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Perfect Patient Pathway Test Bed

Digital Care Home Evaluation Report

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This report presents the findings of an independent evaluation of the Perfect Patient Pathway (PPP) Test Bed, Digital Care Home Project. It has been prepared by The University of Sheffield, in collaboration with National Institute for Health Research, Collaboration for Leadership in Applied Health Research Yorkshire and Humber (NIHR CLAHRC YH) and Healthwatch Sheffield under contract to Sheffield Teaching Hospitals NHS Foundation Trust (STH). Where information is drawn from other sources (e.g. PPP Test Bed Project Management Office (PMO)) it is used with permission and sources are identified within the text.

The first phase of this project is reported in a previous report as part of the Perfect Patient Pathway programme. This report incorporates material from the evaluation of phase-2 and the previous whole programme report to provide an overall view of both phases of project implementation. The findings and interpretations in this report are those of the authors and do not necessarily represent the views of the services or organisations involved in the delivery of the programme or those of the NHS, the NIHR or the Department of Health and Social Care.

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Glossary

A&E	Accident and Emergency
EAC	Equivalent Annual Cost
EWS	Early Warning Score
HRG	Health Resource Grouper
Inhealthcare	The developer and provider of the technology for the DCH project
GP	General Practitioner
SPA	Single Point of Access (for healthcare services)
MEWS	Modified Early Warning Score
NEWS	National Early Warning Score
NEW	National Early Warning
NICE	National Institute of Health and Care Excellence
PMO	Project/programme Management Office
RCT	Randomised Controlled Trial
TAG	Test Bed Advisory Group
DCH	Digital Care Homes project
PPP	Perfect Patient Pathway (title of the main Test Bed Programme of which DCH is one project)
RGN	Registered General Nurse
App	Digital application (in this case the online 'portal' to enter and access NEW scores of residents)
SystmOne	Electronic Patient Record System as used in health care (mostly primary and community care)
ScHARR	School of Health and Related Research (University of Sheffield)
REC	Research Ethics Committee

Executive summary

Emergency admissions from care homes to hospitals in England has been estimated to have increased by around 62% between 2010 and 2016 (Parliament.uk, 2017); suggesting that innovative solutions are required to provide more appropriate and pre-emptive services to this population. Early warning signs have been used in acute settings to detect deteriorating health status. The testing of the usefulness of these signs in pre-hospital settings; to better prioritise allocation and identify the need for further or escalation of care has been suggested (RCP, 2012). However, a systematic review in 2018 (Patel et al, 2018) found evidence of only one study in the care home setting.

The Digital Care Home (DCH) project is a preventative intervention, based on the National Early Warning Score (NEWS), and is intended to improve recognition of clinical deterioration. Regular monitoring of physiological measures is relayed to an NHS single point of access (SPA). There are set parameters, which if exceeded, trigger alerts that SPA staff respond to; initially by contacting the care home. Advice is given to care home staff and referrals made to other appropriate services if required. The primary expected outcome is a reduction in emergency and non-elective use of hospital services.

Following evaluation of the initial project, a number of recommendations and outstanding evaluation questions suggested the value of extending the project. This document reports on the evaluation of both phases of the project, and includes the following general approaches:

- Observation and description of the intervention and implementation
- Theory-based understanding of potential benefits, barriers and facilitators
- Design for development and improvement
- Assessment of sustainability and spread

Between June 2017 and October 2018, 139 participants were recruited to the Digital Care Home intervention across 11 care homes. A mean of 12.6 participants were recruited per care home, with a minimum of 5 and a maximum of 21 recruited per care home. All of the care homes taking part in the project were dual-registered; having a mix of both residential and nursing beds. Some of the participants, however, were residential; not receiving routine nursing care.

- Description of events:

Overall, there were 5985 recorded events associated with the monitoring system; this equates to a median of 598.5 per care home, with a minimum of 110 events (1.8%) and a maximum of 1122 (18.8%) per care home. The majority of events (3,986; 66.6%) were 'NEWS task' related (i.e. instructing care home staff to report physiological measures). The second most common event was a NEWS alert (413; 6.9%), indicating a concern with a resident's health status.

- Summary of conclusions and recommendations

In order to improve future evaluators' ability to understand the events recorded on the system; recommendations for further development of the system include providing a unique episode identifier to link recorded 'Tasks' with associated events such as, 'Alerts' and 'Referrals'. It

would also be useful to have more detailed information regarding the changes in resident care that can be associated with the intervention, such as details of referrals.

The key mechanisms by which the digital care home project is expected to reduce unnecessary emergency presentations rely on timely interventions to prevent care home staff members calling 999 services. These interventions were deemed less necessary in homes with nursing staff that could apply clinical interventions, seek advice and reassurance or medical interventions (e.g. from a GP).

However, care homes with little or no nursing cover were considered to be more likely to rely on emergency services. This need is considered to be greater when a resident's health deteriorates out-of-hours, and access to GPs is limited. This also highlights the importance of continuity of care home and nursing home staff members as well as regular GPs.

The NEW score readings were reported to be helpful additional information in both nursing and care homes when communicating externally, as they were considered to provide objective information to reinforce and legitimise observations. However, whilst some participants were in residential beds (rather than nursing beds) the intervention was in dual-registration (nursing and residential) nursing homes only and the majority of residents were receiving weekly assessments during regular GP operating times. Therefore, it would be considered unlikely that the intervention on its own would detect deterioration or prevent 999 calls in these contexts. The compromise between more frequent monitoring to recognise deteriorating health and the extra work that this would require of staff and residents could possibly be addressed, to some extent, through the use of wearable monitoring devices or self-monitoring. However, this would not cover the full range of measures required for a NEW score, so revised (and possibly bespoke) monitoring regimens and thresholds would be required.

Whilst the additional nursing cover provided by the project was not drawn upon, this was possibly due to all of the homes in the project being nursing homes. This additional service might be considered more useful for residential care homes.

Recommendations for further development of the service include: access to advice and support either out of hours or for care homes with a poor GP relationship; inclusion of softer signs of deterioration that are tailored to individual residents; improved flow of information and medical records; and access to residents' health trends for the key organisations and individuals responsible for that resident's care.

Despite NEWS observations being considered inappropriate on their own for many residents, there were recognised benefits. Regular and systematic contact with residents for measuring vital signs was considered to have unintended positive consequences regarding, for instance; better communication, improved observation (of 'hard' and 'soft' signs) and reassurance.

Developments could include a consideration of practical guidelines for inclusion of homes and individual residents that would benefit most from the intervention and the most suitable type of intervention. The key to preventing inappropriate emergency hospital presentations for care home residents is regular monitoring, coupled with an understanding of the resident and clear and appropriate advanced care plans that are actionable both during surgery hours and out of

hours. The integration of the digital care home intervention could usefully fit within this model of care.

Whilst generally considered useful and appropriate, the NEWS measures were reported to be too limited and inflexible for optimum use in residential and nursing home settings. Other parameters that could be usefully incorporated are those routinely collected for monitoring in residents' records (e.g. food and fluids (MUST & BMI score), pain, mobility, choking risk, communication, medication etc.). However, without being supported by the initiation of mobile digital care home records input, the duplication of record keeping on digital and paper-based systems could be a significant barrier in an already under-resourced sector.

In terms of further integrating the system with other services; the sharing of NEWS data with ambulance crews is one area of obvious development. Relationships with GPs are also fundamentally important for appropriate escalation of care and changes in treatment plans and medications. It would therefore be useful to involve GPs in future development of the intervention.

One important area of development highlighted by this evaluation is the need to integrate interventions into a complex health and social care system, which involves a number of key organisations. An area of development that was therefore recommended by a range of stakeholders is the integration and appropriate sharing of detailed advanced care planning, which should inform all aspects of care; particularly with regard to emergency avoidance.

This project has provided an important milestone to improving care, by demonstrating the proof of concept for a prototype digital care home model. The regular monitoring of clinical signs, combined with real-time integration of care homes with acute hospital liaison and admission services is a concept that this evaluation has demonstrated could be of great benefit to the sector. This evaluation has demonstrated ways in which elements of the digital care home intervention could be implemented within a system-wide understanding of the key issues and contexts of the sector, which could lead to improved care and more efficient and appropriate use of health resources.

1. Introduction

The difficulty of the health care system to respond appropriately to the growing demands of the ageing population is widely recognised.

"A growing frail, elderly population are living with one or multiple long-term conditions. Between 2001 and 2011, the number of people aged 85 or over in England increased at three and a half times the rate of the rest of the population. Older people are far more likely to have immediate or chronic health problems, more likely to need to go to an A&E department and more likely to be admitted into hospital once in A&E." (National Audit Office, 2013, p.34)

A large proportion of elderly people in the UK currently live in care homes. There are approximately 410,000 to 416,000 people living in care homes (Laing and Buisson [survey], 2016). 28,471 emergency admissions from care homes were made to hospitals in England in 2016. This is compared to around 17,539 in 2010, which represents an increase of 62%. Whilst admissions from NHS and local authority run homes have decreased over this time, admissions have more than doubled from other homes (10,510-22,089 (110%)(P. Dunne, 2017).

These increases in the demand for A&E services from care home residents (particularly the private sector), suggest that innovative solutions are required to provide more appropriate and pre-emptive services to this population. Technological solutions facilitate new approaches to care and provide part of this solution to this growing problem. Current evidence suggests that, whilst there are some barriers to overcome, digital innovations could provide appropriate benefits.

The Digital Care Home project is a preventative intervention, based on the National Early Warning Score (NEWS), which was initially designed for use in acute services (such as frailty units) to improve recognition of clinical deterioration. However, more recently the utility of the NEWS tool has been trialled in various non-acute services (Brangan et al, 2018) including care homes (Patel et al, 2018).

1.2 Digital Care Home project description

The Digital Care Home project was originally a part of the Sheffield 'Perfect Patient Pathway' Test Bed programme (PPP Test Bed). It was one of the last projects to start recruitment of participants within the programme and was chosen to be continued beyond the completion of the main programme, in order to refine the intervention and provide further opportunities for evaluation. The programme was implemented by the Test Bed Programme Management Office (PMO) and was overseen by a service-user Test Bed Advisory Group (TAG), which was convened by Healthwatch Sheffield.

A pilot care home was monitored from June to September 2017. The recruitment of an additional six care homes to the project happened from September to December 2017 and monitoring began in these six other homes from October 2017 to January 2018. The project was then funded further until November 2018. A report of this first phase was included in the whole Test Bed evaluation report (July 2018). Once it was decided that the project was to be continued, an additional three homes were recruited during the summer of 2018 (although one

original home decided not to continue). An associated evaluation of this second phase was planned to the end of December 2018. Monitoring at all homes finished at the end of October 2018. This report combines findings from both phases.

Table 1: Recruitment and monitoring of homes

	Pilot	First Phase	Second Phase
Home recruitment	Spring 2017	September to December 2017	Summer 2018 to November 2018
Monitoring dates	June 2017 to November 2018	From October 2017 / January 2018 to November 2018	September 2018 to November 2018
Numbers of homes	1	6	Additional 3 (1 home dropped out from 1st phase)-

1.3 Digital Care Home intervention description

The technology for this project consisted of equipment to measure National Early Warning Scores (NEWS) vital signs observations (section 3.2. provides an overview of NEWS) and a digital tablet application (App) to transmit these readings to a Digital Health Platform which could be viewed by the Single Point of Access (SPA) team at a local hospital.

The following is a list of the physiological measures that are monitored for the NEW score:

1. Respiration rate
2. Oxygen saturation
3. Systolic blood pressure
4. Pulse rate
5. Level of consciousness or new confusion*
6. Temperature

Care home staff used the technology to submit and share these readings electronically (which had to be sent between 7am and noon in order to allow time for a response if required within normal working hours). The nurses at SPA were able to view readings and alerts through the Digital Care Home portal. If the readings triggered an alert at SPA, then the named contact at the care home was called by phone. If a referral was required following an alert and dialogue with the care home team, the information could be uploaded into patient records via SystemOne or made visible to NHS services (e.g. GP, community nursing team) via access to the portal. Through this system, there was flexibility to provide the data where it was needed to support clinical decision-making and interventions. The project began with information linkages between care homes and SPA with access provided for relevant GPs. As the project developed, acute Liaison services at the local hospital's frailty unit were also provided with access. It was also possible for care home staff to recognise that the score was going to trigger an alert at SPA and to view prior readings through the portal and take the actions required.

The frequency of monitoring was variable and ultimately decided by the care home staff. Whilst most residents were monitored weekly, some homes chose to monitor residents twice-weekly and this frequency could be increased or decreased; depending on perceived need. It is also

worth noting that due to practical difficulties (e.g. staff shortages, unavailability of resident), monitoring did not always take place as planned; leading to lower monitoring frequencies. The intervention also included access to the services of a Community Nurse (based at a nearby hospice); to ensure that there was additional clinical cover in case this was required (particularly for out-of-hours cover). However, this additional cover was never called upon.

The following are details of key inputs necessary for the successful implementation of the Digital Care Home intervention.

- Advice from experienced clinical SPA staff who were:
    - used to making clinical judgements over the phone
    - supportive of appropriate admission avoidance
    - able to communicate in non-judgemental, supportive and facilitative manner
    - respectful of the skills and experience of care home staff
- Care home manager and project staff creating, reinforcing and facilitating a work routine that facilitated the project (set person to collect readings and input to the system, and regular days and times)
    - care home manager choosing residents for project
    - care home choosing staff who were to undertake and submit readings
    - reallocation of workload within the home
- PC or digital tablet to record measures
- Clinical observation tools to take readings
- Training on the project, clinical measures, NEW score and technology
- Project team support and regular contact and a positive, problem-solving approach
- Community nurse/palliative care nurse time

It is worth recognising that opinions and feelings about the project changed over time as staff built relationships, learned on-the-job, and routines became established.

The primary outcome that this project was trying to address was the high level of emergency attendances and admissions for care home residents. Care home residents have 40-50% more hospital admissions and Accident and Emergency attendances than the general population age 75 and over. It is possible that translating the NEWS from acute care situations to care homes and linking alerts to clinical responses, that emergency attendances and non-elective hospital admissions might be reduced. However, there is potential for the project to deliver a range of benefits such as: recognising health deterioration that may otherwise go unnoticed, improving communication between health and social care, enabling a more joined-up approach to care, introduction of digital interventions in care homes (potentially leading to other innovations).

Reflecting the huge variety within the care home sector; a number of homes were involved in the project, with varying levels of admissions to A&E, different numbers of residents, and different roles and grades of care home staff members supporting the intervention. Importantly, as these homes are early adopters there was largely a culture at management level of wanting to invest in preventative approaches. All of the homes taking part in the project were dual-registered; having a mix of both residential and nursing beds. Some of the participants, however, were residential; not receiving routine nursing care.

1.4 National Early Warning Score (NEWS): an overview

When a patient is acutely unwell or deteriorates and becomes acutely unwell, time is of the essence and a fast and efficient clinical response is required to optimise clinical outcomes. Evidence has suggested that critical to defining clinical outcomes is the combination of: (i) early detection; (ii) timeliness of response; and (iii) competency of the clinical response (Royal College of Physicians, 2012). NEWS has been recommended to improve the following (ibid): (i) the assessment of acute illness; (ii) the detection of clinical deterioration, and (iii) the initiation of a timely and competent clinical response. NEWS is based on the assessment of six physiological factors which determine an overall NEW score (noting that additional weighting of the NEWS aggregate score can be based on other additional factors; see supplementary appendix S1): respiratory rate, oxygen saturation, temperature, systolic blood pressure, pulse rate, level of consciousness (recommended to be based on the Alert Voice Pain Unresponsive [APVU] scale). Based on the NEW score, these triggers should determine the urgency of the clinical response and the clinical competency of the responder/s (note, the following recommendations were based on the use of NEWS in acute hospital care) (ibid):

- **Low risk score (NEW score 1–4):** should prompt assessment by a competent clinical professional (e.g. registered nurse in acute care) who should decide if a change to frequency of clinical monitoring or an escalation of clinical care is required.
- **Medium risk score (NEW score of 5–6 or RED score i.e. individual parameter scoring 3):** should prompt an urgent review by a clinician skilled with competencies in the assessment of acute illness (e.g. a ward-based doctor or acute team nurse in acute care), who should consider whether escalation of care to a team with critical-care skills is required (e.g. critical care outreach team).
- **High risk score (NEW score of 7 or more):** should prompt emergency assessment by a clinical team/critical care outreach team with critical-care competencies and usually transfer of the patient to a higher dependency care area.

1.5 Brief description of the care homes

The following table shows the types of care provided by the homes taking part in the project and the reported levels of staffing. Whilst the range in the ratio of beds per staff member varies considerably and could therefore indicate inaccurate reporting, it is useful to note that all homes provide elements of nursing care: none are purely residential care homes.

Table 2: Staffing levels of participating homes

ID	Type of care	No. of Beds	Nurse	Nurse assistant	Care assistant	Senior carer	Total staff	Ratio Bed/ Staff
1	Nursing, Residential, Respite	56	4	4	21	4	33	1.7
2	Residential and nursing, dementia and MH	59	*	*	*	*	*	*
3	Respite, Palliative,	63	2	*	10	1	13	4.8

	Nursing, Residential							
4	EMI, Nursing & Residential	52	6	*	N/A	7	13	4
5	EMI, Nursing, Residential	120	29	*	74 (inc. bank)	N/A	103	1.2
6	Nursing and EMI	72	16	*	28	N/A	44	1.6
7	Nursing and intermediate	60	*	*	*	*	*	*
8	Residential, nursing, and rehabilitative	83	*	*	*	*	*	*
9	Residential, nursing, palliative, respite	73	*	*	*	*	*	*
10	Respite, EMI, Palliative, Nursing, MH, Residential	75	*	*	*	*	*	*

* No data provided

Table 3: Most recent Care Quality Commission report

Inspection date	Jun-18	Aug-17	Nov-17	Aug-17	Jun-18	Aug-18	Oct-17	Jan-18	Aug-15	Aug-16
Home ID	1	2	3	4	5	6	7	8	9	10
Overall rating	RI	Good	RI	Good	RI	RI	Good	Good	Good	Good
Is the service safe?	RI	RI	RI	Good	Good	RI	Good	Good	RI	Good
Is the service effective?	RI	Good	RI	Good	Good	RI	Good	Good	Good	Good
Is the service caring?	RI	Good	RI	Good	Good	RI	Good	Good	Good	Good
Is the service responsive ?	RI	Good	RI	Good	Good	Good	Good	RI	Good	Good
Is the service well-led?	Inadequate	Good	RI	Good	RI	RI	Good	Good	Good	Good

*RI= Requires Improvement

2. Evaluation Purpose and Overview

This report presents an independent evaluation of the Digital Care Home project. The evaluation used mixed qualitative and quantitative methods, drawing on routinely collected data and primary data collection to seek to understand long-term experiences and describe activities of the monitoring service from a range of stakeholder perspectives.

We describe the implementation process and how barriers and facilitators operate according to the characteristics of different types of homes, to inform future embedding of the monitoring system. We utilised user-centred, co-design principles to understand the implementation and recommend useful developments.

3. Evaluation scope and approach

3.1 Evaluation questions

The evaluation was delivered in two phases; the first of which coincided with the whole programme evaluation and the second was instigated following confirmation of the extension for the Digital care Home project. These have been combined for the purposes of this report. The evaluation sought to answer the following questions:

1. How has the long-term use of a digital monitoring service been received by key stakeholders?
2. How might a digital monitoring service be optimally designed for embedding in care homes?
3. What are the implementation and operational costs of the intervention?
4. What changes in health service utilisation would be required to achieve cost neutrality?
5. Are there notable differences in A&E admissions before and after the intervention?
6. What are the downstream effects from such a monitoring service on the healthcare system?

3.2 Ruling out comparative analysis

There are a number of evaluation challenges for this project. A clustered analysis with comparator homes and intervention homes was not possible because the number of residents taking part in the intervention at participating homes was smaller than anticipated during project design. It was also deemed not to be feasible to recruit homes that were not receiving the intervention. Therefore, an analysis performed at an individual level is required.

We have considered, and ruled out a number of possible approaches to obtaining comparative data in order to assess the effectiveness of the intervention:

> **Primary care data**: GP records for care/nursing home residents are not generally located at a single GP practice, but are spread over a number of practices. Even when a home has a dedicated GP or GP practice, residents often remain on the list of GP practices from their former residences. Relevant GP practices can therefore not be known in advance of identifying individuals. Obtaining permissions and gathering GP data, which is always problematic, would therefore be extremely time-consuming and

risky, even if relevant ethics, governance and data protection regulations can be navigated.

Informed consent for comparison group: A comparison group formed from comparable residents that are not receiving the intervention and have consented to provide their care home and health care data would provide a good opportunity to identify whether anticipated benefits are being realised. However, recruitment of care/nursing homes is difficult due to competing demands of caring for residents and would be anticipated to be particularly problematic for a purely observational study. This approach would also reduce the number of intervention participants that could be recruited with the available resources, and therefore limit the extent of learning from this intervention.

3.3 Work Package Summaries

To achieve these outputs and answer the key evaluation questions the study has been broken down into the following 6 Work Packages:

WP1: Impact and economic analysis:
An analysis of the costs of the intervention, and an assessment of the changes in health service-use required to achieve cost-neutrality (i.e. return on investment) and quantitative analysis of A&E admissions before and after the intervention to assess whether any changes are observable. The objective was to analyse routinely collected health service use data to begin to understand the effects of the project.

WP2: Description of alerts and assessment of potential consequences:
Qualitative and quantitative description of records stored in the Digital Care Home monitoring system. Objectives were to

1. Analyse alerts and subsequent activities (including development of theories e.g. activities, mechanisms and contextual factors which might lead to specific outcomes such as reduced unplanned attendance at A&E and person-centred care)
2. Review individual resident readings / learning for care home staff members and influences on care and care planning

WP3: Qualitative investigation, Process evaluation, and Theory development:
Qualitative interviews and group discussions to develop, refine and test theories about how the intervention is expected to work, describe the implementation process and key stakeholders' experiences of the intervention. Objectives were to:

1. Conduct qualitative interviews with residents / friends and family / staff to: understand culture and reception of service etc. 1 year on; contribute to developing theories about intervention effectiveness; and contribute to process evaluation
2. Evaluate implementation process to understand process of 'embedding'

WP4: Care plan reviews:
The review describes the content of current care plans, to understand the processes and activities by which these are compiled, maintained and updated, and understand how (and if) the changes in monitoring related to the Digital Care Home project are recorded in the care plans. The objective was to understand the extent to which the readings taken for the NEW scores were embedded in the practices, procedures and record-keeping in the homes.

WP5: User-centred design approach:
Through participation of stakeholders as partners in the process of co-design and development of the intervention they are provided with opportunities to voice their concerns, preferences, aspirations and expectations to guide recommendations for further development. The objective s were to

1. Conduct co-design groups with key stakeholders to find out what they would find useful to monitor and report on and identify how to best design the intervention around the needs of key stakeholders (i.e. what is the value to care homes?)

WP6: Evidence Review:
The evidence review has two strands: the first generally informed the evaluation activities, providing background information for the evaluation and secondly it has a specifically focused element to inform the understanding of emergent themes and evidence about Early Warning Systems.

3.5 Ethical approvals

Ethical approval for this service evaluation was provided by the University of Sheffield's School of Health and Related Research (ScHARR) research ethics committee (REC). The evaluation protocols, participant information sheets and consent forms were written with the assistance of the PPP Test Bed PMO and the PPP Test Bed Advisory Group (TAG) convened by Healthwatch Sheffield. Amendments to the protocols and participant information materials were submitted and approved by the REC as the evaluation responded to implementation developments.

3.6 Engagement with the public and service users

A key partner and stakeholder within the PPP Test Bed Sheffield was Healthwatch Sheffield; an independent organisation working in partnership with local people, to ensure that their views are heard by the people making decisions about health and social care. Members of the evaluation team presented the evaluation proposal from Wave 1 of the Perfect Patient Pathway Test Bed at a TAG meeting in September 2018 and received feedback from the group members and a summary report.

4. WP1: Impact and economic analysis

4.1 Methods: Intervention costs and achieving cost-neutrality

Discussions were held with the providers of the technology (Inhealthcare), the implementation team, clinical staff and care homes associated with implementing the intervention to understand the resources and costs associated with implementing the Digital Care Home (DCH) interventions. This included the assessment of the cost of the Digital Care Home interventions themselves and any staff, training or additional resources associated with the practical use of the device. The resource-use implications were based on these discussions and assumptions as needed (e.g. it was necessary to make assumptions about the time taken for taking the readings or otherwise in real-world settings where it was not possible to conduct a time-and-motion study). Unit costs for the Digital Care Home interventions themselves were based on those costs suggested by the developers (Inhealthcare).

Two types of costs are considered in this cost estimation of the DCH intervention:

1. **Implementation costs:** this includes the cost of the technology for vital sign monitoring (i.e. pulse oximeter, thermometer, and blood pressure monitor) and data entry (i.e. a tablet and case), the Inhealthcare platform itself (i.e. where data is stored and transferred), and monitoring modules for care home residents as part of the Inhealthcare platform (e.g. for monitoring long term conditions or malnutrition)
2. **Operational costs:** this includes staff time at the care home (for monitoring and recording the relevant residents' data) and Single Point of Access (SPA) staff (for responding to alerts due to the monitoring of care home residents).

All intervention costs are estimated for one year to provide a standardised estimate of the potential intervention costs for comparison against the statistical analysis conducted for this study (i.e. change in hospital contacts per year). For the purpose of providing cost estimations as generalisable examples, we assume care home sizes can be categorised into three broad groups based on the number of residents as suggested by the Care Quality Commission; (2017) these care home sizes are: 'large' homes (50+ beds); 'medium' homes (11 to 49 beds); and small homes (1 to 10 beds; small homes are not included in these costing examples). For the purpose of these cost estimations, we will base the costing assumptions on those care homes and residents included in the first phase of the study; that is, seven 'large' homes (seven homes in total). Two types of costing are performed for the technology involved in the intervention costing estimations:

1. total sunk costs (i.e. the initial purchase cost of the technology);
2. equivalent annual cost (EAC; i.e. the cost of the technology per year assuming a 3-year capital life).

For the EAC, it is assumed that the capital life of the technology is three years and that an interest rate of 3.5%, which is based on the future discounting rate suggested by NICE (2013) is paid each year as a depreciation rate equal to the cost of maintaining the technology; the annuitization and calculation procedure for estimating the EAC are described by Drummond et

al 2015 All additional methods and details about applying unit costs to the DCH intervention are provided in the separate scientific report (https://eprints.whiterose.ac.uk/).

The DCH intervention cost estimates were compared to those unit costs associated with a long or short-stay non-elective inpatient admission, or an A&E visit (i.e. hospital contacts which could be avoided using the intervention) in order to suggest how many contacts may need to be avoided to achieve cost-neutrality when investing in the DCH intervention (i.e. the intervention cost is equal to the cost-savings of avoiding down hospital contacts).

Unit costs associated with healthcare staff and resources were obtained from appropriate reference cost sources, such as NHS Reference costs (NHS Improvement, 2017) and Personal Social Services Research Unit (PSSRU) Unit Costs of Health and Social Care (Curtis & Burns, 2017).

4.2 Methods: Pre-Post intervention A&E admissions

We conducted a quantitative analysis at an interim stage (at the end of the Wave 1 of the Test Bed and prior to recruiting further homes in Summer 2018) to test for feasibility and whether the analysis would provide any meaningful results. For each resident involved in the intervention, data were collected on their age, sex, date of joining the intervention, date of entry to the care home, and numbers of emergency contacts both between the start of the intervention and 29th May 2018 (cut-off date for data collection for whole programme reporting), and in the equivalent time period 12 months earlier, before the start of the intervention. Emergency contacts included both Accident & Emergency (A&E) attendance, and Inpatient contacts that were listed as emergency cases (and therefore excluded elective and day cases). Where there were multiple inpatient episodes with the same admission date, these were treated as a single emergency contact.

Descriptive analysis was conducted for all variables. The primary hypothesis was that the rate of emergency contacts would be lower for residents using the intervention than it was for these residents before they used the intervention. This was tested using a multilevel Poisson regression analysis, details of which can be found in the scientific report. Primary analysis was restricted to those participants who were already resident in their care home at the start of the baseline period, but a secondary analysis included all data, regardless of when residents entered the care home.

4.3 Findings: Intervention costs and achieving cost-neutrality

When accounting for the implementation and operational costs of the DCH intervention (i.e. at the end of Wave 1 of the Test Bed this was 67 residents and 7 care homes), the total estimated intervention cost in the first year is £66,840 which equates to an equivalent annual cost of £64,172 (details around how this intervention cost was calculated are presented in appendix 6).

Table 4 shows the unit costs of non-elective inpatient long stays, short stays, and A&E visits as reported in the NHS Reference costs for 2016/17 (NHS Improvement, 2017). Based on the estimated equivalent annual intervention cost of £64,172, it is estimated that across the 67 residents in first wave, the intervention would need to avoid 21.5 long stay non-elective inpatient contacts per year at £2,984.71 per contact to achieve cost-neutrality; which is

equivalent to a decrease of 0.32 long stay non-elective inpatient contacts per resident/year (see Table 4). For short-stay non-elective inpatient stays or emergency medicine contacts (e.g. A&E visits), a decrease of 1.55 or 6.46 contacts per resident/year would be needed to achieve cost-neutrality (see Table 4). If the decision maker wanted to re-coop the technology costs via hospital cost-savings over the first year of implementation, the intervention would have to avoid 0.33 long stay non-elective inpatient contacts, or 1.62 short-stay non-elective inpatient stay contacts, or 6.72 emergency medicine contacts per resident in the first year, as examples (see Table 4**Error! Reference source not found.**). For the purpose of these examples, these estimates are assuming that avoiding contacts are independent of each other, whereas in reality various types of healthcare contacts could be avoided to achieve cost-neutrality (e.g. avoid both non-elective inpatient and A&E visits). Based on the statistical analysis of hospital contacts conducted for this study, there is no clear evidence to suggest whether these reductions in hospital contacts are achievable; further evidence is required.

Table 4: Number of hospital contacts needed to avoid for DCH intervention cost-neutrality

Parameters	No. residents	Based on total cost (first year)	Based on total EAC
Total DCH intervention cost (£)	67	£66,839.58	£64,172.07
Non-Elective Long Stay cost (£)	1	£2,984.71	£2,984.71
No. to avoid per year (cost-neutrality)	67	22.4	21.5
No. to avoid per resident/year (cost-neutrality)	1	0.33	0.32
Non-elective Short Stay cost (£)	1	£617.11	£617.11
No. to avoid per year (cost-neutrality)	67	108.3	104.0
No. to avoid per resident/year (cost-neutrality)	1	1.62	1.55
Emergency medicine cost (£)	1	£148.36	£148.36
No. to avoid per year (cost-neutrality)	67	450.5	432.5
No. to avoid per resident/year (cost-neutrality)	1	6.72	6.46

Footnote. All hospital contact costs sourced from National Reference cost for 2016/17.[32] EAC = Equivalent Annual Cost; see also Table 10 in appendix 6.

4.4 Findings: Pre-post intervention A&E admissions

In the first wave there were 67 residents who used the intervention across the seven care homes. The number per home ranged from 5 to 16.

The start date for the intervention varied by care home, from 5 June 2017 to 11 January 2018. As the date for the end of the study period was 29 May 2018 (data collection cut-off date to allow for whole programme reporting), this gave between 137 and 357 days for the intervention period.

The baseline period was treated as exactly one year before the intervention period; therefore, this varied by care home also. 36 of the residents (54%) were in the care homes before the baseline period started; 12 (18%) became resident during the baseline period; 13 (19%) only became resident after the baseline period finished; and for six residents we did not have the date of their becoming a resident.

The total numbers of emergency contacts per resident across the baseline and intervention periods are shown in the following table (including all participants). Across all the participants there were 81 emergency contacts in the baseline period (44 A&E, 37 inpatient), and 60 in the intervention period (35 A&E, 25 inpatient).

Table 5: Emergency contact frequency

Baseline period			Intervention period		
Emergency contacts	Frequency	%	Emergency contacts	Frequency	%
0	36	53.7%	0	39	58.2%
1	8	11.9%	1	11	16.4%
2	10	14.9%	2	10	14.9%
3	3	4.5%	3	1	1.5%
4	7	10.4%	4	4	6.0%
5	2	3.0%	5	2	3.0%
6	1	1.5%			

The underlying periods for this differ by care home, however, due to the staggered start dates of the intervention. A more useful way of showing the data is as a rate of emergency contacts over a 12-month period. The following table shows the mean, standard deviation, median and interquartile range for each period, both including all cases, and then only including the 36 cases that were resident in the care home at the start of the baseline period (labelled as consistent cases).

Table 6: Emergency contact rate per 12 months

Contacts per 12 months			
Baseline period		**Intervention period**	
All cases		***All cases***	
Mean (SD)	2.4 (3.3)	Mean (SD)	1.8 (2.9)
Median (IQR)	0 (0.0-3.9)	Median (IQR)	0 (0.0-2.7)
Consistent cases		***Consistent cases***	
Mean (SD)	1.0 (2.1)	Mean (SD)	1.7 (3.0)
Median (IQR)	0 (0.0-1.9)	Median (IQR)	0 (0.0-2.4)

This reveals an interesting effect. When all cases are considered, there appears to be a slight decrease in the number of emergency contacts during the intervention period compared with the baseline period. However, when only considering participants who were resident in the care home at start of the baseline period, there appears to be a slight increase in emergency contacts over the intervention period compared with baseline. This highlights the importance of considering like-for-like cases. Often, entry into the care home may be precipitated by a care episode, which may involve an emergency contact. Therefore, the higher rate of contacts in the baseline period when all cases are considered is possibly connected to the very reason that some participants entered the care home in the first place. This suggests that to get a meaningful comparison, the use of consistent cases (those who were care home residents across the whole of both periods) is indeed the more sensible approach.

4.5 Conclusions

The methodology used in this work-package was carried out part-way through the DCH intervention (i.e. for the whole programme evaluation). Whilst the findings were considered

useful at this stage, there were limitations with the approach, and therefore few expected benefits of repeating the analysis with a full data set.

Based on the estimated equivalent annual intervention cost of £64,172, for 67 residents in first wave, the intervention would need to avoid 21.5 long stay non-elective inpatient contacts per year to achieve cost-neutrality; which is equivalent to a decrease of 0.32 long stay non-elective inpatient contacts per resident/year. To re-coop the intervention costs via hospital cost-savings over the first year of implementation, the intervention would have to avoid 0.33 long stay non-elective inpatient contacts, or 1.62 short-stay non-elective inpatient stay contacts, or 6.72 emergency medicine contacts per resident in the first year

It should be noted the exact cost, if the Digital Care Home intervention was to be rolled out further is dependent on the number of residents involved, and number and size of the care homes connected to the platform in terms of potential residents that require monitoring; the unit costs associated with each of these aspects are presented in the scientific report (https://eprints.whiterose.ac.uk/) to enable future studies and/or decision makers to calculate the potential cost of the DCH intervention for their own circumstance.

To test whether there was a difference in the rate of emergency contacts between the intervention and baseline periods, we ran a repeated-measures Poisson mixed effects model, using intervention period as the offset.

This confirmed what the descriptive statistics had suggested: that there is a slight but non-significant increase in emergency contacts in the intervention period compared with the baseline period. Specifically, the incidence ratio for events occurring in the intervention period compared with the baseline period was 1.59 (95% confidence interval (0.62, 4.06)), p = 0.329.

The conclusion, therefore, is that there is no difference that can be inferred between the rate of emergency contacts while using the intervention compared with baseline. The observed number shows a slightly increase (a rate of 0.6 per year higher in the intervention period), but the confidence interval here is (-0.4, 1.6), therefore including zero and meaning no firm conclusions could be drawn.

Even if there were an increase in emergency contacts during the intervention period, there could be a logical explanation for this that has nothing to do with the intervention itself. These residents are typically old and are often frail or experiencing multiple comorbidities; the extra year of age in the intervention period could well be associated with greater health problems generally, which might cause the higher rate of emergency contacts. Without an appropriate comparison group, it is impossible to know whether this would be the reason.

As a secondary analysis, we examined the rate using the same analysis but including all cases. Again, this was in accordance with the descriptive statistics: there is a slight but non-significant decrease in emergency contacts in the intervention period compared with the baseline period. Specifically, the incidence ratio for events occurring in the intervention period compared with the baseline period was 0.74 (95% confidence interval (0.45, 1.23)), p = 0.245.

5. WP2: Description of system records and assessment of potential consequences of the intervention

5.1 Methods: Description of alerts

The following analysis links those participants and care homes recruited to the project with their DCH monitoring system tasks data (which can include NEWS-related alerts data) and A&E events data over the period the person was being monitored using the DCH system.

A variety of different tasks were recorded on the monitoring system which can be classed as 'alerts', such as those tasks associated with recording a NEW score (used to suggest the risk of the person's health deteriorating) which may require medical care, a referral to another health care professional (e.g. a doctor), or to start monitoring the person more often.

When linked with a person's A&E data, of 35 A&E events which occurred during the observation period, 13 A&E events occurred within 7 days of a task recorded within the DCH monitoring system; however, only in one case did a NEW score indicate that the person's health was at medium to high risk of deteriorating and therefore the person would require further medical care.

Due to the nature of the study, it is not possible to suggest how many A&E events could have been avoided, and as the monitoring of NEWS in care homes is quite new and there is no published study of a similar monitoring system in a similar setting (that is, care homes), there is no previous evidence to suggest the potential benefit of such a monitoring system. However, expert opinion from health professionals suggests that the DCH system could prevent adverse events associated with poor vital signs (for example, high temperature and low resting blood pressure), such as falls. Therefore, there is potential for the monitoring system to prevent harms to those in care homes in some circumstances, such as avoiding falls, but further research is required to understand the extent of this potential benefit.

5.1.1 Aims

An observational assessment of quantitative data from three data sources related to the subjects recruited to the study:

1. Primary data collection
2. Task data from the DCH NEWS monitoring system (routinely collected for the study)
3. Accident and Emergency (A&E) data (routinely collected)

The key data for this analysis consist of the following items:

- A&E **events**: These are hospital records of a resident attending the A&E department
- NEW **scores**: These are the aggregated scores that are produced as a result of the vital sign monitoring: very low risk (NEWS = 0), low risk (NEWS = 1 to 4) or high risk of deteriorating (NEWS= 7 to 10)
- **Tasks:** These are any task recorded within the DCH Monitoring system, which could include NEWS-related ***alerts*** (see below).

- **Unique tasks**: unique in this context refers to a single task or multiple tasks occurring on the same day which are assumed to be linked (whereby date of task is used as a proxy for an association as no unique identifier linking related tasks exists within the current monitoring system).
- **Alerts**: These are records on the monitoring system of the care home being alerted, regarding a NEW score

The purpose of this assessment is to:

- describe the tasks data and associated notes and their use within the recruited care homes related to consenting participants
- cross-reference the tasks data with A&E data to understand the circumstances around the A&E event
- apply unit costs to the A&E data to estimate downstream cost implications
- discuss the observations between tasks (with a particular focus on alerts) and A&E data, how this data can be interpreted, and compare the results to a developed logic model informed by expert clinical opinion
- the observational results are also compared to evidence of efficacy related to the predictive ability and use of EWS in pre-hospital settings (of which care homes can be classified) to assess if there is generalizable evidence from the empirical literature to support the use of the Digital Care Home NEWS monitoring system within a care home setting.
- recommendations are made for future studies wanting to assess the effect and cost-effectiveness of the Digital Care Home monitoring system.

5.2 Findings: Description of alerts

5.2.1 Subjects

The dataset listed 133 participants as being recruited to the intervention across 11 care homes. No task data was obtained for one care home (10 participants). For five care home participants (across two care homes) the DCH monitoring system was deactivated and reactivated again over a period of 13 days up to 3 months which may have an effect on how the monitoring system could avoid adverse outcomes during the deactivated and reactivated period, and therefore represents a subgroup who were omitted from analysis.

Overall, the subsequent observational assessment was conducted using data for 118 participants recruited to 10 care homes.

5.2.2 Tasks and alerts

Residents were recruited to the intervention between 25th May 2017 and 25th September 2018 dependent on individual and care home recruitment date, and alert data was analysed up until 26th October 2018 (noting that for some participants, the system was deactivated before this date); therefore, depending on when the person was recruited and the system was subsequently activated, alert-based data is available for from 1 month up to 17 months.

Overall, there were 5331 recorded tasks associated with the monitoring system; this equated to a median of 67 tasks per person, with a minimum of 9 tasks associated with one person for whom the system was active for 11 months and a maximum of 150 tasks associated with another person for whom the system was also active for 11 months but in a different care home.

Overall the types of tasks and frequency across all care homes in descending order of frequency are presented in Table 7; the majority were associated with a 'NEWS task' (n = 3,594; 67.4% of overall number of tasks) with the second highest number of tasks associated with 'NEWS alert' (n = 347; 6.5% of overall number of tasks).

It should be noted that in some cases, tasks appear to be connected (e.g. a NEWS task associated with a NEWS alert) which could be based on a single specific event with multiple associated tasks (e.g. a fall in blood pressure triggers an alert, which triggers a task, which results in a referral). If it is assumed tasks linked to the same event occur on the same date (as a proxy given no unique identifier is provided suggesting which tasks are actually linked), then there are 3,679 (of 5331 tasks recorded; 69%) unique tasks recorded; this equated to a median of 48 unique tasks per person, with a minimum of 4 unique tasks associated with two people from different care homes for whom the system was active for 4 months, and a maximum of 104 unique tasks associated with another person for whom the system was active for 11 months. It should also be noted, as there is no 'unique task/alert identifier' which naturally links connected alerts and tasks together, it is difficult to assess exactly what events are linked and which are new/unique; therefore, date of task is used as a proxy for the purpose of discussion.

NEW scores were generally associated with eight types of tasks: NEWS task, NEWS alert, NEWS non-responder alert, Modify referral, Start increased observation period, Suspend service, Referral and End increased observation period.

Focussing on what are perceived to be unique tasks, NEW scores were associated with 1585 (of 3,594 assumed unique tasks; 44%) unique tasks. In the vast majority of cases, NEWS determined the care home residents as being at very low risk of deteriorating (NEW score of 0: 597 occurrences, 37.7%) or low risk of deteriorating (NEW score between 1 and 4: 919 occurrences, 58.0%), compared to medium (NEW score of 5 or 6: 63 occurrences, 4.0%) or high risk (NEW score of 7 to 10: 6 occurrences, 0.4%). NEW scores by score and score category for these 1585 tasks are presented in Table 8.

Table 7: Description and frequency of all DCH monitoring system tasks and alerts

Task name	Frequency (N)	Percentage (%)
NEWS task	3,594	67.42
NEWS alert	347	6.51
NEWS non-responder alert	329	6.17
Modify referral	291	5.46
Start increased observation period	257	4.82

Suspend service	211	3.96
Referral	204	3.83
End increased observation period	91	1.71
Modify suspension	7	0.13
Total	5984	100.0

Table 8: NEW Scores

NEWS category	NEW score	Frequency (N)	Percentage (%)
Very low risk	0	597	37.67
Low risk	1	426	26.88
	2	266	16.78
	3	172	10.85
	4	55	3.47
	Sub Total (1-4)	*919*	*57.98*
Medium risk	5	45	2.84
	6	18	1.14
	Sub Total (5-6)	*63*	*3.98*
High risk	7	3	0.19
	8	2	0.13
	9	0	0.00
	10	1	0.06
	Sub Total (7-10)	*6*	*0.38*
Total		**1585**	**100%**

5.2.3 A&E events cross-referenced with tasks and alerts data

Hospital records were matched for participants to understand use of Accident and Emergency (A&E) services for those who were being monitored by the DCH monitoring system. These A&E data included recorded times, dates and reasons for emergency attendances, as well as means of transport.

- The A&E data was extracted from the hospital system as of 26th October 2018; therefore, the care homes will have had the DCH monitoring system active for between 1 to 17 months at the point the A&E data was extracted. It should be noted, as there is no comparison group, it is not possible to suggest how many A&E events were avoided by the monitoring system; therefore, the focus here is on those A&E events which did occur and could they have been avoided by the monitoring system based on those tasks recorded within the monitoring system (e.g. a NEWS alert).
- During the observed period between the DCH monitoring system being implemented and the extraction date of the A&E data or deactivation of the alert system, 24 (of 118;

20.3%) participants across 6 (of 10; 60%) care homes had between one and five recorded A&E events (mean, 1.6 events; median, 1 event).

- In total, 37 A&E events occurred, 25 (68%) of which resulted in an inpatient admission.
- Of these 37 A&E events, in 35 (95%) cases an ambulance was used as the mode of admission; in two cases (5%), public transport was used.
- The Health Resource Grouper version 4 (HRG-4) codes associated with these 37 events, which can be directly linked to the National Reference costs (2017/18), are presented in Table 9 alongside the frequency of these events and associated reference cost.
- It is assumed that only tasks which occur before an A&E event can possibly avoid an A&E events; of 37 A&E events, 26 events (70%) occurred after a recorded task in the system. The mean (median; min to max) time difference between the A&E attendance and closest task on the DCH system for those 26 A&E events (17 people) when the closest task occurred *before* the A&E event was 39 days (6.5 days; 0 to 225 days). If we dismiss those tasks which occurred more than 7 days *before* the A&E event as being too far in the future to avoid an A&E event, 13 (of 26; 50%) events were within this time period.
- In the case of those 13 A&E events occurring within 7 days of a recorded task, the associated NEWS, HRG-4 code, unit cost, and total associated cost for these events are presented in Table 10. To summarise, no NEW score was associated with the task in five instances (38%), in seven (54%) instances a NEW score indicating very low or low risk of deteriorating (i.e. NEW score of 0 to 4) was recorded with the task, and in one (8%) case a medium risk of deteriorating was recorded with the task (a score of 5 in this instance); no NEW score suggesting high risk of deteriorating (i.e. a score between 7 and 10) was recorded alongside a task within 7 days of an A&E event.
- To summarise: tasks were not necessarily linked to a NEW score, but seemed to be triggered by other factors (e.g. text notes); only A&E events occurring up to 7-days after a task were deemed to potentially be associated (total 13); for these 13 (A&E events with associated alerts), 5 did not have a related NEW score and of the remaining 8, none indicated high risk.

Table 9: Description and frequency of A&E events based on HRG-4 codes

HRG-4 code	HRG-4 description	Unit cost*	Frequency (admitted)	Total cost
VB02Z	Emergency Medicine, Category 3 Investigation with Category 4 Treatment	£406	2 (2)	£812
VB03Z	Emergency Medicine, Category 3 Investigation with Category 1-3 Treatment	£266	6 (4)	£1,506
VB04Z	Emergency Medicine, Category 2 Investigation with Category 4 Treatment	£281	13 (13)	£3,653
VB05Z	Emergency Medicine, Category 2	£234	3 (1)	£702

	Investigation with Category 3 Treatment			
VB07Z	Emergency Medicine, Category 2 Investigation with Category 2 Treatment	£184	4 (3)	£736
VB08Z	Emergency Medicine, Category 2 Investigation with Category 1 Treatment	£183	7 (2)	£1,281
VB09Z	Emergency Medicine, Category 1 Investigation with Category 1-2 Treatment	£113	2 (0)	£226
Total		N/A	37 (25)	£9,006

Footnote. The above costs are for the A&E event only and do not account for the cost of the inpatient admission.
* Source: NHS Reference cost 2017/18, available at: https://improvement.nhs.uk/resources/reference-costs/

Table 10: Summary of presenting complaints, NEWS, HRG-4 codes and associated costs, and if admitted for A & E attendances which occurred within 7 days of an alert

Presenting complaint	Frequency, N (%)	NEW score	HRG-4 code	Unit cost (£)	Admitted (Y/N)
Blood in urine	1 (7.7)	None	VB04Z	£281	Yes
Difficulty breathing	2 (15.4)	3 None	VB04Z VB08Z	£281 £183	Yes No
Headache	1 (7.7)	1	VB08Z	£183	No
Joint swelling	1 (7.7)	0	VB08Z	£183	No
Seizure (fit)	1 (7.7)	None	VB03Z	£266	Yes
Short of breath	3 (23.1)	3 5 None	VB05Z VB04Z VB07Z	£234 £281 £184	No Yes Yes
Sore throat symptom	1 (7.7)	2	VB03Z	£266	No
Swollen leg (single)	1 (7.7)	1	VB03Z	£266	No
Vomiting + / - nausea	1 (7.7)	1	VB04Z	£281	Yes
Fall-pain in left hip	1 (7.7)	None	VB04Z	£281	Yes
Total	**13 (100)**	N/A	N/A	**£3,170**	Yes = 7

Footnote. The above costs are for the A&E event only and do not account for the cost of the inpatient admission.
* Source: NHS Reference cost 2017/18, available at: https://improvement.nhs.uk/resources/reference-costs/

5.3 Findings: Description of notes associated with alerts

From a total of 5985 records, 82.4% (4932) of notes were recorded as '\N' (no notes). There were a few common notes and some common themes embedded within the text. For instance the next largest category can be summarised as a simple acknowledgement (Comment acknowledged/noted, acknowledged, alert acknowledged etc) which account for 369 (17.6%) notes. The resident being away for social reasons accounted for 44 cases (0.7%), and attending a hospital or other health appointment accounted for 46 cases (0.8%). No Concerns were reported 23 times (0.4%). Smoker or ex-smoker was used to explain the alert for 15 cases.

There were 14 instances of readings being declined. It is not clear why in most cases, however agitation was mentioned in 1 case and being unwell in 2 cases. Also the emotional state of

residents was cited for inaccurate readings (e.g. 'very restless and not getting the right reading' & very 'agitated hence the reading is showing error tried numerous time'). Nine residents had died and 9 were asleep. Seven residents were reported to be on end of life pathway or receiving palliative care, and 6 cases were reported as being within normal limits (i.e. expected for that resident). Quite a large number of longer text notes can be assumed to indicate that alerts can be expected or normal for certain residents:

> 'Telephone contact with RGN this lady has several long-term chest problems and is on LTOT 0.5L overnight, SP02 reading this morning taken on air, staff have been encouraging breathing and coughing exercises and have no concerns she is as normal'
>
> 'Target for oxygen is 88-92. This lady has recently been discharged from hospital on pallative care'
>
> 'Not required to contact care home. Patient has a UTI and on antibiotics.' (X5)

There are some instances of longer text notes where further action is required. However, it is not clear to what extent further actions is initiated by the SPA team, or whether it has been initiated by the care home staff:

> 'Spoken to Nurse X. The patient is a palliative care patient approaching end of life. The staff have called GP today who has just examined her and written up pre emptive medications. Respirations are now 28.'
>
> 'Patient alerted on SAT levels of 93%. Spoke with Staff X at the Home who said that Resident X had been a little chesty. After discussion she is monitoring the patient today and will refer on if any GP intervention needed today. No further input at this time.'

Some alerts were attributed to environmental or contextual reasons:

> 'gardening outside whilst checking his observation'
>
> 'Spoke with Manager X. Resident X\'s room was very hot this morning. Problem resolved when normal temperature restored.'
>
> 'Resident X was wearing nail varnish when oxygen and pulse was checked'

There were several occasions where a re-test of measures revealed that there was no cause for concern. On some occasions it was clear that there had been an erroring measuring or recording the readings. On one occasion, a series of low readings prompted the SPA team to report a possible equipment malfunction.

> 'Spoke with X. Low BP caused alert. BP has now increased to 103/70 and pulse has reduced to 76. No further concerns or action at this time.'
>
> 'Spoke with senior carer and wrong information put in for Patients respiratory rate, and patient was fine'

> ‘Spoke with care staff on unit and he confirmed heart rate was in fact 67 and not 6 as entered on system.’
>
> ‘Discussed with RGN who says he is fine no concerns, I\'m wondering if the temperature probe is working accurately as all patients on this floor have very low temperatures, we will email project manager’

Some of the more lengthy notes contain a lot of information and can therefore be difficult to categorise, without in-depth qualitative analysis and coding:

> ‘Contacted via phone and discussed low saturation with nurse X. She has no concerns about the patient. Not unwell, no cough, fever and not known to have breathing problems only swallowing difficulties. No signs of infection. Saturation rechecked and patient still at 91%. Advised to keep an eye on him for any signs of being unwell and if so contact GP to review. No further support needed today.’
>
> ‘Contacted and discussed patient with registered nurse on duty today looking after Resident X. She has had a recent hospital admission on Monday with a seizure and was reviewed by GP following hospital visit. Patient is currently taking prednisolone and had nebulizers in hospital. Registered nurse stated patient is improving. I have asked Registered nurse to repeat patient\'s observations which have now improved as HR is 102, sats 90-92% and systolic BP is 117 which is an improved score of 3 now. No further action to be taken today.’

5.4 Discussion: Description of alerts

It is important to note that there is no control group for the purpose of this analysis, and therefore it is difficult to assess what would have occurred without the DCH intervention. It is also important to note that the aforementioned results are purely descriptive and do not present a causal relationship between the DCH intervention being in place, the system being utilised, and A&E events occurring; rather, these events have all happened at the same time and there is no assessment of causality or even association. The following discussion is purely an *observation* of the data (compared to a statistical analysis accounting for confounding factors, for example).

What is observed is that the vast majority of participants in this study were deemed at very low risk (NEWS = 0) or low risk (NEWS = 1 to 4) of deterioration. For those at low risk, there is a suggestion that the score “should prompt assessment by a competent clinical professional (e.g. registered nurse in acute care) who should decide if a change to frequency of clinical monitoring or an escalation of clinical care is required”; however, the DCH monitoring system doesn’t record the response to the alert (e.g. if the person was referred to a GP or otherwise) other than in some cases using free-text and so this aspect is difficult to assess based on the quantitative data alone.

For those 13 tasks which occurred 7 days before an A&E event, the NEW score in most cases suggested the person was at low risk of deteriorating or there was no NEW score associated with the task. It is therefore unclear if the interventioncould have avoided these A&E events. It is also worth noting that no information is provided as to the actions taken in these cases.

To summarize: for all of the alerts on the system that happened within a week of an A&E attendance there were no NEW scores that indicated a high risk of deterioration and only one score that indicated a medium risk of deteriorating. Therefore, the system did not predict that the resident would decline to the extent that they would require an emergency attendance.

As there is no comparison group, it is difficult to suggest if A&E events have changed either due to the DCH project or even over the time horizon the system has been used; therefore, any suggestion of change in A&E events over the time horizon of monitoring would be speculative. It should be noted that the statistical analysis of A&E data before and after implementation was carried out in Wave 1 of the Perfect Patient Pathway Test Bed, and no firm conclusions were drawn from this analysis.

5.4.1 Descriptions of alert types in relation to potential outcomes and downstream activities

- A logic model was developed through initial theories from the literature and interim analysis of early interviews, which were tested and refined through an expert panel workshop and user-centred design groups. The logic model explores the potential mechanisms for preventing emergency admission in residential or nursing care homes, such as A&E events, dependent on conditions which often results in emergency events such as: falls/observed gradual decline, those requiring end of life care, multiple physical long-term comorbidities, and co-morbid mental health and life-threatening long-term physical health problem (e.g. dementia and diabetes). This logic model is presented in supplementary appendix S3.
- To summarise, the Digital Care Home service could aid with avoiding some, but certainly not all, emergency events (and subsequent transportation to acute hospital services) dependent on the condition and/or events.
- As an example of where the Digital Care Home service could avoid an emergency admission, it could be possible to prevent falls by monitoring vital signs for indicators of increased falls risk (e.g. high temperature, low resting BP) which are already monitored within the Digital Care Home system. However, increased risk is unlikely to be particularly sudden and other indicators that could be monitored might aid with detecting falls risk; for example, orthostatic hypotension (difference between resting and standing blood pressure).
- As an example of where the Digital Care Home service might not avoid an emergency admission, it is unclear how monitoring might operate to prevent admissions owing to rapid unexpected health decline. Even if the person was being monitored daily, which could be too much burden on staff and residents (N.B. this is evidenced by the number of missed readings (9.25%) from the generally infrequent schedule for most residents on the project).
- No clear suggestion can be made to what extent the Digital Care Home service can or could avoid emergency admissions based on current quantitative data and observational assessment; the logic model suggests the Digital Care Home service could in theory avoid some, but certainly not all, A&E events resulting from care home based events or related condition of the residents.

5.5 Summary of evidence from the Literature: use of early warning scores

The Rationale for the use of Early Warning systems (EWSs) is that early detection of physiological measures can help prevent or lead to better management of serious health problems (Hogan et al, 2012; Hillman et al, 2001; RCP, 2012). In recent years there have been calls to enhance pre-hospital care by using EWSs (RCP, 2012; NCEPOD, 2017). However, there is currently a lack of evidence of effectiveness in these settings (Fullerton et al, 2012; Gray et al, 2010; Roland & Jahn, 2012).

A systematic review of the literature investigated the effectiveness of identifying health deterioration in pre-hospital settings (Patel et al, 2018). However, only one of the identified studies was conducted within a community nursing home and this was focussed on the use of the Modified Early Warning Score (MEWS) rather than NEWS (Pattison & Vernon, 2011). The majority of the literature is focused on ambulance services, which therefore have limited relevance. No studies compared pre-hospital settings that used EWS with settings that did not, and so comparative analysis to determine the relative effectiveness of EWS to current care was not conducted (which is similar to our study design) and remains missing from the empirical literature. A retrospective review concluded that MEWS does not predict mortality in community dwelling nursing home residents and thus had limited ability for avoiding this outcome through early prevention alerted by the use of MEWS (Pattison et al, 2011).

Evidence from ambulance-based studies suggests that a very low EWS score (0) means patients are unlikely to deteriorate, which adds confidence to clinical judgement that such a patient can be safely managed outside hospital. Patients with very high scores (>=7) are more likely to deteriorate and should receive appropriate intervention. However, little is understood about patients with intermediate scores (1–6). In summary, evidence in this area should be considered lacking, rather than supportive or not of the Digital Care Home NEWS monitoring system in a care home setting.

We concur with current conclusions about evidence required in this field that a cluster RCT focussed specifically in a care home setting would be required to determine effectiveness and cost-effectiveness of the Digital Care Home NEWS monitoring system to usual care. The following outcomes should be considered as the potential focus of such a study (noting that the optimum outcome to measure benefit relative to NEWS is unclear): short-term mortality, incidence of sepsis, admission to hospital and/or escalation of care. An extended summary of current literature is available in the appendices (S4).

5.6 Conclusions: Description of alerts and notes

Based on the current observational study of A&E events and DCH monitoring system 'tasks and alerts' associated with care home residents, when A&E events did occur they exhibited one of the following four features; either:

- The time between alerts and A&E events on the DCH monitoring system were so far apart that it is uncertain if such an alert could have avoided the A&E event
- No alert occurred before the A&E event

- An A&E event occurred within 7 days after an alert but the NEW score generally suggested the person was at low risk of deteriorating
- No NEW score was recorded

Also, the A&E events which did occur were due to a variety of medical reasons from a headache to a seizure; it is unclear if and how the monitoring system could avoid all of these types of reasons for A&E events. Therefore, in relation to those A&E events which did occur, it is unclear if the intervention could have avoided them. As there is no comparison group against which the 'effectiveness' of the DCH intervention can be judged to suggest potential avoided A&E events and there are no previous published studies of a similar intervention in a similar setting to make useful comparisons, this aspect requires further research to determine any conclusions useful to decision makers. Our logic model based on expert opinion suggests that use of the DCH monitoring system could help to avoid some adverse events which could lead to the requirement of further medical intervention if such adverse events are related to vital sign monitoring associated with NEWS (e.g. falls can be associated with high temperature and low blood pressure); therefore, the DCH monitoring system has potential benefits which should be examined as part of future research.

The exploration of the textual content of the notes associated with alerts demonstrated that notes were mostly not entered (82.4%). The next most common category was a simple acknowledgement (17.6%). The next most common categories described the resident being away for a health appointment or hospitalisation (0.8%), or a social event (0.7%). The longer textual notes contained a lot of information and were difficult to categorise.

The notes section seemed to be being used for 4 quite different functions:

1) Simply acknowledge the alert, describe that there is no concern or provide a brief description (such as in hospital, away with family, asleep etc.)
2) Record actions to be taken or concerns
3) Provide detailed information about the resident's situation
4) Record the interaction surrounding the alert including advice given

For future evaluations it would be useful if these functions could be given separate data fields and pre-coded where possible; particularly regarding point 1 (and possibly point 2) above.

6. WP3: Qualitative investigation, Process evaluation, and Theory development

6.1 Methods: Qualitative investigation

6.1.1 Aims and approach

This work-package consisted of qualitative interviews. Preliminary interview findings were combined with available literature and early findings from the other work-packages to inform an expert panel consultation in which the events recorded in the system were explored to investigate potential benefits of the intervention. Findings were then drawn together to provide the seven key themes used in work-package 5 for the user-centred design workshops and the logic models for care and nursing homes (appendix S3). The logic models were shared with members of the panel and the Test Bed Advisory Group as a final validity check.

Interviews were conducted over two phases. Analysis of the interview data identified contexts, mechanisms and outcomes associated with the digital monitoring service. These were then used to:

- Understand the culture and reception of the service 1-year after original implementation
- Contribute to developing hypotheses for the project
- Contribute to process evaluation

6.1.2 Interviews

Staff interviews were conducted face to face or over the telephone.. Resident and family/friends interviews were conducted face to face. Interviewer notes were taken for all interviews using experience maps. In addition, staff interviews were audio recorded and transcribed verbatim

The interviews were semi-structured and were carried out in two phases, to identify early themes and to follow these up following further experience of the intervention. Interviewers used a topic guide to ensure that the same topics were covered. However, respondents were free to respond to these topics as they wished. The topic guide was iteratively developed over time, as emerging themes were sense checked with participants during the interviews.

During recruitment of participants, care home managers acted as gate keepers to staff and residents. In face to face meetings with home managers the evaluation was explained and participant information sheets provided. Where face to face meetings were not possible, they were emailed and telephoned to identify potential staff participants. These staff members were then sent participant information sheets by email. Where original requests were not successful, emails were sent and phone calls made. If no response was forthcoming after three additional attempted contacts, no further attempts were made.

Thematic analysis (Braun and Clarke, 2006) of transcriptions and evaluator notes was undertaken using NVivo software for qualitative data analysis. This identified codes, key themes regarding the context, mechanisms and outcomes of the Digital Care Home project in addition to implementation barriers and facilitators.

6.1.3 Expert panel consultation

Anonymised summaries of events recorded on the Digital Care Home system were combined with summaries of hospital attendances, to form six case studies. These were displayed on a large screen and explored in chronological order. Participants were encouraged to develop hypotheses about how, in each case, the Digital Care Home system might work to prevent or reduce use of hospital services.

Other relevant issues were explored as they arose, and theories regarding key themes were tested for validity or need of refining. Contemporaneous notes were made and the interaction was audio recorded to check for accuracy and to create a transcript of relevant sections. A total of 82 themes were identified, which were then used to develop the matrix of seven key themes with associated contextual variations and the 2 logic models for both nursing and residential care homes.

6.1.4 Participation

Twenty-four interviews were conducted in total. These comprised:

- 4 GPs
- 4 SPA staff
- 3 clinical RGN leads
- 3 nursing assistants
- 1 care home manager
- DCH project lead
- 5 residents over four care homes
- 3 family/friends over 2 care homes.

Two care homes did not participate. However, the perspective of GPs covering these homes was obtained. An additional two homes felt that none of their residents were able to participate in interviews.

Expert panel:

The expert panel consisted of managers, a nurse and a carer from nursing homes, a member of SPA, and a nurse from acute hospital liaison services. Qualitative evaluators were also present to provide perspectives gleaned from other stakeholders. Outputs from the session were distributed for feedback to the wider group (including a GP specialising in care homes and a geriatrician) and were also considered by the service-users advisory group (TAG).

6.2 Findings: Qualitative investigation

The following table lists the key questions that arose over the course of the evaluation, with associated findings, derived from the qualitative investigation.

Table 11: Detailed evaluation questions and findings

	Evaluation Questions	Findings
Conclusions and implications	Are NEWS scores appropriate for those with long term conditions or at end of life?	Overall, NEWS was felt to be appropriate. However, the ability to vary frequency of measurements according to clinical needs and judgement was deemed essential. NEWS baseline and routine monitoring was felt useful for those with long-term conditions.
	Would tailoring of alert parameters or recording additional information be useful?	SPA and care home staff recognised that the ability to tailor thresholds for alerts (based on the 'normal' readings for that specific individual) might be useful, but not essential. In particular, some residents were recognised as routinely triggering alerts despite not being of any immediate concern. The ability to be flexible was preferred by care home staff to allow for practical difficulties of taking measurements and inputting to the system in the allocated time-slot (i.e. before noon), although the routine and 'obligatory' nature of the project were also noted as key mechanisms. It was useful to have the opportunity for notes that created variation in processes, for instance delaying the input of readings due to residents not being available etc. Some respondents felt that additional important measures such as weight or blood sugars would be useful to monitor (depending on the health condition of the resident). But routinely, the basic NEWS was felt by residents and staff (overall) to be enough.
	What is the optimum frequency of monitoring?	More frequent observations were felt useful for picking up declining health. However, the key mechanisms was reported that this additional formal contact time facilitated residents having more physical contact with staff which promoted the assessment of 'soft signs', for instance reduced mobility, drowsiness, change of mood or loss of appetite. More regular observations are useful to pick

		up. In addition to more frequent monitoring, continuity of staff is useful to pick up signs that the resident's health might be declining.
	How useful is the advice from SPA?	SPA advice was seen as supportive and reassuring, although it was reported to rarely change clinical practice. It did seem to improve knowledge of care staff. Context was an important factor in determining the usefulness of advice from SPA: for staff with difficulty accessing GP care at times, advice was reported as helpful.
	Is the intervention considered acceptable and feasible for all residents (e.g. for residents with moderate/severe dementia)?	The intervention felt acceptable and feasible on the current scale of delivery. However, there were some concerns regarding difficulties being foreseen if more residents were to be monitored, owing to capacity issues. Interviewees had a mixed opinion about the appropriateness of the project for those who had palliative or end of life care needs. The monitoring could be viewed as overly intrusive and lacking in value for these residents. It was deemed a useful project for people with dementia diagnoses, as long as monitoring was done flexibly and according to the resident's needs and emotional abilities.
	How could the intervention support Multidisciplinary Team (MDT) advance care planning (including 'ceilings of treatment')?	Care planning (and their regular review and accessibility) appear key in the prevention of hospital admissions. As does the provision of pre-emptive medication. Outcomes could vary according to access to or quality of relationship with GPs, advanced care planning process, resident mix, staff skills mix Information available via a portal/online for the NHS, care homes, and GPs to be all able to access would be

		useful. Residents that were consulted were unanimous in not wanting to go to hospital unless very poorly. Staff felt early and ongoing conversations about 'end of life'/hospital avoidance were needed with residents and family and were very helpful in preventing admissions. These conversations would then form part of a detailed care plan.
	Is the response to deteriorating health of residents rapid enough to prevent admissions?	Submitting readings before noon meant that there was ample time for SPA to respond to alerts and make arrangements with the care home, during normal working hours. However, issues about timely 'out of hours' responses appear crucial to admission prevention, particularly regarding access to medication/prescriptions and joint management of risk with medical staff (e.g. GPs).
	Is it important to communicate with staff and other stakeholders about impact of project?	Feedback about the impact of the project seems to be essential for 'buy in'. Project participants identified that knowing this was making a difference to residents, and motivated them to carry on with the project. Some residents want to know and liked to know their observations. Feedback indicated that it would be useful for sustainability to consider how to share data with residents (even if no problems were identified) for example in the form of a print-out of their readings. This could also be a useful aid to self-management and possibly have beneficial reassurance effects.
	Are alerts dealt with effectively?	When an alert is triggered SPA call the care home to speak to care home staff. However, it can be difficult to get hold of key members of staff if they are busy. Often the resulting discussions were reported as identifying action that had already been taken – i.e. contact GP, do observations again. The discussion reinforced clinical judgement (which is predominantly contact GP for advice) and made

		suggestions as to why reading may be low and reasons to check again. (e.g. cold extremities (effecting measurement of blood oxygen saturation), resident not sat up or not had breakfast or drink yet)
	Are data being used effectively?	The general feeling was that there were significant limitations experienced in sharing data across services. However, this was mostly not due to technical limitations but to lack of awareness or lack of integration of data into routine working practices. The system successfully shared data from the care homes to the Teaching Hospitals NHS Trust, the hospital frailty unit, the community nursing support and GP practices. Some GPs claimed that they could not access the observational data (as they did not use SystmOne). However, they seemed unaware that they could access the data through the online portal. Most GPs who could access SystmOne, were also unaware the data were there. This was attributed to lack of engagement of GPs in the project. Emergency care practitioners (and some acute care staff) could not see the observations. This is a clear area of possible development of the system. Some care home staff were unaware of the ability to see residents' trends over time. One care home did print off trends over time and used these in discussions with the GP, another used written records (not the digital record) of the observations taken for the project to discuss with GPs.

	How does the role of community nurse work within the intervention? [Note: It was considered that the project should provide additional clinical support, especially to help manage concerns out of normal operating hours for SPA and GPs. A community nurse from a local hospice was made available to participating homes.]	There were no incidents of the project-specific community nurses being called upon. This was reportedly due to the type of homes that engaged in the project (none of the homes within current project were purely residential care homes with no nursing staff on site). Homes with nursing staff on-site could not anticipate any benefit in calling on the services of another nurse (particularly when they would be unlikely to have any knowledge of the resident). It was felt that although the project appeared to have had benefits in the participating homes, it would be more helpful for ' residential-only care home' staff. For the residential care homes, the ability to call on nursing expertise (particularly out-of-hours) could be a welcome service.

6.2.1 Contexts

In line with findings from the user-centred design work-package 5, the interview findings recognised that the context in which the digital monitoring service was implemented had important implications for how the intervention operated and potentially for related outcomes.

6.2.1.1 Individual staff member's clinical knowledge and experience

When some care home staff members began recording measurements there were mistakes, which highlighted a lack of knowledge about the observations; indicating that some fairly junior staff members had been delegated to enter the readings. However, when these mistakes were recognised, they were quickly resolved; indicating that the project had suitable mechanisms to train and educate staff. The level of seniority was reported to be important in the interaction with SPA

Another important area of knowledge is support links, referral routes and pathways available for the residents, which is an important area of support that can be offered to care homes by SPA.

6.2.1.2 Attitudes and beliefs of care home staff

There were a range of themes where attitudes of care home staff (often informed by prior experiences) had an influence on how the project was received. For instance views of: technology, staff development and innovation, clinical risks/health risks influenced the nature of engagement with the intervention. Other influencing factors were attitude and expectations towards hospital admissions, and attitudes and expectations of end of life care

For some care home staff the project was viewed as too focused on clinical readings and numbers, which was somewhat at odds with their attitudes towards individualised care and client centredness.

6.2.1.3 The care home's context

There were various aspects of the care home, which influenced the way that the intervention was received and delivered. Larger homes were reported to encounter greater difficulties owing to the additional complexity of the organisation. The type of residents in the home, for instance whether they were mostly well and medically stable, whether there were a large number of residents with dementia or nearing end of life or requiring palliative care had an effect on the care required and therefore on the importance of the monitoring and possible difficulties with maintaining a monitoring routine.

There were a number of factors that broadly were dependent on management of the home. For instance the support of managers for the project (particularly noticeable when management personnel changed) was important for effective implementation and sustainability. Staffing levels and turnover had an influence on continuity of care and ability to sustain the intervention.

Communication issues within the home were also a factor, such as the ability to easily access information about residents, the presence and availability of up to date care plans, and the use of handovers

The ability and motivations to engage with innovations, including a concern with the CQC rating, the organisational focus of the care home, opportunities for reflection and development were important factors. The success of the intervention with individual residents also required good relationships and conversations with residents' families.

6.2.1.4 The relationship between the care home and GP(s)

The main service-provider that is turned to by care homes for additional health care is the resident's GP. Indeed, much of the information recorded on the system regarding further actions taken, indicated that the GP was contacted in the first instance. Therefore, the nature of the relationship between the care home and GPs is a critical element in providing good quality care and avoiding inappropriate hospital admissions. The nature of this relationship was highly variable between the homes involved in the project.

6.2.2 Mechanisms

The following appear to be key mechanisms (or processes by which outcomes can be expected to occur) that describe how the project as a whole operated:

6.2.2.1 Facilitates discussions

The observations provide objective information to base a clinical discussion on and to support decisions. SPA contacting the care homes when alerts are triggered helps to develop relationships and create better communication between care homes, SPA and the Teaching Hospitals Trust. The activity of taking the observations helps to develop relationships between Care home staff and residents. A routine and system that ensures observations are taken and rapidly checked to instigate a clinical discussion if problems become apparent.

When alerts are triggered, this facilitates a proactive contact from an external experienced clinician at SPA who is aware of need for admission avoidance where possible and experienced in making clinical judgements over the phone. They act as an additional checkpoint and support prior to making decisions about what actions to take.

6.2.2.2 Provides regular observation readings and records

The record of readings can provide baselines of what is expected to be normal readings and information regarding trends over time and for each individual resident. Abnormal readings (particularly when alerts are triggered) can therefore be used to instigate action (usually instigated by home and reinforced by SPA)

The activity of taking and inputting readings sets up a routine and system (which feels obligatory) and which prioritises attention on those in need. This contact also provides opportunities to get to know residents and their care plans better. These extra checks provide information on 'soft' and 'hard' signs of health status.

6.2.2.3 Provides support and reassurance (via discussions)

Care home staff can feel supported and gain advice and feel more confident, which can provide a 'block' or 'buffer' to prevent avoidable calls to emergency services. This can help to upskill care home staff knowledge, clinical reasoning and clinical practice.

Some residents reported feeling reassured that their health signs were being regularly monitored.

6.2.2.4 Neutral and negative views of the intervention

Some of the participants reported little or no impact as a result of the project. Some residents and family members did not feel the project had impacted on them at all, and whilst there were some exceptions, generally many care home staff did not feel the project had impacted on emergency admissions.

Whilst most care home staff (managers, nursing assistants, nurses) suggested they had benefitted in some way from the project, many felt the project would be most helpful in purely residential homes where there are no nurses (all participating homes had nursing staff within them in some capacity). It was also felt the project would be most helpful to staff who lacked clinical confidence and experience. Many staff did not feel the SPA conversation had changed the clinical response, as they had usually taken action regarding abnormal readings before they were contacted by SPA.

SPA staff felt overall that the project had some benefit to residents and care home staff, but no direct benefit for themselves.

Interviewed GPs did not feel regular monitoring of observations would impact on resident care or clinical decisions, or that the project had impacted on them at all: they could not identify any specific benefit from the project. This is in contrast to GPs and other medical staff that provided expert opinion for the evaluation, and identified situations in which the access to longitudinal, systematically collected health data could be beneficial. It is useful to note that, whilst GPs did engage with the evaluation, they were not particularly active regarding the intervention and reported not accessing the data; their responses therefore seem to be based on opinion rather than experience of the intervention and this remains an area that would warrant further investigation.

Two care home staff members felt that the concentration of the NEW score on biometrics could have the effect of reducing patient centred care and some staff felt it increased their work load.

It was also reported that one resident did not like their observations being taken.

6.3 Summary of recommendations: Qualitative investigation

A systematic approach to choosing which residents and care homes would potentially benefit most from the intervention is an area that requires further investigation. Some respondents thought that a larger number of residents in each home should take part. However, the resource implications for this could be a barrier. There was generally support for inclusion of people with dementia, providing a flexible approach could be taken.

The intervention was anticipated to be more effective in improving care in residential care homes, rather than nursing homes. The use in the community with people in their own home was also suggested as a potential area of investigation.

Information sharing was an area that had large potential for development for instance: care homes being able to see NHS/GP notes and advanced care plans (and DNACPR) being available for NHS services (particularly emergency services). In terms of project delivery, primary care engagement can be problematic and is required in the early stages.

Overall the frequency of observations (weekly or twice weekly, with the option to increase frequency when required) was considered to be adequate. Additional measures for some residents (e.g. blood sugar levels for people with diabetes) may be helpful, and routine measurement of weight was also considered beneficial by some respondents. The need to personalise alert thresholds based on a resident's normal baseline readings was considered. However, this was largely in relation to blood oxygen levels and residents with COPD and it is worth noting that the new modified version of NEWS (NEWS2) takes account of this.

The time to input the measures was restricted to before noon, if readings were not input during this time they were recorded as missing and could not be input. Therefore care home staff thought it would be worthwhile considering extending the inputting deadline to mid-afternoon. However, this delay could lead to responses having to be made using out-of-hours services.

Care home staff were keen to incorporate monitoring of 'soft signs' and have ability to increase formal observations when someone is noticeably 'poorly'. There is a text box where staff can submit written notes as well as the readings, although this was inconsistently used and automatically triggered an alert. The option to enter text without triggering an alert would be welcome, and this should be combined with more systematic use of the 'comments' box.

In terms of changes recommended for the technology it could be made clearer and easier for staff to get trends over time, and the interface could be refined for flagging up to the inputter when there is an obvious inputting error. Currently when readings are not input in time, this triggers an alert. However, this was often for an understandable reason.

7. WP4: Care plan reviews

7.1 Aims

A review of participating residents' care plans was undertaken, with their informed consent, by making contemporaneous notes. There was a member of the care home staff available before and after to discuss details of processes and activities. The review sought to:

- describe the content of current care plans
- understand the processes and activities by which care plans are compiled, maintained and updated
- understand how (and if) the changes in monitoring related to the Digital Care Home project are recorded in the care plans
- understand what these changes might mean to the residents' care pathways and potential changes in clinical responses to illness events or deteriorations in residents' health status

7.2 Resident recruitment

All Care Home managers were contacted to arrange a mutually convenient initial visit to explain what was being requested from them, their staff and residents to inform the evaluation. These meetings were generally done jointly with the qualitative researcher so that interviews could also be arranged. Eight visits were undertaken (one of which had to be cancelled due to staff being unavailable to meet). Care home managers or senior nursing staff acted as gatekeepers, identifying residents who could give informed consent and who may be interested in participating.

Residents were met, given a Participant Information Sheet and had the chance to discuss the evaluation with the researcher. For those who were interested in participating a time was arranged to return and take informed consent prior to reviewing the care plans. Whilst attempts were made to review notes from all of the participating care homes, owing to difficulties in obtaining access and gaining informed consent, this was eventually undertaken for four residents from three Care Homes. A summary is included in Table 12.

7.3 Care plans

We requested copies of blank care plan templates from the manager/lead nurses from all the homes we visited and received these from six homes. Where it was not possible for the researcher to review care plans a short discussion was held with care home managers or nursing staff regarding whether the weekly Digital Care Home monitoring records were noted in the paper records and who created, updated and reviewed the care plans

7.4 Findings: Care plan reviews

7.4.1 Digital Care Home Monitoring

Of the four resident care plans which were reviewed none held any note of the weekly Digital Care Home monitoring. Only one of the six homes available for review/discussion stated that they noted the weekly observations within the care plan (reported by lead nurse and deputy

manager). The others do not note them. Most, but not all have said that if an alert was raised they would note this and any response in the daily notes summary. However, this was not confirmed by observation.

Table 12: Summary of Residents available at the time of the review

Care Home ID	Number of residents monitored (at time of review)	Care Plans reviewed	Care plan framework received	NEWS reported to be included in Care plan?
1	12	2	Y	N
2	12	1	Y	N
3	7	1	Y	N
4	15	0	Y	N
5	14	0	N	N
6	10	0	N	Do not know
7	5	0	Y	Y
8	13	0	Y	Do not know
9	4	0	N	Do not know

7.4.2 Care planning review

Care plans were held securely in the nursing offices. They are paper records held in ring/lever-arch binders for individual residents. Nursing or senior carers create the care plans in line with a template specific to their organisation. Plans are generally reviewed on a monthly basis (or as needed) by nursing or senior care staff and daily notes are written within the care plan.

7.5 Limitations

Only a small number of residents' care plans were available for review. Care plan templates were received for six out of the nine homes participating.

7.6 Conclusions: Care plan reviews

Digital Care Home Monitoring is generally undertaken once per week (2 homes had twice-weekly monitoring) for a sample of the residents from the care homes (the choice of residents being offered monitoring and monitoring frequency is defined by the individual care home).The monitoring of the NEWS parameters are not noted in the paper records for the residents, other than in the case of one care home (apparently longitudinal data can be downloaded from the device but there was no evidence of this being done).

The weekly monitoring of NEWS parameters was reported to not currently be included as a part of the care plan in the majority of Care Homes evaluated. Therefore it can be assumed that NEW scores have limited impact on daily care. For some (if not all) homes, the recording of NEWS observations in the care record would require a change of policy, as there is nowhere to include this in the current templates.

Some of the care plan templates that were assessed contained some elements that could be associated with the NEW score: e.g. breathing, circulation, medication side effects. However, it was reported by care staff that the NEW score was not used to populate these areas of the care plan. This could be viewed as a result of problems in linking digital and paper records, particularly when this requires additional work to duplicate entries.

Some of the care plan templates that were assessed contained places for information about falls risk, which are a key reason for A&E attendances for care home residents, and which could potentially be informed by the NEWS observations.

Only two of the templates examined included 'End of Life' provisions, and only one had a sub-category for 'Preferred priorities of care'. Rapid health decline at the end of life can be a cause of inappropriate emergency admission to hospital, particularly when preferences for conservative care are not clearly communicated or planned for. Only two of the templates examined included a section for 'Do Not Attempt Cardio-Pulmonary Resuscitation' (DNACPR).

8. WP5: User-centred design approach

8.1 Methods

This participatory approach to evaluate the intervention with stakeholders included conducting co-design workshops to discuss the Digital Care Home intervention and the changes it has made to the care of participating residents. Initially a series of scenarios were used to evaluate and discuss the development of the Digital Care Home intervention. This led to the development of a set of contextual variables, which were considered to affect the way that the intervention worked (see Table 13).

The findings of the co-design workshops were then fed back to innovators and the rest of the stakeholders to consider appropriate improvements to the design of the DCH intervention including the technology, service design and clinical pathways.

Participants were a range of stakeholders including care homes staff, clinical staff (nurses, GPs), care home representative from user groups, and the innovators (members of the company providing the technology). In total, 17 people were consented and participated in two workshops.

8.1.1 Aim

The aim of the user-centred design approach was to encourage engagement and participation of all stakeholders as partners in the process of co-design and development of the intervention and provide them with opportunities to voice their concerns, preferences, aspirations and expectations.

Table 13: Key contextual factors influencing the intervention

Home conditions	Workforce	Wider services	Other information flows	NEWS	Individual residents	Care plans
Size of home	Nursing staff ratio	SPA open hours (8.00-22.00, 7-days)	What info or communication is needed for:	Is it appropriate for all residents?	How are residents chosen for monitoring?	Are care plans well developed and up-to-date?
Turnover of staff	Bank/Casual (evenings/ weekends)	Relationship with GP (and sharing of information)	GPs	Is it appropriate for end of life care?	How should residents be chosen for monitoring?	Are care plans accessible (who needs to see them?)
Availability of staff to take readings	Level of skills/training	Availability of community nursing	Out Of Hours services	Are there other readings that should be taken? (or any that shouldn't?)	What are the numbers of residents that can be monitored at once?	Could inappropriate transfers (e.g. ambulance to A&E) be prevented with a clear care plan?
General needs of residents (e.g. whether there are large numbers with mental health problems or nearing end of life)	Knowledge of residents	Acute care liaison team (and the info they can access)	SPA	Are scores or readings recorded in resident records? Would this be useful?	Should some residents be excluded? Why?	
	Relationships with other services (e.g. GP)	Availability of out of hours services	Acute liaison	Do staff members/ residents/ family members look back at readings?		
	Knowledge about other services	Ambulance services	Care homes	What is the appropriate monitoring frequency?		
	Staff turnover		Ambulance services			

8.2 Findings: User-centred design approach

It was assumed that the Digital Care Home intervention could be most beneficial if the care home has limited access to nursing staff and does not have a positive relationship with a GP practice. The enabling influence of the Digital Care Home intervention was described as facilitating communication between health professionals including GPs, nurses, and intermediate care staff to share information in a timely and effective fashion.

Participants generally talked about two models that support either a palliative/end-of-life care model or a monitoring model. In a monitoring model it was considered useful if weekly baseline observations were linked to knowledge of the residents' general assessment: any change in the NEW scores should be interpreted while taking into consideration the resident's general history. It was also considered important that observations should be compared to identify any changes over time. Whilst this is possible within the system, we did not encounter any systematic use of this feature.

It was also considered important for weekly observation to be combined with ad hoc observations of 'softer signs' (such as drowsiness, reduced mobility, lack of appetite etc.) to identify any deterioration in the resident's conditions. Interestingly, these 'softer signs' are usually relied on for identifying health decline in residents.

Whilst respondents generally thought that individualised parameters should be included for residents based on their medical history and background, this would be particularly problematic to initiate, as the NEW scores are designed to be systematically applied; without variation from one person to the next. A key element of the intervention was considered to be technical and clinical support and training for members of staff to use the Digital Care Home intervention and interpret the scores effectively.

The data also suggested that the participants discussed ideas around a holistic, person-centred and personalised palliative/end-of-life care model; where the focus should be on comfort and observing residents for their pattern of drinking, eating, engaging, passing water and their level of confusion. The DCH intervention was discussed within the context of a range of other elements of care provision; indicating that the context in which the intervention is introduced is critical in preventing unnecessary hospital admissions. In this model the continuity of care and nursing, stable management and investing in more staff, play an important role. End of life care should be discussed with the residents and families and advanced care plans implemented to avoid unnecessary hospital admission.

8.2.1 Evaluation of the technology interface (the App)

Whilst there were some recommendations for improving the interface with the technology (the App), it was considered to work reasonably well. It is important to understand that what follows is a summary of people's opinions, and they would have had variable exposure to different aspects of the intervention. Therefore, where these are not supported by more substantial findings, they will require further exploration.

8.2.1.1 App appearance and operation

Respondents offered some suggestions for improving visual clarity and increasing usability of the interface, such as size and colour of the font, use of different colours for different sections and use of symbols. Improved ease of navigating to a resident list and searching for residents was also suggested.

8.2.1.2 App content or functionality

Wi-Fi access in some homes was a problem, resulting in repeated or missed observations being reported. Details of the location of the resident's room in the home was reported to be a feature that would be useful in large care homes.

There were some suggestions that would rely on a re-design of the process, based on clinical input, such as having bespoke alert thresholds for residents and additional measurements.

Some respondents were clearly unaware of some of the features of the system, indicating that it would be useful to have features that were already available, such as: the name of the person taking the observation, access to past readings for the resident, and recording 'softer signs' (e.g. how the resident is feeling).

8.2.1.3 Information and data flows

It was felt that the system had potential for improving communication between homes and NHS services. It was considered useful if it were possible to add personal care plan with useful information for GP, nurses and carers. The speed of hospital call-back to give advice was considered important. The restriction to the window of time in the mornings (5 hours from 7am to noon) to take and upload readings was considered a challenge by some respondents.

8.2.1.4 Support and training

Additional support & training for care staff was requested, particularly in testing and reporting the level of consciousness.

8.2.2 Main contextual themes

8.2.2.1 Home conditions

In terms of sustainability, if there were considerable costs involved in delivering the intervention, the smaller financially challenged homes might struggle to pay for the Digital Care Home technology so the benefits should be clear for the care homes. Small homes will have less complex implementation issues, but might be limited in availability of suitable staff to monitor and input readings and receive calls from SPA. Care home staff require some training and support to increase their level of confidence and accuracy of taking and recording readings. Respondents reported that turnover of staff can be high and might present problems in maintaining the availability of suitably trained staff members.

The general needs of residents could also present different challenges, for instance if there are a large number of residents with dementia or requiring palliative care. The analysis of notes recorded on the DCH monitoring system demonstrated problems with taking readings for a small number of residents with dementia or nearing end of life.

8.2.2.2 Workforce

Some respondents speculated that the additional time required to take readings and enter them onto the system could create extra pressure for care homes, resulting in the system potentially not being used at times when workloads increase. If the care home has a number of Bank/casual

staff who don't have appropriate skills and training to use the App, this can be difficult to manage. However, providing staff with training was reported to be likely to give some staff greater job satisfaction and confidence and create better communication with health care professionals. Respondents clearly stated that the intervention would probably be more useful for residential care homes with no nursing staff.

8.2.2.3 Wider services and other information flows

A critical contextual element that can influence the appropriate use of other health services is access to and relationships with these services (such as GP practices, acute liaison teams, SPA, community nursing etc.). Training for staff can improve their communication, and practice in taking measures and discussing these with others could increase confidence to talk to external health services. The flow of information and the use of this information between services is another important contextual factor, and there is potential to further develop this aspect of the intervention.

8.2.2.4 NEWS

The NEWS measures were not considered appropriate for all residents. The thresholds for alerts were also not considered appropriate for some residents, such as those with COPD and end of life care needs. There were concerns that monitoring might medicalise the elderly population and can create distress in certain residents. It was felt that the readings could be useful but could be better tailored to the needs of the elderly living in the community.

Readings that were considered more appropriate for this population are those that are generally already used in the care home setting (e.g. consciousness level, bowels, eating, monthly weight and Malnutrition Universal Screening Tool (MUST)). Consequently there was no capacity to enter the NEW scores in the residents' records. As discussed elsewhere, there was a misconception that the staff could not track the readings on the App once they are entered. This indicates that additional training regarding the features of the system is required. If residents are monitored daily there might be more chance of recognising when residents' health is declining rapidly and requiring an intervention to prevent and emergency admission. However, this would place a large burden on care staff and residents. The weekly, or twice-weekly monitoring, with flexibility to increase or decrease as required was considered a useful compromise.

8.2.2.5 Individual residents

The number of residents being monitored could be increased by having less frequent monitoring for reasonably stable residents. However, this might result in limiting the potential effectiveness of the intervention, which is intended to pick-up as early as possible that the 'stable' residents are still stable and catch any deterioration early rather than waiting to see visible signs of deterioration. Residents that are less well could be monitored more regularly.

There were concerns from some care staff that residents with severe/moderate dementia should be excluded from monitoring as it can cause them distress and anxiety. However, experience gained during the project indicated that this was not necessarily a problem, providing residents were treated sensitively and there was flexibility regarding whether the resident was happy to provide readings. The managers advised who could take part based on their knowledge and experience. Residents and their families participated in consenting and the opportunity to take part was extended to all residents. As a test phase this explored what benefits could be brought for which types of residents hence there were no pre-existing exclusion criteria in the testing phase.

8.2.2.6 Care plans

It was suggested by the participants in the workshops to develop care plans for all residents as the basis on which the Digital Care Home intervention could be implemented. The care plans would need to be reviewed and changes made if the resident's health condition deteriorates. Appropriate advanced care planning and sharing, accessibility and visibility of advanced care plans could potentially reduce unnecessary emergency admissions.

8.2.3 Other themes generated from the scenarios

The Digital Care Home intervention would help even if there were normal scores for residents, as it is possible that the home care staff could pick up on 'softer' signs whilst taking readings. The scheduled clinical observations would need to be combined with recognition of 'softer', ad hoc signs and more flexible responsive approach to monitoring with input from visitors, families, friends and carers. It was suggested that a person-centred approach should be adopted which provides evidence, access to services and assistance for decision-making out-of-hours (e.g. at weekends) to prevent hospital admission.

8.3 Summary of limitations

This evaluation was a rapid, real-world, multi-methodology evaluation of a complex intervention, and therefore has a number of constraints regarding the design and types of evidence that were able to be produced. The reliance on routinely collected quantitative data from within the study only means that comparative analysis of effectiveness was only possible using pre-post measures. However, there were a number of problems with this approach, perhaps the key difficulty was a lack of ability to understand whether there would be natural change in the outcomes in this population despite the intervention. Without a robust measure of effectiveness, it was also problematic to carry out an economic analysis of cost effectiveness or cost-benefit.

The reliance on routinely collected data was also problematic regarding the analysis of the data captured by the DCH monitoring system. There was scant and variable quantity and quality of data regarding communication between SPA and the care homes the actions taken as a result of interventions. There was also no possible method to link items in the records. For instance it was not clear whether an action was related to a specific alert or NEW score.

The qualitative data analysis work-packages benefitted from recruiting a wide range of stakeholders. However, a key concern was the extent of exposure to and understanding of the intervention. For instance, GPs interviewed did not perceive the intervention to be of great benefit to them. However, there was evidence to indicate that they had not fully engaged with the project or used the data in the course of their work. In addition, responses from people that were using the system, demonstrated that they did not fully appreciate the possibilities. Whilst this highlighted training needs (which were more fully addressed as the project progressed), the data did not always give a true representation of the intervention, rather, in some cases, it highlighted misconceptions and lack of understanding.

8.4 Conclusions and implications

The key mechanisms by which the Digital Care Home project is expected to reduce unnecessary emergency admissions rely on timely interventions to prevent care home staff members calling 999 services. Once paramedic or ambulance services attend, it was considered difficult to prevent transportation to emergency acute services. These interventions were deemed less necessary in nursing homes because the nursing staff had the ability to apply clinical

interventions, seek advice and reassurance or medical interventions (e.g. from a GP). Therefore, it would be likely that when emergency admissions occur from nursing homes these are appropriate and unavoidable as everything will have been done to try to manage these issues within the home.

However, residential care homes with little or no nursing cover were considered to be less well supported in cases of apparent emergencies, and care staff members would therefore be more likely to rely on emergency services. Reliance on emergency services is considered to be greater when a resident's health deteriorates out-of-hours, and access to GPs is limited. This also highlights the importance of continuity of carers as a protecting factor for preventing unnecessary emergency admissions; including care home and nursing home staff members as well as regular GPs. The NEW score readings were reported to be helpful additional information in both nursing and residential care homes when communicating externally, as they were considered to provide objective information to reinforce and legitimise observations.

In cases where continuity of carers cannot be managed, then continuity of information has an increasingly important role. Continuity of information was reported to be often lacking in advanced care planning, which was reported to be variable. Permission for the resident to remain at the home, in the case of declining health was reported to mostly rely on a phone call to the resident's GP, which was problematic when they were unavailable. This circumstance was reported to be a key cause for unnecessary transportation, and was considered more likely to occur at a residential home with no nursing staff. However, it was considered that contact with the nurses at the Single Point of Access (SPA) could provide the requisite advice and reassurance to prevent unnecessary transportation.

This factor highlights an important limitation of the Digital Care Home project; the inflexibility of the intervention regarding the following.

1. Direction of communication

The care home sent the observations to the portal which could be accessed by SPA and only if there was an alert following a reading would SPA contact the home. There was a facility for the home to contact SPA if they had concerns about a resident; by including a note on the reading submission, which would automatically trigger an alert. However, staff at the care home could not amend a note after it was submitted.

2. Timing and frequency of contact

In this test phase, readings were scheduled for the morning, so that there was time during the day to respond, perhaps carry out further observations, verify readings and recommend an escalated response if required. Therefore, incidents of health problems being recognised at other times of the day could not be dealt with through the system; despite out-of-hours emergencies being reported most likely to result in transportation to acute services.

Resource limitations and the residential focus of care homes are some of the barriers to very frequent measurement of early warning scores in the care home setting. Consequently, measurements for residents in this study were mostly taken once or twice weekly, thereby reducing the potential for detecting rapid health deterioration. The use of wearable monitoring technology for some parameters could enhance monitoring by providing real-time data. However, the incorporation of these greater quantities of data would require significant

developmental work. For instance, temporary fluctuations would normally be expected, but could also be indicative of health decline and the need for a rapid response.

3. The NEWS measures

Care home staff members are familiar with recognising and responding to 'softer' signs of deteriorating health such as food and fluid intake, activity, mobility, interaction, toilet habits etc; rather than the vital sign monitoring required for the NEW score. Whilst the NEW score was considered to be useful additional information, the ability to record and communicate 'softer' signs and the more traditional observations that would be entered in the resident's care record was considered to be an important omission. This could be a valuable alteration in future iterations of the technology

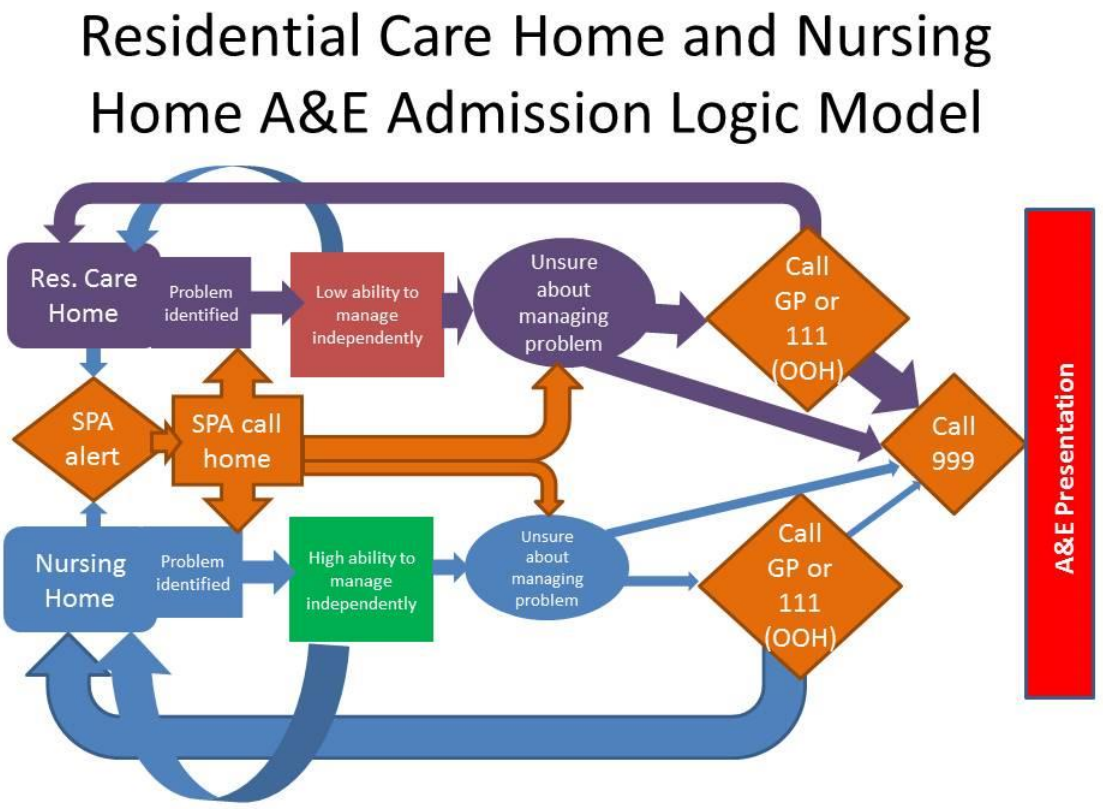
4. Flow/access to information

The project demonstrated that the technology is a useful tool to begin to connect disparate parts of health and social care systems. The lack of integration of information across primary, acute and social care is a well-documented problem, which was reported to be a considerable barrier to the effective functioning of the project. For instance the staff at SPA had very limited information about residents apart from the NEWS readings and previous notes recorded on the system, which made it difficult to provide appropriate and timely advice. A time-consuming 'work-around' involved SPA staff going through the process of admitting the resident to the hospital, to view any records on SystmOne (if there were any), and then logging this admission as an error. GPs reported not being aware of access to the NEWS readings, despite this being available. Care home records (as is usually the case) were stored as paper copies in lever-arch files, and the DCH technology proved to be an effective way of digitally capturing and transferring records of residents' health.

Over the course of the project some of these data-flow issues began to be addressed. For instance, acute liaison staff did not initially have access to the NEWS readings, although they did say that this would be useful additional information for managing an admission; they achieved this access during the extension of the project.

The following logic model demonstrates key relationships between the main elements required for preventing unnecessary emergency transportations to acute care. The logic model provides a graphic representation of some of the important findings from the evaluation; importantly the potential differences between residential care homes and nursing homes. Note that all homes involved in the project were dual-registered nursing homes. Therefore, the situation in residential care homes is mostly derived from the experiences and opinions of people working in nursing homes.

Figure 1: A&E admissions, visual logic model



In nursing homes, most concerns about residents' health are dealt with in-house; either independently or following a call to a GP or 111 (out of hours) service. In this project, the SPA team contacted the home, if an alert was raised, and therefore had an opportunity to intervene to help prevent unnecessary emergency calls. It would be expected that residential care homes have less ability to deal with health problems in-house and therefore rely on GPs and 111 services to a greater extent. Even with primary care support, the residential care home staff might still not feel confident in the resident remaining in the home and will resort to calling emergency services. Therefore, the link to the SPA team could be considered more valuable and more likely to prevent unnecessary admissions from residential care.

For instance, the nursing homes involved in the project reported that they were usually successfully managing any health problems before SPA responded to an alert by calling the home. Although it is not possible to verify the extent of these claims, they reported that they had often recognised the problem and contacted the GP if it was considered necessary (as the SPA intervention happened during GP office hours). However, difficulties were reported at other times, when the out of hours service was relied upon.

On the other hand, respondents considered residential care homes to be less able to confidently manage problems independently, and therefore be more likely to rely on external support or advice. The ability for the GP or OOH service to prevent a call to 999 services was considered to rely, to a large extent, on prior knowledge of the resident. It was considered that having clear and well-considered advanced care plans in place and accessible at any point in the model could help prevent unnecessary emergency admissions. However, once the emergency services were in attendance, the likelihood was that the resident would be transported to acute care.

Whilst we were not able to fully test these theories about the relative value of the DCH for residential vs nursing homes (particularly due to only dual registered homes taking part in the project), logically, residential homes would be less well resourced (in terms of facilities and expertise) to manage serious declines in residents' health. Increased demand for limited nursing home places and therefore a greater number of very frail older people being accommodated in residential homes with no nursing staff could also be considered to exacerbate this situation.

Despite NEWS being increasingly recommended for use outside acute hospital settings (Brangan et al, 2018) this evaluation project has begun to identify some of the complex elements that might define the effectiveness of the use of NEWS in nursing and residential care homes. We have identified a number of mechanisms through which the intervention might be expected to work and some of the key contextual factors and design details of supporting services that could contribute to successful early intervention.

Whilst the use of NEWS in ambulance services seems to be well supported (NHS England, 2017), the lack of evidence for the use of early warning scores in pre-hospital settings is well-established. It is unclear as to how benefits might be realised in other non-acute hospital services and care homes in particular, although it is advocated for the assessment of acutely unwell patients and handover of care between healthcare settings, organisations and care providers (WEAHSN, 2017).

The evaluation supports key findings from the only other previous qualitative investigation of the NEW score in non-acute settings (Brangan et al, 2018). The following are key findings from Brangan et al (2018), which concur with findings from this evaluation:

- Usefulness in communicating clinical acuity in a standardised way rather than relying on narrative and variable selections of physiological indicators (particularly across organisations) and in confirming 'intuition'/'gut reactions'
- Useful to provide leverage in escalating care, particularly when dealing with hierarchies in professional status and to overcome resistance in admitting to acute care
- NEWS measures are not deemed relevant in some cases and might not necessarily reflect prioritisation of treatment needs (such as stroke, some cardiac complaints or traumatic head injury)
- Patient selection is important in contexts where NEWS is only relevant for a small proportion of the population
- Need for NEWS to be used alongside other sources such as 'history and clinical judgement' as a 'rule-in' rather than a 'rule-out' for escalation to further services (Brangan et al, 2018)
- GPs tend to find NEWS measures do not fit into their usual clinical practice; relying more on history, symptoms and instincts. Whereas ambulance services are more used to rapidly taking sets of observations
- 'Repurposing ' of NEWS timescales/frequency of measurements was found when people are not acutely ill; to provide a baseline to contextualise episodes of acute illness or identify long-term deterioration (e.g. weekly)
- NEWS measures could be useful for nursing and medical staff in acute liaison posts or working with acutely unwell hospital admissions

A key area where this evaluation aligns with previous work in this field is the suggestion that a more tailored approach to different settings might be required. This tailoring should consider:

- Practical guidelines regarding patient/resident selection (or an opt-in or opt-out model when moving into the home)
- How to incorporate NEW scores with clinical judgement for specific populations
- Definitions of appropriate alert criteria and associated actions for specific circumstances

It was recognised that NEWS related monitoring in care homes has the potential to indirectly improve the care of residents. It is possible that the act of regular monitoring increases the knowledge and understanding of care home staff, and also increases vigilance and attention. There is evidence in the literature for this (Brangan et al, 2018) and it is corroborated by notes associated with responses to alerts, where care home staff members have taken actions to improve measures. There is also a possibility that involvement in the project has helped to improve the level of service that some homes are receiving from GPs.

9. Recommendations

The implementation and evaluation of the Digital Care Home project has been a timely and important investigation into how recommendations to use early warning scores in non-acute settings might work. In its current incarnation the digital care home intervention has significant limitations. However, this extended evaluation supports other studies that recommend tailoring of early warning scores and development of subsequent responses to specific circumstances and settings, and provides some clear recommendations for development.

The regular (usually weekly) monitoring of NEW scores in residential care or nursing homes is considered unlikely to provide timely detection of acute health-decline requiring immediate attention and subsequently preventing emergency transportation to hospital. However, there are circumstances where the recording of NEW scores as a baseline measure, or as an additional set of systematic observations in cases of decline being recognised through 'softer' signs could be useful; particularly when communicating with other care professionals.

It is not clear to what extent the remote triggering of alerts through SPA is a useful addition to local recognition of NEW scores, although, the contact with SPA was reported to be beneficial in promoting communication and in supporting decision-making. This linkage would potentially be more beneficial for residential care homes than nursing homes. It should also be recognised that if the SPA service were not involved, local collation and interpretation of NEW scores at homes would require additional training and knowledge (particularly in residential care homes), and there is the possibility that alerts might be missed.

The remote gathering of NEWS data could be a useful addition to existing residents' records if the readings are available to the right services at the right time. This requires additional access to other sources of clinical history. Access to NEW scores for ambulance services, acute admissions, out-of-hours services and GPs were all reported to have potential benefits. There are also issues regarding local recording of and access to NEWS readings, for instance only one home reported recording NEW scores in resident's records; making it difficult for members of staff to easily understand trends over time. Whilst viewing trends over time was available as a function of the technology, this was not reported to be systematically utilised within the project; possibly due to limited access to PCs in a care home.

Currently, the key mechanisms for reducing inappropriate transportation to acute services are reported to be:

- flexible 24-hour access to alternative sources of care and support
- well-planned accessible MDT advanced care plans
- continuity of care and access to clinical history records

Overwhelming evidence points towards tailoring of the intervention to include the 'softer' signs that are traditionally relied upon in these settings. Tailoring of an early warning score would require consideration of working within the context of these key mechanisms. However, the evaluation clearly indicates that the opportunity to record and communicate 'softer' signs would be valued by care/nursing home staff. There is also some evidence that it would be useful to amend the threshold for triggering alerts for some residents, particularly in the case of COPD (the MEWS or NEWS2 might be considered more suitable). Despite NEWS observations being considered inappropriate on their own for many residents, there were recognised benefits. Regular and systematic contact with residents for measuring vital signs was considered to have

unintended consequences regarding, for instance; better communication, improved observation (of 'hard' and 'soft' signs) and reassurance.

It would be important to carry out a consideration of criteria for inclusion of homes and individual residents that would benefit most from the intervention and the type of intervention that would be most suitable. Residential care homes, with little or no nursing staff were considered to be those that might benefit most from this type of intervention, which is supported by the logic models that were developed as a result of evaluation findings. That is not to discount potential benefits for residents with certain characteristics in nursing homes; depending on the suitability of the design of a tailored intervention.

Within the confines of this study, the inflexibility of the intervention did not necessarily meet the needs of homes in terms of the:

- One-way contact with additional support and advice services at SPA (regardless of NEW score)
- Lack of 24-hour contact and inflexible timings of NEWS submissions
- Rigidity of NEWS measures and alert thresholds
- Lack of appropriate information sharing

The additional nursing cover provided by the project was not drawn upon. When questioned about why this might be, members of staff from nursing homes stated that they had adequate nursing cover, and had personal knowledge about residents that an external nurse would not. However, they thought that this might have been more useful for residential care homes, which do not have in-house nursing staff.

To improve the ability to evaluate the intervention, it would be useful to record additional information about communication through the system. This would include:

- Details of referral suggestions
- Actions taken by care home staff in the case of alerts (pre and post contact from SPA)
- Inclusion of a unique episode identifier to determine which tasks/alerts are linked

The user-centred design work-package provided recommendations about the app appearance, content and functionality as well as information requirements and data flows. From combining the qualitative and quantitative work, we have also developed a framework, which could be used to direct further investigations and development work and includes the following dimensions:

1. Home conditions
2. Workforce
3. Wider services
4. Other information flows
5. Recorded data
6. Individual resident contexts
7. Care plans (including advanced care planning and treatment thresholds)

The NEWS measures and the frequency and method of data collection were generally considered useful and appropriate, but too limited and inflexible for optimum use in residential and nursing home settings. The evaluation provides good evidence from a range of stakeholders to support the inclusion of other parameters; these include the types of observations that are

routinely collected for monitoring in residents' records (e.g. food and fluids (MUST & BMI score), pain, mobility, choking risk, communication, medication etc.). However, this development would ideally be supported by the initiation of digital care home records, which would collect information on mobile devices for sharing across integrated services. Otherwise the duplication of record keeping on digital and paper-based systems could be a significant barrier in an already under-resourced sector.

The ability to choose from a small range of options to indicate, for instance, that the alert has been acknowledged and quickly indicate why measures are not being input to the system would be beneficial (e.g. resident in hospital, resident away, resident distressed etc.). This would also be beneficial for ongoing monitoring or further evaluation of the use of the system. Currently, these short messages are entered in the same field as other detailed descriptions about readings and residents' health.

In terms of further integrating the system with other services; the sharing of NEWS data with ambulance crews is one area of obvious developmental, as there is some evidence for the effectiveness of NEWS in this sector. The improvement of communication with ambulance crews regarding conservative treatment options and permission to stay is a key mechanism that could potentially prevent avoidable emergency admissions. Whilst the project had GPs in various steering roles, those involved with providing care for residents directly affected by the project had a limited role in development. Relationships with GPs are fundamentally important for appropriate escalation of care and changes in treatment plans and medications. However, GPs were generally not convinced about the value of the project. It would therefore be useful to involve them in future development of the intervention; to ensure buy-in and the inclusion of features that GPs would see as useful for them.

One important area of development highlighted by this evaluation is the need to integrate interventions into a complex health and social care system, which involves a number of key organisations. An area of development that was therefore recommended by a range of stakeholders is the integration and appropriate sharing of detailed advanced care planning, which should inform all aspects of care; particularly with regard to emergency avoidance.

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11. Supplementary appendix

S1. Physiological parameters incorporated into NEWS: review of the six physiological parameters

This supplementary appendix provides an overview of the physiological factors incorporated into the National Early Warning Score (NEWS) system, including: respiratory rate, oxygen saturation, temperature, systolic blood pressure, pulse rate, and level of consciousness. Note that the Modified Early Warning System (MEWS) replaces oxygen saturation with Hourly urine output (for previous 2 hours).

This following review has been directly extracted from the Royal College of Physicians (2012) "National Early Warning System (NEWS): standardising the assessment of acute-illness severity in the NHS" report (pages 9 to 10). It should be noted that within that report, there are a number of other parameters discussed which could be used to provide additional weighting of the NEWS aggregate score (i.e. supplemental oxygen, chronic obstructive pulmonary disease with known hypercapnic respiratory failure) and physiological parameters considered but not included in the NEWS (i.e. age, urine output, pain, gender, ethnicity, obesity, pregnancy, and comorbidities including immunosuppression). These other parameters and how they are relevant to NEWS are not described below, but the interested reader can refer to the Royal College of Physicians (2012) report.

Respiratory rate

An elevated respiratory rate is a powerful sign of acute illness and distress, in all patients. The respiratory rate may also be elevated as a consequence of generalised pain and distress, sepsis remote from the lungs, central nervous system (CNS) disturbance and metabolic disturbances such as metabolic acidosis. A reduced respiratory rate is an important indicator of CNS depression and narcosis.

Oxygen saturations

The non-invasive measurement of oxygen saturation by pulse oximetry is routinely used in clinical assessment in the acute setting but until recently was less often incorporated into currently used EWS systems. As the routine measurement of oxygen saturations is now practical, it was considered to be an important parameter to include in the NEWS. Oxygen saturations are a powerful tool for the integrated assessment of pulmonary and cardiac function. The technology required for the measurement of oxygen saturations, i.e. pulse oximetry, is now widely available, portable and inexpensive. The NEWSDIG recommended that oxygen saturation measured by pulse oximetry should become a routine part of the assessment of acute-illness severity as part of the NEWS.

Temperature

Both pyrexia and hypothermia are included in the NEWS system reflecting the fact that the extremes of temperature are sensitive markers of acute-illness severity and physiological disturbance.

Systolic blood pressure

Although an elevated blood pressure (hypertension) is an important risk factor for cardiovascular disease, it is a low or falling systolic blood pressure (hypotension) that is most significant in the context of assessing acute-illness severity. Hypotension may indicate circulatory compromise due to sepsis or volume depletion, cardiac failure or cardiac rhythm disturbance, CNS depression, hypoadrenalism and/or the effect of blood pressure lowering medications. It is important to note that some people have a naturally low systolic blood pressure (<100 mmHg) and this might be suspected if the patient is well and all other physiological parameters are normal, or confirmed by reference to previous records of blood pressure. Hypertension is given less weighting in the context of acute-illness assessment. Severe hypertension, e.g. systolic blood pressure 200 mmHg, may occur as a consequence of pain or distress but

it is important to consider whether the acute illness may also be a consequence of, or exacerbated by severe hypertension and take appropriate clinical action. Diastolic blood pressure does not form part of the scoring system for acute-illness severity because it does not add value in this context. However, diastolic blood pressure should be routinely recorded as it may be severely elevated and require treatment in some acute settings, i.e. accelerated hypertension.

Pulse rate

The measurement of heart rate is an important indicator of a patient's clinical condition. Tachycardia may be indicative of circulatory compromise due to sepsis or volume depletion, cardiac failure, pyrexia, or pain and general distress. It may also be due to cardiac arrhythmia, metabolic disturbance, e.g. hyperthyroidism, or drug intoxication, e.g. sympathomimetics or anticholinergic drugs.

Bradycardia is also an important physiological indicator. A low heart rate may be normal with physical conditioning, or as a consequence of medication, e.g. with beta-blockers. However, it may also be an important indicator of hypothermia, CNS depression, hypothyroidism or heart block.

Level of consciousness

Level of consciousness is an important indicator of acute-illness severity. We recommend the use of the already widely used Alert Voice Pain Unresponsive (AVPU) scale which assesses four possible outcomes to measure and record a patient's level of consciousness. The assessment is done in sequence and only one outcome is recorded. For example, if the patient responds to voice, it is not necessary to assess the response to pain.

Alert: a fully awake (although not necessarily orientated) patient. Such a patients will have spontaneous opening of the eyes, will respond to voice (although may be confused) and will have motor function.

Voice: the patient makes some kind of response when you talk to them, which could be in any of the three component measures of eyes, voice or motor – e.g. patient's eyes open on being asked, 'Are you okay?'. The response could be as little as a grunt, moan, or slight movement of a limb when prompted by voice.

Pain: the patient makes a response to a pain stimulus. A patient who is not alert and who has not responded to voice (hence having the test performed on them) is likely to exhibit only withdrawal from pain, or even involuntary flexion or extension of the limbs from the pain stimulus. The person undertaking the assessment should always exercise care and be suitably trained when using a pain stimulus as a method of assessing levels of consciousness.

Unresponsive: this is also commonly referred to as 'unconscious'. This outcome is recorded if the patient does not give any eye, voice or motor response to voice or pain.

New onset confusion: as indicated above, a patient may be confused but alert. Thus, assessment of confusion does not form part of the AVPU assessment. Nevertheless, **new onset or worsening confusion should always prompt concern about potentially serious underlying causes and warrants urgent clinical evaluation.**

S2: Details of digital care home intervention costs

Table 14: Total DCH intervention estimated cost: total first year cost and equivalent annual cost (EAC)

Cost aspects	Sunk costs	Sunk EAC cost	Variable costs	Units	Total cost		Total EAC
Technology costs[a]							
Large home	*£581.67*	*£200.60*	-	*7*	*£4,071.69*		*£1,404.18*
Medium home	*£387.78*	*£133.73*	-	*0*	*£0.00*		*£0.00*
Inhealthcare platform	*£11,000.00*	*£11,000.00*	-	*1*	*£11,000.00*		*£11,000.00*
Connecting residents[b]	-	-	*£80.00*	*67*	*£2,680.00*		*£2,680.00*
Technology sub-total					£17,751.69		£15,084.18
Weighted care home staff cost per resident/year[c]							
Large home	-	-	*£231.48*	*67*	*£15,508.93*		*£15,508.93*
Medium home	-	-	*£245.54*	*0*	*£0.00*		*£0.00*
Care home staff sub-total					£15,508.93		£15,508.93
SPA staff cost per resident/year[d]							
SPA staff sub-total	-	-	*£501.18*	*67*	£33,578.96		£33,578.96
Total DCH intervention cost					**£66,839.58**		**£64,172.07**

Footnote. EAC = Equivalent Annual Cost (based on 3 year capital life; 3.5% discount rate)[18]

[a] Technology costs include 3 or 2 of the following pieces of technology for a large (50+ beds) or medium (11 to 49 beds) home, respectively: £80 per Tablet Device; £5 per Tablet case; £44.95 per Pulse Oximeter; £39.95 per Thermometer; £23.99 per Blood Pressure Monitor. Inhealthcare platform costs are presented online[19]

[b] The first 100 people connected to the Inhealthcare platform do not receive the £40 module charge for the first six-months;[19] therefore, the cost of £2,680 is the cost for the 67 residents for the second six months such that £2,680 = 67 residents * 67 people

[c] Weighted care home staff cost (including staff on-costs and capital costs based on the calculations from Curtis and Burns[10]) per resident/year are based on one nurse (band 5; £33.27 per hour) and either an additional one or two health care assistants (HCA band 3; £23.51 per hour) for a medium or large home, respectively, performing monitoring which takes 10 minutes per patient, per week.

[d] Single Point of Access (SPA) staff cost (band 6; £40.36 per hour including staff on-costs and capital costs based on the calculations from Curtis and Burns[10]) per resident/year when 16 hours are spent monitoring 67 residents per week, as reported by SPA staff for the DCH study.

S3. Digital Care Home logic models: mechanism for preventing emergency admissions in residential and nursing care homes

The following logic models were developed from the synthesised findings from the qualitative, quantitative and user-centred design work-packages, and expert panel discussions. They also include consideration of current literature. The two models represent extreme examples of differences between nursing homes, which are set-up to deliver intensive nursing care, and might also have additional clinical input (such as mental health support) depending of the needs of the residents, when compared to residential care homes, which have little or no nursing staff.

These two types of homes usefully demonstrate the different needs and mechanisms that could be expected to be operating at each type of home. However, it should be recognised that there are likely to homes that fall between these two extreme models. For instance a nursing home might have only a few residents that routinely require nursing input and therefore might have very limited nursing staff levels, which might be considerably reduced out of hours, or the home might rely on agency staff; meaning that nurses have little personal knowledge of residents.

S3.1. Nursing home; extreme scenario

Table S3.1. Nursing home - regular staffing levels with day and night nursing staff, and psychological support if required

Conditions	**Mechanisms for preventing emergency admission**: *The key mechanism by which the intervention is intended to operate, might not work in nursing homes that are well-staffed with nurses and there is continuity of staff members; as health decline might be expected to be noticed and acted on rapidly without the NEWS intervention. However, the additional clinical information might be useful in making decisions and communicating to others about resident's care in some cases.* *There could be some cases where serious problems are identified by NEWS scores and acted upon in a timely manner to prevent an emergency (e.g. sepsis?)*	**Notes** (In cases of rapid decline, where GP consultation is required, separate plans would be required for out of hours)

Frail/observed gradual decline	Key reasons for emergency admission are: 1) falls or 2) unexpected rapid health decline. <u>Falls:</u> It could be possible to prevent falls by monitoring vital signs for indicators of increased falls risk (e.g. high temp, low resting BP (e.g. Klein et al BMC Geriatrics, 2013; 13:50), whilst orthostatic hypotension could be a better indicator, it is more time consuming to measure). <u>Rapid decline:</u> It is not clear how monitoring might operate to prevent admissions owing to rapid unexpected health decline. Even if they are being monitored daily, which is unlikely (too much burden on staff and residents). Main mechanism to prevent admission to A&E is having an advanced care plan in place that is shared and integrated into care pathways. Nursing staff (if possible, in collaboration with GPs) could then make decision for resident to stay (do not call 999).	Weekly monitoring would probably be most suitable. Possibly increased frequency if rapid decline were anticipated.

End of life	Main mechanism to prevent admission to A&E is having an advanced care plan in place that is shared and integrated into care pathways. Acute Liaison could intervene to help hospital admission to be targeted at more appropriate services (e.g. palliative care, cancer services, frailty unit). Decisions about whether to transport to acute care for treatment can be made by: • Nursing staff (if non-emergency) • GPs (if available and knowledgeable about the resident) • Paramedics/ambulance crew. However, once 999 called, resident will usually be transported to hospital. Availability of pre-emptive medication can also help to prevent need for emergency services transportation. Probably difficulties in providing for residents at end of life in a residential home.	There are concerns about whether monitoring is appropriate for end of life situations, unless possibly for selected limited vital signs, but not whole NEWS.

	Key monitoring should be for main physical health problems, which are not necessarily covered by NEWS measures (e.g. blood sugar), with Digital Care Home as an additional monitoring system; picking up symptoms of any acute, treatable & non-urgent conditions (e.g. UTI). Weekly monitoring would probably be most suitable. In these circumstances it would be expected that care home staff or residents might often notice symptoms, before any Digital Care Home monitoring alerts are triggered.	Monitoring for main physical health problems, which are not necessarily covered by NEWS measures; as and when required by care home nursing staff, GP, District Nurse. Weekly monitoring would probably be most suitable for NEWS.
Multiple physical long-term co-morbidity	However, the observations are useful for care home staff to give them clinical signs to discuss with other care providers (e.g. GPs); this might help them to feel as if they are not wasting the time of other professionals, to justify requesting additional help and to confirm their suspicions. Some early problems in providing and gaining access to information about the resident for all necessary people were addressed. For instance diabetes care will often be provided by care home nurses in collaboration with GPs & records will not be routinely available for SPA staff or acute care services. This was a particular problem when SPA staff respond to alerts, especially when there was no members of care home staff available to speak to that know the resident. This was overcome during the project by temporarily admitting the resident as a hospital patient. However, in the longer-term, more permanent solutions should be sought and key people should be informed about how to efficiently share information.	

Co-morbid mental health and life-threatening long-term physical health problem (e.g. dementia and diabetes)	Key monitoring should be for main physical health problems, which are not necessarily covered by NEWS measures (e.g. blood sugar) with Digital Care Home as an additional monitoring system; picking up symptoms of any acute, treatable & non-urgent conditions (e.g. UTI). Frequency of monitoring would be dependent on resident's health problems and emotional condition. In these circumstances it would be expected that care home staff or residents might notice symptoms, before any Digital Care Home monitoring alerts are triggered. As described above there are inherent problems in the right people getting access to the right information at the right time. There might be additional practical difficulties in gaining cooperation/consent of residents with mental health problems: resulting in missing observations.	Frequency of monitoring would be dependent on resident's health problems and emotional condition.

S3.2. Residential care home; extreme scenario

Table S3.2: Residential Care home - high number of agency staff with minimal or no nursing staff (day-time only)

Conditions	**Mechanisms for preventing emergency admission:** *The key mechanism for the Digital Care Home system preventing A&E admissions in residential care are providing members of staff with someone to talk with at SPA about making decisions, and being reassured that an emergency response is not in the resident's best interest. However, the rigid scheduling of tasks is likely to restrict access to the SPA service, whereas an 'as-and-when-required' advice-line might be more*	**Notes** *(In cases of rapid decline, where GP consultation is required, separate plans would be required for out of hours)*

valuable.

Another potential mechanism is providing care home staff with clinical readings that can support their feelings that someone is unwell, in order to request GP intervention.

There could be some cases where serious problems are identified by NEWS scores and acted upon in a timely manner to prevent an emergency (e.g. sepsis?).

It is possible that in a residential home, particularly with large numbers of agency staff, that relationships with residents are not well developed and declining health is not normally recognised in a timely manner; therefore the NEWS scores can be a valuable early indicator.

Indirect mechanisms could be: 1) additional time spent with residents increasing the possibility of observing health problems, 2) up-skilling of care home staff in identifying and responding to warning signs through taking readings and communicating with SPA

	Key reasons for emergency admission are: 1) falls or 2) unexpected rapid health decline. <u>Falls:</u> It could be possible to prevent falls by monitoring vital signs for indicators of increased falls risk (e.g. high temp, low resting BP (e.g. Klein et al BMC Geriatrics, 2013; 13:50), whilst orthostatic hypotension could be a better indicator, it is more time consuming to measure).	Weekly monitoring would probably be most suitable. Possibly increased frequency if rapid decline were anticipated.
Frail/observed gradual decline	<u>Rapid decline:</u> It is not clear how monitoring might operate to prevent admissions owing to rapid unexpected health decline. Even if they are being monitored daily, which is unlikely (too much burden on staff and residents). It would be expected that care home staff or residents might often notice symptoms, before any Digital Care Home monitoring alerts are triggered. Main mechanism to prevent admission to A&E is having an advanced care plan in place that is shared and integrated into care pathways. However, it is not clear how the decision for resident to stay would be made and who would make this decision; if there are no available nursing staff on hand, perhaps a senior carer or home manager would make a call to GP. If an ambulance is called, would ambulance crew make the decision for the resident to stay if an advance care plan were in evidence, which recommended non-hospitalisation?	

End of life	Main mechanism to prevent admission to A&E is having an advanced care plan in place that is shared and integrated into care pathways. Acute Liaison could intervene to help hospital admission to be targeted at more appropriate services (e.g. palliative care, cancer services, frailty unit). Decisions about whether to transport to acute care for treatment can be made by: • Care home management/Senior carer • GPs (if available and knowledgeable about the resident) • Paramedics/ambulance crew. However, once 999 called, resident will usually be transported to hospital. N.B. Unsure of potential availability of pre-emptive medication (probably very limited).	End of life care could be difficult to provide in residential care. There are concerns about whether monitoring is appropriate for end of life situations, unless possibly for selected limited vital signs, but not whole NEWS.

Multiple physical long-term co-morbidity	Monitoring for main physical health problems, which are not necessarily covered by NEWS measures (e.g. blood sugar), would be expected to be carried out by GP/District nurse, with Digital Care Home as an additional monitoring system; picking up symptoms of any acute, treatable & non-urgent conditions (e.g. UTI). In these circumstances it would be expected that care home staff or residents might often notice symptoms, before any Digital Care Home monitoring alerts are triggered. However, the observations are useful for care home staff to give them clinical signs to discuss with other care providers (e.g. GPs & SPA); this might help them to feel as if they are not wasting the time of other professionals, to justify requesting additional help and to confirm their suspicions. The Digital Care Home system has inherent problems in providing access to information about the resident for all necessary people. For instance diabetes care will often be self-managed or provided by GPs & records not available for SPA staff or acute care services. This is a particular problem when SPA staff respond to alerts, especially when there are no members of care home staff available that know the resident.	Monitoring for main physical health problems, which are not necessarily covered by NEWS measures; as and when required (by e.g. GP, District Nurse). Weekly monitoring would probably be most suitable for NEWS.

Co-morbid mental health and life-threatening long-term physical health problem (e.g. dementia and diabetes)	Key monitoring should be for main physical health problems, which are not necessarily covered by NEWS measures (e.g. blood sugar) with Digital Care Home as an additional monitoring system; picking up symptoms of any acute, treatable & non-urgent conditions (e.g. UTI). In these circumstances it would be expected that care home staff or residents might notice symptoms, before any Digital Care Home monitoring alerts are triggered. As described above there are inherent problems in the right people getting access to the right information at the right time. There might be additional practical difficulties in gaining cooperation/consent of residents with mental health problems: resulting in missing observations.	Frequency of monitoring would be dependent on resident's health problems and emotional condition.

S4: Extended summary of evidence for the use of EWS in pre-hospital settings

- It is hypothesised that if early warning systems (EWS) can provide a means of early detection of changes in physiological parameters (e.g. heart rate, systolic blood pressure, respiratory rate, oxygen saturation, level of consciousness and temperature) associated with deteriorating health status, monitoring a change in these parameters could provide an opportunity to initiate a prioritised clinical response and prevent serious health outcomes (Hogan et al, 2012; Hillman et al, 2001; RCP, 2012).

- In pre-hospital settings (e.g. care homes, ambulance services, primary care, mental health services), it is suggested EWS should be used as an adjunct to clinical decision making rather than replacing it, to better prioritise allocation and need for further or escalation of care (RCP, 2012; NCEPOD, 2017). However, current use in pre-hospital setting is considered controversial due to lack of evidence of effectiveness in these settings (Fullerton et al, 2012; Gray et al, 2010; Roland & Jahn, 2012).

- In a separate published study by Patel et al (2018), a systematic review was conducted to assess if early warning scores (EWS) identify deteriorating patients in pre-hospital settings. This systematic review included identified papers up until August 2017 with a particular focus on NEWS rather than other types of EWS; although, other types of EWS, including the modified early warning score (MEWS) (Stenhouse et al, 1999), is included in some of the identified studies. The focus of the discussion in this section is based mainly on those papers identified by Patel et al (2018). A focussed search was used to identify published evidence in 'UK' based 'care homes' using 'NEWS' up until December 2018 to identify the most recent published evidence pertinent to the intervention discussed within this report; however, no relevant papers were identified for the purpose of discussion.

- It is worth noting that Patel et al (2018) mentioned they were aware of one previous systematic review that evaluated EWS in prehospital settings (Williams et al, 2016), but this review was restricted to studies conducted in the ambulance/ emergency medical settings and used a broader definition of EWS than their review, including studies on disease-specific EWS and single item EWS. Therefore, as part of this discussion which is specifically focussed on NEWS, this other systematic review is provided as a reference only and its results are not described nor discussed.

- The searches by Patel et al (2018) identified 2026 papers of which 50 were considered potentially relevant and screened as full text articles. Seventeen studies (157,878 participants) using EWS for predicting outcomes were included in the final review. Only one of these studies was conducted within a community nursing home and was focussed on the use of MEWS rather than NEWS (Pattison & Vernon, 2011); all other studies were ambulance based. No studies compared pre-hospital settings that used EWS with settings that did not, and so comparative analysis to determine the relative effectiveness of EWS to current care was not conducted (which is similar to our study design) and remains missing from the empirical literature.

- The UK-based retrospective chart review study by Pattison et al (2011) was focussed on the use of MEWS in a community nursing home setting. MEWS was used routinely by a nursing home case management service, to triage [medical] visit requests. The study included 178 people (mean age, 83; 37% male). This study reported lower 'area under the receiver operating characteristic curves' (AUCs; a measure of how well a parameter can distinguish between two diagnostic groups (Zweig & Campbell, 1993)) than studies conducted in the ambulance service when it evaluated mortality at 7 days, 30 days and 90 days with AUCs ranging from 0.53 to 0.63. Based on these AUCs, the study concluded that MEWS does not predict mortality in community dwelling nursing home residents

and thus had limited ability for avoiding this outcome through early prevention alerted by the use of MEWS.

- In the ambulance-based service studies (with a particular focus on NEWS), the overall conclusion as reported by Patel et al (2018) suggested that a very low EWS score (0) means patients are unlikely to deteriorate. This adds confidence to clinical judgement that such a patient can be safely managed outside hospital. Patients with very high scores (>=7) are more likely to deteriorate and should receive appropriate intervention. In practice this means urgent referral to secondary care as the patient requires urgent assessment and treatment. There is insufficient data available to draw strong conclusions regarding the effectiveness or accuracy of EWS in patients with intermediate scores (1–6).

- To Summarise, the suggestion from this review is that the use of EWS has potential in ambulance-based services, but there is no evidence to suggest the same in a care home setting. It is important to note that only one study (Pattison & Vernon, 2011) suggested that MEWS (rather than NEWS) didn't predict mortality in community nursing homes, which is a slightly different focus and purpose to the Digital Care Home NEWS monitoring system. Therefore, evidence in this area should be considered lacking, rather than supportive or not of the Digital Care Home NEWS monitoring system in a care home setting.

- There is no evidence about whether patient outcomes differ between pre-hospital settings that do and do not use EWS; as such, Patel et al (2018) suggests the need for a cluster randomised controlled trial (RCT) to determine relative effectiveness of EWS in pre-hospital settings. The authors of this current report concur that a cluster RCT focussed specifically in a care home setting would be required to determine effectiveness and cost-effectiveness of the Digital Care Home NEWS monitoring system to usual care, with the following outcomes as its potential focus (noting that the optimum outcome to measure benefit relative to NEWS is unclear): short-term mortality, incidence of sepsis, admission to hospital and/or escalation of care.