E
SR of PEW scores	X	X			
SR of context and mechanism	X	X		X	
Routine data and (PICANET data)			X		
Clinical observations				X	X
Clinician interviews				X	X
Parent interviews				X	X

8 Statistics Consideration

8.1 Randomisation

As we aim to investigate the changes before and after the implementation in four individual hospitals with different characteristics, each hospital will be regarded as a separate interrupted time series and the same analysis approach will be used. Therefore, randomisation is not applicable in this study.

8.2 Primary outcome measure

The primary outcome measure is a composite outcome measure, which comprise of the monthly collected rates of mortality and the following critical events: unplanned admission to Paediatric Intensive Care (PICU) or Paediatric High Dependency Unit (PHDU), cardiac arrest, respiratory arrest, medical emergencies requiring immediate assistance (arrest calls who were not respiratory or cardiac arrests), referrals for PICU review (in tertiary centres) or PICU retrieval (DGHs) and the Critical Deterioration (CD) metric (47).

8.3 Secondary outcome measures

The secondary outcome measures are single outcome measures, where we look at the monthly rates of the following critical events separately:

- mortality
- unplanned admission to PICU or PHDU
- cardiac arrest
- respiratory arrest
- medical emergencies requiring immediate assistance
- referrals for PICU review (in tertiary centres) or PICU retrieval (DGHs)
- CD metric
- PIM3

8.4 Sample size

A simulation-based approach (51) to calculate the power has been used as it is challenging to derive a formula for the sample size (52). With the event rate of unplanned admission to PICU (206/20696=1%) and the monthly admission to hospital overnight from the historical data of the Alder Hey Hospital and Morriston Hospital, we obtain the monthly prevalence of unplanned admission to PICU at pre-intervention stage. Tibbals (10) have shown that implementation of calling criteria (similar to a track and trigger tool) with a rapid response team resulted in a risk ratio of 0.65 in terms of total avoidable hospital mortality. We have assumed that the implementation of the new track and trigger tool will result in a similar risk ratio of 0.65 and based on data for admission rates to PICU (full CD data was not robustly identifiable from available data sources). For comparing the pre- and post- intervention monthly events of unplanned admission to PICU, this results in a potential the effect size of 2.8 with mean difference 2.0 and common standard deviation 0.7. We will have 90% power with a total of 24-month observations (12 pre- and 12 post), if the effect size is at least 2.0 (52). Given the potential for seasonal effects, we have taken this as a conservative approach for the sample size.

9 Analysis

9.1 Quantitative Analysis

9.1.1 Main Analysis

Each hospital will be regarded as a separate interrupted time series and the autoregressive integrated moving average (ARIMA)(53) model will be used for the analysis. This aims to identify a change in the monthly rate of outcomes which will be mortality and the following critical events; unplanned admission to PICU or PHDU, cardiac arrest, respiratory arrest, medical emergencies requiring immediate assistance (arrest calls who were not respiratory or cardiac arrests), referrals for PICU review (in tertiary centres) or PICU retrieval (DGHs) and the CD metric which has been shown by to be a valid proximate outcome for evaluating PEWS performance. It has previously been demonstrated that CD was more than 8 times more common than respiratory and cardiac arrests and was associated with a more than 13-fold increased risk of in-hospital death (54). First-order autocorrelation will be tested by using the Durbin-Watson statistic, and higher-order autocorrelations will be investigated by using the autocorrelation and partial autocorrelation function. As some hospitals will switch from paper-based system to electronic-based system, this factor will be added in the models accordingly to accommodate the impact of the change. The changes of level and of slope at the adjacent time point between pre-implementation and post-implementation phases will be analysed and we will conclude the effectiveness of the intervention if either of these two changes is statistically significant at a 5% level (55).

9.1.2 Secondary Analysis

We will utilize the same approach for the analysis of primary outcome to analyse the component parts of the composite primary outcome (mortality, unplanned admission to PICU or PHDU, cardiac arrest, respiratory arrest, medical emergencies requiring immediate assistance, referrals for PICU review (in tertiary centres) or PICU retrieval (DGHs), the CD metric) to assess the effectiveness of our intervention on each component element of critical events individually. As low/zero monthly rates may occur in some component elements (such as mortality), we will monitor the measures of these outcomes and consider alternative time series approach for the analysis of those with non-ignorable zero values.

We will also analyse the quality and completeness of recording of vital signs in a selection of medical records as a quantitative marker of process and the frequency of escalation and compliance.

We will compare the severity of children admitted to PICU using PIM3, which is a model to assess the child's risk of mortality among children admitted to PICU. This is collected monthly as routine audit data via PICANET in each hospital and we will use the average PIM3 to investigate changing case mix of children admitted over time.

9.2 Qualitative Analysis

For each phase (pre-intervention, implementation and post-intervention) data generation and analysis will be undertaken concurrently facilitating a progressive narrowing of focus designed to develop in-depth understanding of the activity systems in each case and the implications of the intervention for practice. The various materials collected (field notes, interviews, documents) will be used in a triangulating fashion to develop concrete descriptions of relevant aspects of activity systems targeting the key themes and topics of specific analytic concern. The whole team and service user representatives will contribute to this process. All data will be transcribed and entered into Atlas/ti to augment retrieval and management.

Analysis will be undertaken in four phases.

Phase 1 will develop a description and analysis of the PEW activity systems in each case: people, processes, structures, technologies and artefacts and their interrelationships. These data will be used to inform the implementation package. In addition, drawing on the literature review in each case we will identify factors likely to be consequential for the effective implementation of the track and trigger tool to be taken into account in the implementation stage.

Phase 2 analysis will concentrate on the implementation process in each case. We will explore the 'coherence' of the intervention from the perspective of participants, participant's experiences of the effectiveness of the intervention in enrolling actors (human and non-human) necessary for implementation and the reasons for this; the work necessary to bring the intervention into use; and the 'reflexive monitoring' necessary to keep the intervention in place.

Phase 3 will evaluate the post intervention PEW activity systems in each case. As in phase 1 we will develop a description and analysis of the PEW activity systems: people, processes technologies and artefacts and their interrelationships. We will assess the

changes that have taken place pre and post intervention and the normalisation of the intervention using the four domains of NPT to inform our analyses.

Phase 4 will triangulate all data to build up a picture of PEWS, the tool's use and the factors consequential for its pattern of impact. Within and cross-case analysis will be undertaken to develop an analysis of the relationship between the intervention, context, mechanisms and outcomes in order to inform the implementation of a national PEW tool.

9.3 Data storage & retention

Essential study documentation and source data will be archived in line with Cardiff University's Research Governance Framework Regulations (RGFR) for clinical research and the Cardiff University Archiving SOP (CU/08/S22). All data will be archived for 15 years. This data will be stored confidentially on password-protected servers maintained on the Cardiff University Network.

Electronic data will be stored on fire-walled University computers, and only accessible to researchers involved in the study. All procedures for data storage, processing and management will be in compliance with the Data Protection Act 1998. All paper records will be stored in a locked filing cabinet, with keys available only to the study management team. The SS will carry out analysis. All essential documents generated by the Study will be kept in the Study Master File (TMF).

10 Study Closure

The end of the study will be considered as the date on which the last data collection point has been completed.

11 Regulatory Issues

11.1 Ethical and research governance approval

The study will be conducted in accordance with the recommendations for physicians involved in research on human participants adopted by the 18th World Medical Assembly, Helsinki 1964 and later revisions.

This Study Protocol will be submitted to a Research Ethics Committee (REC) recognised by the United Kingdom Ethics Committee Authority (UKECA) for review and approval. A

favourable ethical opinion will be obtained from the REC before commencement of any study procedures.

Research governance approvals will be sought from the respective NHS Health Boards/Trusts in Wales and England.

All substantial protocol amendments must be approved by the REC responsible for the trial, in addition to approval by NHS Research and Development (R&D). Non-substantial amendments will not require prior approval by the REC.

If the study is stopped due to adverse events or an urgent safety measure it will not be recommenced without reference to the REC responsible for the study.

The outcome of the study (e.g. completed) will be reported to the REC responsible for the study within 90 calendar days of trial closure. In the event of the study being prematurely terminated a report will be submitted to the REC responsible for the trial within 15 calendar days.

A summary of the Study Report will be submitted to the REC responsible for the trial within one year of completion of study closure.

Section 251 support will be sought for post-intervention patient notes review. An amendment to this application and protocol will be submitted once details (such as information to be recorded, how many patients notes to be reviewed) have been decided. These decisions will be informed by the pre-intervention clinical observations. PPI input will be sought on how parents, patients and staff will be informed prior to this amendment submission.

11.2 Consent

Where required, informed consent will be taken by only suitably qualified, experienced and trained personnel in accordance with the principles of GCP on taking consent and before any study related procedures are undertaken.

11.3 Confidentiality

The PIs and the PUMA research team will preserve the confidentiality of participants in accordance with the Data Protection Act 1998. All data will be handled according to the principles of the Data Protection Act, especially for sensitive and personal data. Data will be anonymised and stored on a password-protected computer located in secure University buildings and be appropriately backed up. Any data transfer across participant

organisations will be closely monitored by a designated member of the study team. A privacy risk assessment will proactively identify and ameliorate risks of breaches of confidentiality and clearly designate the named individuals who will be allowed access to identifiable information. Published outcomes of the study will not enable identification of the individual participants. All data will be retained for 15 years in line with Cardiff University's procedures.

11.4 Indemnity

Cardiff University will provide indemnity and compensation in the event of a claim by, and on behalf of participants, for negligent harm as a result of the trial design and/or in respect of the Protocol authors/research team. Cardiff University will not provide compensation for non-negligent harm.

All participants will be recruited at NHS sites and therefore the NHS indemnity scheme/NHS professional indemnity will apply with respect to claims arising from harm to participants at site management organisations.

11.5 Study sponsorship

Cardiff University will act as sponsor for the study. Delegated responsibilities will be assigned to the NHS Health Boards/Trusts and collaborating institutes taking part in this study.

11.6 Funding

This study is funded by the National Institute for Health Research (NIHR) Health Services and Delivery Research (HS&DR) programme (12/178/17).

11.7 Audits & inspections

The study is open to inspection by the NIHR HS&DR as the funding organisation. The study may also be subject to inspection and audit by Cardiff University under their remit as sponsor.

12 Study Management

12.1 Project Team (PT)

This group will consist of members of the study team involved in the day-to-day conduct of the study, and will include the Chief Investigators (CIs), Principal investigators (PIs), Study Manager (SM), Study Statistician (SS), Data Manager (DM) and Study Administrator (SA). The group will normally meet weekly to discuss the day-to-day issues that arise from the trial. Important discussions will be relayed to the Study Management Group (SMG) for a final decision.

12.2 Study Management Group (SMG)

The SMG will consist of the CIs, Co-Applicants and Collaborators.

The SMG will be the formal decision making group and will oversee set up the study by providing specialist advice, input to and comment on procedures and documents (information sheets, Protocol, etc.). They will also advise on the promotion and running of the study and deal with any issues that arise. The group will normally meet monthly throughout the course of the study. SMG members will be required to sign up to the remit and conditions as set out in the SMG Charter which will be filed in the Study Master File (SMF).

12.3 Public Advisory Group

A Patient and Public Involvement (PPI) advisory group consisting of approximately 6-8 parents/ carers, will be convened at regular intervals over the study's lifetime in order to ensure PPI input to the research process. This will include: advice on tool and implementation package development, information leaflets for research ethics purposes, the design of interview schedules and the data generation templates, and qualitative data analysis, particularly parent interviews and dissemination strategies. Members of the advisory group will also be invited on a rotational basis to attend the study steering group, stakeholder meetings and dissemination event. We will invite parents to contribute actively to dissemination events, including presenting parents' views/stories.

12.4 Study Steering Committee (SSC)

A SSC, consisting of an independent chair, and five other independent members and two patient representative, will meet at least annually. The first meeting will be before the study commences to review the Protocol and arrange the timelines for the subsequent

meetings. If necessary, additional/more frequent meetings may occur. The SSC will provide overall supervision for the study and provide advice through its independent chair. The ultimate decision for the continuation of the study lies with the SSC.

SSC members will be required to sign up to the remit and conditions as set out in the SSC Charter which will be filed in the SMF.

13 Data Monitoring and Quality Assurance

Regular monitoring will be performed according to the principles of GCP. Data will be evaluated for compliance with the Protocol and accuracy in relation to source documents. Following written SOPs, the monitors will verify that the PUMA study is conducted and data are generated, documented and reported in compliance with the Protocol, GCP and the applicable regulatory requirements.

14 Dissemination & Publication Policy

The dissemination strategy will begin at the start of the study through a launch event to publicise it with relevant organisations, publishing the study protocol and establishing the PUMA website with the study protocol and lay summary creating an 'appetite' for the findings. On-going liaison with key organisations throughout the study will allow a dialogue to ensure that the findings are configured and disseminated effectively.

Our research will be relevant to the Department of Health, NHS England and NHS Wales (undertaking the work of the former body the NPSA), the National Institute for Clinical Excellence, the Royal College of Nursing, the Royal College of Paediatrics and Child Health, the Royal College of Anaesthetists, the Paediatric Intensive Care Society, and patient charities such as WellChild, Action Medical Research, Action for Sick Children, Children in Wales and SPARKS. The investigators are integrated within these clinical communities and organisations, so are well placed to engage with them on an on-going basis. These organisations and other key national personnel will be invited to both a launch meeting and a stakeholder dissemination meeting at the end of the project to present the findings and recommendations. In addition, each NHS site participating in the study will receive individual feedback of the results of their centre.

All publications and presentations relating to the PUMA study will be authorised by the SMG and will be in accordance with the study's publication policy. In addition to the required final report and monograph for the HS&DR Programme, we will publish our

research findings in a high impact open access journal in paediatrics to generate early impact.

With the assistance of our collaborators and lay representatives we will provide formal written feedback via an executive summary report, lay summary and evidence based recommendations to all stakeholders.

The team will work with our communications experts to produce a policy-briefing document. The launch and dissemination stakeholder meetings are essential to maximise the impact of the study and actually translate the findings into practice. The key stakeholders we intend to invite are cited above. The parents on the steering group together with JP (PPI co-applicant), will prepare the lay summary document to ensure its relevance for the target audience. This strategy for dissemination should ensure that the results of this study impact upon reducing avoidable mortality and morbidity in hospitalised children in a timely manner.

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16 Appendices

16.1 Appendix 1- Systematic Review Search Terms

1. ("early warning" adj5 scor*).ab,ti.
2. ("early warning" adj5 system* adj5 (deteriorat* or mortality or death or outcome* or harm* or safety)).ab,ti.
3. "acute illness severity".mp.
4. "early medical intervention"/ and ((prevent* or reduc* or improv*) adj5 (deteriorat* or mortality or death or outcome* or harm* or safety)).ab,ti.
5. ("early medical intervention" adj5 (tool* or scor* or index* or indicator* or indice* or assessment* or guide* or instrument* or criteria or parameter* or deteriorat* or mortality or death or monitor* or outcome* or harm* or safety)).ab,ti.
6. exp Health Status Indicators/ and ((tool* or scor* or index* or indicator* or indice* or assessment* or instrument* or criteria or parameter*) adj3 ((prevent* or reduc* or improv*) adj3 (deteriorat* or mortality or death or outcome* or harm* or safety))).ab,ti.
7. "Severity of Illness Index"/ and ((tool* or scor* or index* or indicator* or indice* or assessment* or instrument* or criteria or parameter*) adj5 ((prevent* or reduc* or improv*) adj5 (deteriorat* or mortality or death or outcome* or harm* or safety))).ab,ti.
8. exp Health Status Indicators/ and ((tool* or scor* or index* or indicator* or indice* or assessment* or instrument* or criteria or parameter*) adj3 ((prevent* or reduc* or improv*) adj3 (deteriorat* or mortality or death or outcome* or harm* or safety))).ab,ti.
9. "activation criteria".ab,ti.
10. Hospital Rapid Response Team/
11. Clinical Alarms/
12. (outreach adj3 emergency).tw.
13. VitalPAC Early Warning Score.tw.
14. medical emergency team.tw.
15. Rapid Response Systems.mp.
16. Rapid Response Team.tw.
17. ((Detecting or managing) adj3 deterioration).tw.
18. track-and-trigger system.tw.
19. (Track adj trigger).tw.
20. (Track and trigger).tw.
21. trigger tools.tw.
22. Calling criteria.tw.
23. Alert criteria.mp.
24. Rapid response.tw.
25. (score adj3 severity of illness).tw.
26. or/1-25
27. limit 26 to (humans and "all child (0 to 18 years)")
28. pediatric early warning.mp.
29. Paediatric Early Warning.mp.
30. p?ediatric alert.tw.
31. p?ediatric early warning systems.mp.
32. p?ediatric risk of mortality.tw.
33. Pediatric Rapid Response Team.tw.
34. Point-of-Care Systems/ and ((paediatric or pediatric) adj3 (improve or identify or detect* or outcome or early or critical or emergency)).tw.
35. Pediatric Advanced Warning Score.tw.
36. or/28-35
37. neonatal early warning.tw.

38. infant early warning.tw.
39. paediatric rapid response.tw.
40. pediatric rapid response.tw.
41. Bedside paediatric early warning.tw.
42. Bedside PEWS.tw.
43. or/28-42
44. 27 or 43

The following table is an explanation of the symbols used in the search strategy above.

/	after an index term (MeSH heading) indicates that all subheadings were selected.
*	before an index term indicates that that term was focused - i.e. limited to records where the term was a major MeSH/Emtree term.
"exp"	before an index term indicates that the term was exploded.
.ti, ab.	indicates a search for a term in title/abstract
.tw.	indicates a search for a term in title/abstract
.mp.	indicates a free text search for a term
adj	indicates a search for two terms where they appear adjacent to one another

16.2 Appendix 2 – Site Details

1) Arrowe Park Hospital

Arrowe Park Hospital (APH) is a large, acute District General Hospital, located on a 15-acre site, on the Wirral, Merseyside. In March 2011, the existing maternity and gynaecology unit underwent a £11.5 million refurbishment and was renamed Wirral Women and Children's Hospital. The children's ward has 22 beds plus two high dependency beds. They see 6500 admissions per year including short-term assessment on the Paediatric assessment ward.

Of these approximately 2500 children per year are admitted staying at least one overnight stay. There are on average 100 admissions to Paediatric High dependency unit (PHDU) per year.

From Jan 2013-2014,

- 27 in-patients were referred for PICU retrieval (1% of the population)
- 13 patients transferred for PICU (0.5% population).

2) Morriston Hospital

Morriston Hospital is one of 4 hospitals in Abertawe Bro Morgannwg University Health Board (ABMUHB) which serves a population of 500,000 patients in South Wales. The paediatric services within Morriston Hospital for children/young people is provided in 3 areas; The Paediatric Assessment Unit (PAU) for short term medical observation so that clinical decisions can be made to admit or send home. The paediatric medical ward treats inpatients with medical conditions including breathing difficulties, diabetes, cystic fibrosis, neurology or nephrology. This also includes high dependency beds. The paediatric surgical ward cares for in-patients who require surgical procedures, such as appendicectomy, GU dental, maxillofacial, orthopaedic, ENT, and ophthalmology conditions. This ward also admits children who have had trauma. This area also includes a high dependency area.

Admissions for last year were:

2013	All Patient Class	DAYCASE	INPATIENT
January	666	36	630
February	667	22	645
March	914	23	891
April	714	23	691
May	587	23	564
June	553	27	526
July	645	20	625
August	474	27	447
September	572	19	553

October	688	29	659
November	716	27	689
December	607	14	593
Total	7803	290	7513

3) Children's Hospital for Wales

Cardiff and Vale University Health Board (C&V UHB) is one of the largest NHS organisations in the UK. It provides day-to-day health services to a population of around 472,400 people living in Cardiff and the Vale of Glamorgan. The Children's Hospital for Wales is part of this large Health Board. The Children's hospital is part way through a 2-phase redevelopment.

The hospital serves Cardiff as well as South, Mid and West Wales. The hospital is expected to admit 23,000 patients (inpatient as well as short stay day cases/assessments) per year. It provides a number of tertiary specialties: neurosurgery, spinal surgery, complex airway surgery (ENT) as well as general paediatric surgery. It has a tertiary Paediatric Intensive Care Unit (PICU) [7 beds which can increase to 9 beds during periods of peak demand]. In addition, there is a 6 bed Paediatric High Dependency Unit (PHDU) managed geographically away from the PICU but within the hospital. Admissions to PICU are essentially about 300 children per year; there is no cardiac surgery. There are about 400-450 admissions to PHDU per year.

4) Alder Hey Hospital

Alder Hey has 337 in-patient beds treating more than 200,000 patients annually. The Trust provides the general paediatric service to the locality in addition to tertiary services for many specialities. The tertiary services include cardiac surgery, cardiology, nephrology, infectious diseases, neurosurgery, neurology, orthopaedics, burns, endocrinology, haematology/oncology, bone marrow transplantation, rheumatology, gastroenterology & plastics.

There is a 24-hour Accident & Emergency department, 23 bed Paediatric Intensive Care Unit and a 15 bed High Dependency Unit.

PICU has 1100 admissions per year

HDU has 650 admissions per year

Cardiac arrests, respiratory arrests or medical emergencies are outside of the ED or PICU (just wards)

	Total hospital admissions Staying one night or more (n)	Respiratory arrest (n)	Cardiac arrest (n)	Medical Emergency (n)	Incidence
2012	20696	72	11	5	0.4%
Unplanned admission to PICU from wards within hospital = 206					1.0%
Unplanned admission to HDU from wards with hospital = 112					0.5%

Requests for PICU review on the wards are approximately 300 episodes per year (2/3 lead to a PICU admission).