|  |  |
| --- | --- |
|  |  |
|  | **CFHealthHub Digital Learning Health System** |
|  | **A Quality Improvement project and Trials within Cohort platform for Cystic Fibrosis** |
|  |  |
|  | **RESEARCH PROTOCOL**  **Version 13 – 07 November 2022** |
|  |  |
|  | **IRAS: 216782**  **STH: 19387** |
|  |  |
|  | **Authorised by: Martin Wildman** |
|  |  |
|  |  |
|  |  |

# Funding

This project was funded by the NHS England Commissioning for Quality and Innovation (CQUIN)

The views and opinions expressed by authors in this publication are those of the authors and do not necessarily reflect those of the NHS

Roles and responsibilities

## Names, affiliations, and roles of protocol contributors

The following all contributed to drafting elements throughout the first version of the protocol: Martin Wildman, Consultant Respiratory Medicine (Sheffield Teaching Hospitals NHS Foundation Trust); Pauline Whelan, mHealth Applications Manager (University of Manchester); Kimberley Horspool, Carla Girling Study Manager, Daniel Hind, Assistant Director, Mike Bradburn, medical statistician, Amanda Loban, data manager (Sheffield Clinical Trials Research Unit, University of Sheffield). The revised version of the protocol (2022) has involved contributions by Zhe Hui Hoo, Lana Lai, Matthew Sperrin, Lisa Watson and Sophie Farrell.

MW is the guarantor of the study design; MB is the guarantor of the statistical design and analysis plan

## Sponsor

Sheffield Teaching Hospitals NHS Foundation Trust (STH NHS FT)

D Floor

Clinical Research Office

Royal Hallamshire Hospital

Glossop Road

Sheffield

S10 2JF

Tel: (0114) 2256424

Fax: (0114) 2265937

## Role of study sponsor and funders

Neither the funder nor the sponsor have had any role in study design, data collection and analysis, decision to publish, or preparation of manuscripts.

Key Contacts

|  |  |
| --- | --- |
| **Study Manager**  Miss Sophie Farrell  Organisational Development  Northern General Hospital  Herries Road  Sheffield  S5 7AU  E-mail: sophie.farrell3@nhs.net sth.cfhealthhub@nhs.net | **Chief Investigator**  Dr Martin Wildman  Adult CF Centre  Northern General Hospital  Herries Road  Sheffield  S5 7AU  Tel: (0114) 2715212  Fax: (0114) 222 0870  e-mail: martin.wildman3@nhs.net |
|  |  |

## Composition, roles, and responsibilities

### Project Management Group

|  |  |  |
| --- | --- | --- |
| **Name** | **Role** | **Institution** |
| Dr Martin Wildman | Chief Investigator | Sheffield Teaching Hospitals NHS Foundation Trust |
| Dr Pauline Whelan | m-Health Applications Manager | University of Manchester |
| Prof Madelynne Arden | Behavioural Psychologist | Sheffield Hallam University |
| Marlene Hutchings | Lead CF physiotherapist | Sheffield Teaching Hospital NHS Foundation Trust |
| Sophie Dawson | National CFHH Quality Improvement Lead | Nottingham University Hospital NHS Foundation Trust |
| Tracey Daniels | Research Fellow in CF | York and Scarborough Teaching Hospitals NHS Foundation Trust |
| Sophie Farrell | Project Manager | Sheffield Teaching Hospitals NHS Foundation Trust |
| Robert Sandler | Clinical Fellow in CF | Sheffield Teaching Hospitals NHS Foundation Trust |
| Sarah Cameron | CF Interventionist | Sheffield Teaching Hospitals NHS Foundation Trust |
| Lana Yin Hui Lai | Statistician | University of Manchester |
| Matthew Sperrin | Consultant Statistician | University of Manchester |

**Table of Contents**

[Funding 2](#_Toc118705476)

[Roles and responsibilities 2](#_Toc118705477)

[Names, affiliations, and roles of protocol contributors 2](#_Toc118705478)

[Sponsor 2](#_Toc118705479)

[Role of study sponsor and funders 2](#_Toc118705480)

[Key Contacts 3](#_Toc118705481)

[Composition, roles, and responsibilities 3](#_Toc118705482)

[Project Management Group 3](#_Toc118705483)

[Tables 7](#_Toc118705484)

[Figures 7](#_Toc118705485)

[Protocol amendments since version 1 8](#_Toc118705486)

[Lay Summary 11](#_Toc118705487)

[1 Introduction 13](#_Toc118705488)

[1.1 Background 13](#_Toc118705489)

[1.2 Rationale 13](#_Toc118705490)

[2 Aims and Objectives 15](#_Toc118705491)

[3 Design 16](#_Toc118705492)

[4 Existing Interventions 17](#_Toc118705493)

[4.1 Overview 17](#_Toc118705494)

[4.2 Chipped nebuliser devices 17](#_Toc118705495)

[4.2.1 The eTrack nebuliser system (Pari GmbH) 17](#_Toc118705496)

[4.2.2 The i-neb AAD System from (Philips Healthcare) 18](#_Toc118705497)

[4.3 Medicine Possession Ratio 18](#_Toc118705498)

[4.4 Information technology infrastructure 18](#_Toc118705499)

[4.5 The i-neb data transfer system 19](#_Toc118705500)

[4.6 The eTrack and Qualcomm hub 19](#_Toc118705501)

[4.7 CFHealthHub 19](#_Toc118705502)

[5 Participants and Study Setting 23](#_Toc118705503)

[5.1 Locations 23](#_Toc118705504)

[5.2 Participant Eligibility Criteria 23](#_Toc118705505)

[5.2.1 Inclusion criteria for participants 23](#_Toc118705506)

[5.2.2 Exclusion criteria for participants 23](#_Toc118705507)

[5.3 Sampling 23](#_Toc118705508)

[5.4 Recruitment and Screening 23](#_Toc118705509)

[5.5 Informed Consent 23](#_Toc118705510)

[5.6 Uncontactable participants 24](#_Toc118705511)

[5.7 Re-approaching patients who decline or withdraw 25](#_Toc118705512)

[5.8 Screening new patients 25](#_Toc118705513)

[5.9 Participants from the CFHealthHub RCT 25](#_Toc118705514)

[5.10 Participants from paediatrics substudy 26](#_Toc118705515)

[5.11 Participant withdrawal 26](#_Toc118705516)

[5.12 Participant transfer between sites 26](#_Toc118705517)

[5.13 Patient Stories 26](#_Toc118705518)

[5.14 Health Episode Statistics Data Linkage 27](#_Toc118705519)

[6 CFHealthHub Digital Learning Health System 28](#_Toc118705520)

[6.1 Training for local CFHealthHub researchers and the CF team 28](#_Toc118705521)

[6.2 Participant ‘set up’ in the Digital Learning Health System 28](#_Toc118705522)

[6.3 Ongoing support/contact for Participants 28](#_Toc118705523)

[6.3.1 Delivering the Behaviour Change Intervention 29](#_Toc118705524)

[6.3.2 Troubleshooting 29](#_Toc118705525)

[6.4 Development of the CFHealthHub platform 29](#_Toc118705526)

[6.5 Quality Improvement (QI) 29](#_Toc118705527)

[6.5.1 Microsystems Coaching 30](#_Toc118705528)

[6.5.2 Metrics and tests of change 30](#_Toc118705529)

[6.6 Trials within Cohorts (TWiCs) methodology 31](#_Toc118705530)

[6.7 Procedures for the CFHealthHub Cohort 32](#_Toc118705531)

[6.7.1 Participant Consent to future research 32](#_Toc118705532)

[6.7.2 Quality assurance of supported research studies 32](#_Toc118705533)

[6.7.3 Data security and supported research studies 33](#_Toc118705534)

[6.8 Medicines Optimisation 34](#_Toc118705535)

[6.9 Quality Improvement and embedding behaviour change intervention within clinical practice by using the NICE quality indicator for centre comparisons 35](#_Toc118705536)

[7 Sub-studies 36](#_Toc118705537)

[7.1 Using the CFHealthHub digital learning health system to support preventative self-care for patients with Cystic Fibrosis (CF) during the COVID-19 emergency 36](#_Toc118705538)

[7.2 Refining the CFHealthHub Behaviour Change Intervention (BCI) to help young people with CF manage treatment adherence: 36](#_Toc118705539)

[Paediatrics Acceptability Sub-Study 36](#_Toc118705540)

[7.3 Process evaluation sub-study 36](#_Toc118705541)

[8 Data Collection and Management 37](#_Toc118705542)

[8.1 Data collection sources 37](#_Toc118705543)

[8.2 Data handling and record keeping 38](#_Toc118705544)

[8.3 Data Management 38](#_Toc118705545)

[8.3.1 University of Manchester 38](#_Toc118705546)

[8.3.2 Not-for-profit CFHealthHub Company 39](#_Toc118705547)

[8.4 Data Analysis 39](#_Toc118705548)

[9 Monitoring and Oversight 41](#_Toc118705549)

[9.1 Management of the study 41](#_Toc118705550)

[9.2 Harms (safety assessments) 41](#_Toc118705551)

[9.3 Auditing 41](#_Toc118705552)

[9.4 Finance and indemnity 41](#_Toc118705553)

[10 Ethics and dissemination 41](#_Toc118705554)

[10.1 Approvals 41](#_Toc118705555)

[10.2 Amendments to the project 42](#_Toc118705556)

[10.3 Consent procedures 42](#_Toc118705557)

[10.4 Confidentiality 42](#_Toc118705558)

[10.5 Declaration of Interests 42](#_Toc118705559)

[10.6 Dissemination policy 42](#_Toc118705560)

[11 References 43](#_Toc118705561)

[12 Appendices 46](#_Toc118705562)

[Appendix 1. Logic Model 46](#_Toc118705563)

[Appendix 2. Implementation Strategy (publication submitted for review) 47](#_Toc118705564)

[Appendix 3. Using the CFHealthHub digital learning health system to support preventative self-care for patients with Cystic Fibrosis (CF) during the COVID-19 emergency 48](#_Toc118705565)

[12.1 Background 48](#_Toc118705566)

[12.2 Aim 48](#_Toc118705567)

[12.3 Objectives 49](#_Toc118705568)

[12.4 Description of revised CFHH support 50](#_Toc118705569)

[12.4.1 Initial phase 50](#_Toc118705570)

[12.4.2 Intermediate phase 51](#_Toc118705571)

[12.4.3 Peak phase 51](#_Toc118705572)

[12.4.4 ‘Hand back’ Phase 52](#_Toc118705573)

[12.5 Patients using I-neb nebuliser devices 52](#_Toc118705574)

[12.6 Setting up of new participants 52](#_Toc118705575)

[12.7 Functions of the Central team 53](#_Toc118705576)

[12.8 Central team resilience strategy 53](#_Toc118705577)

[12.9 Resources 53](#_Toc118705578)

[12.9.1 Central team 53](#_Toc118705579)

[12.9.2 Local CF centres 54](#_Toc118705580)

[12.10 Equipment 54](#_Toc118705581)

[12.11 Risks 54](#_Toc118705582)

[12.11.1 Context 54](#_Toc118705583)

[12.11.2 Why is CFHH valuable to pwCF? 55](#_Toc118705584)

[12.11.3 What are the risks if CFHH is not available? 55](#_Toc118705585)

[12.11.4 Levels of distress to patients and the clinical team 56](#_Toc118705586)

[Appendix 4. Refining the CF HealthHub Behaviour Change Intervention (BCI) to help young people with CF manage treatment adherence: Sub-study protocol 57](#_Toc118705587)

[Background and rationale 57](#_Toc118705588)

[Aims and objectives 58](#_Toc118705589)

[Method 58](#_Toc118705590)

[Study design 58](#_Toc118705591)

[Study setting 58](#_Toc118705592)

[Sample size 58](#_Toc118705593)

[Eligibility criteria 59](#_Toc118705594)

[Recruitment 59](#_Toc118705595)

[The Behaviour Change Intervention 60](#_Toc118705596)

[Study procedures 60](#_Toc118705597)

[Study visit 1 – Consent and initial assessment visit 64](#_Toc118705598)

[Study visit 2 – intervention session 1 and participant assessment 64](#_Toc118705599)

[Study visit 3 – Intervention session 2 (review) and audio recording 65](#_Toc118705600)

[Study visit 4 – data collection around intervention feedback 65](#_Toc118705601)

[Study visit 5 – researcher physiotherapist interviews 66](#_Toc118705602)

[Data management and analysis 66](#_Toc118705603)

[Data handling and record keeping 66](#_Toc118705604)

[Data Analysis 66](#_Toc118705605)

[CFHealthHub data collected 67](#_Toc118705606)

[Monitoring and Oversight 67](#_Toc118705607)

[Ethics and dissemination 67](#_Toc118705608)

[References 68](#_Toc118705609)

[Appendix 5. Process evaluation sub-study: substudy protocol 69](#_Toc118705610)

[1.1 Background and rationale 69](#_Toc118705611)

[1.2 Aims and objectives 69](#_Toc118705612)

[1.3 Study design 69](#_Toc118705613)

[1.3.1 Quantitative process data 70](#_Toc118705614)

[1.3.2 Qualitative process data 71](#_Toc118705615)

[1.3.3 Sampling 71](#_Toc118705616)

[1.3.4 Interview procedures 72](#_Toc118705617)

[1.3.5 Analysis 73](#_Toc118705618)

## Tables

[Table 1**:** CFHealthHub modules, theoretical behaviour change (COM-B) and theoretical domains framework 16](#_Toc487556091)

[Table 2: Consent requirements for the study 19](#_Toc487556092)

[Table 3. Sources of Data within CFHealthHub Digital Learning Health System 31](#_Toc487556093)

## Figures

[Figure 1: Interaction of existing intervention and the CF patient 13](#_Toc487556099)

[Figure 2: Interplay between COM-B components during habit formation 15](#_Toc487556100)

[Figure 3. CFHealthHub and Microsystems coaching 24](#_Toc487556101)

[Figure 4. TwiCs two-stage consent procedure 25](#_Toc487556102)

## Protocol amendments since version 1

|  |  |
| --- | --- |
| Version number | Changes made |
| 2 | Section 7.3.3. Correction to describe roles under the CIC will be contracted, not sub-contracted.  Table 2. Consent statement removed. |
| 3 | Expansion of Project Management group to include Professor of Health Psychology and Research Physiotherapist, removal of team member no longer supporting PMG. Date of site opening amended in Lay Summary, clarified informed consent process, including sending letter to patients’ GP to inform of participation and make follow up recruitment call optional (Section 5.5). Updated Table 2 to reflect new consent statement. Update to Uncontactable participants (Section 5.6) to reflect optional telephone call. Additional section on re-screening (Section 5.7), screening new patients (Section 5.8) and patient stories (Section 5.10). Removed unnecessary detail training for CF team (Section 6.1). Patient data collection; additional patient reported questions on effort and automaticity at baseline (Section 6.2), Table 3 updated to be consistent and additional clarity on time points for data collection including the removal of prospective data collection for exacerbations (updated also in 7.4) and inclusion of chipped nebuliser data from existing devices, patient report effort and automaticity of nebuliser use at baseline and review, patient reported involvement in other research studies at baseline and review, additional criteria used for screening (pseudomonas status, diabetes status, deprivation index, lung transplant status) and removal of 2 year time window for adding retrospective data to CFHealthHub. A period of 4 weeks between consent and ongoing support for adherence (Section 6.3). Quality Improvement baseline adherence questionnaire will be administered to each CF centre prior to undertaking QI work (Section 6.5). Acronym ‘TWiCs’ updated throughout. Anonymised Screening data to be encrypted and sent to Sheffield CTRU(Section 7.2). |
| 3.1 | Recruitment of patients for studies supported in the Digital Learning Health System can be performed by a member of the local CF team |
| 4 | Change of Project Management group membership to remove Kim Horspool as Study Manager and include Anna Packham as Research Assistant. Exclusion criteria updated (Section 5.2.2) to exclude patients post lung transplant. Behaviour change intervention to be offered two months post consent visit (Section 6.3). Research requesting use of the Digital Learning Health System platform requirements updated to include approval from recognised ethics committees outside of the NHS (Section 6.7.2). New section added (Section 7) to detail the Process Evaluation sub-study. Appendix 1 added to document the Digital Learning Health System Logic Model. |
| 5 | Kimberley Horspool removed as Study manager throughout document. New section 5.9 added to detail the phased approach for existing CFHealthHub RCT participants. Section 5.10 withdrawal option updated to remove option to use CFHealthHub without participating in the study. New section (5.11) added to detail request and linkage of HES data. Table 3, section 9 updated to include HES data, section 9.2 data handling and recording keeping updated to include details for HES data, removal of 1998 DP act. Section 9.3.3 updated to 2019 (removing 2017) as the year of transition into the CIC. Sponsor named as data controller. |
| 6 | Additional information in section 5.11 to detail video recordings of participants for conferences and training/educational purposes. |
| 7 | Project management group updated. Spelling and grammar corrections throughout. Clarity of the aims of the project by specifying the aim to study implementation. The process for recruitment of new participants into Digital Learning Health System and full transition of RCT sites described in section 5.9. Sampling wording updated. Section 4.4.2 updated to explain end of the use of the Binebs, and the inclusion of ineb devices. Clarity in section 4.6 that CFHealthHub also collects metrics on usage by the clinical team, and that usage data will be shared. Ongoing support for patients section (section 6.3) updated to explain new participants in 2019 will not require a two month gap between consent and CFHealthHub access/support. |
| 8 | Inclusion of additional study objective required by the funder for 2019-2020. Confirmation of ineb device entry, and explanation of bineb devices being removed from the study. Removal of lung transplant exclusion criteria. New section (6.8) to describe the inclusion of three work packages for medicines optimisation for completion during 2019-2020 funding. Updates to section 7, Process Evaluation, to give details of data collected from the revised logic model and the inclusion of a questionnaire for healthcare professionals at participating CF centres to complete to measure barriers to implementation. Sampling of health care professionals in phase 4 sites clarified. Logic model revised (see appendix 1). Inclusion of implementation strategy (appendix 2). |
| 9 | Addition of new/changed project management members under the 2019-2020 CF self-care CQUIN funding.  All further changes made to adapt CFHH to changing healthcare system during the COVID-19 pandemic. For pwCF, CFHH must continue to be available and accurate, to support participants with adherence to their preventative inhaled medications.  Section 5.5 new information about using telephone consent appointments to reduce unnecessary patient contact.  Section 6.3 amended so that CFHH central team can perform local CFHH researcher functions during the pandemic, allowing patient continuity on CFHH during potential NHS staff shortages. Footnote added to specify who these members would be.  Appendix 3. New appendix added detailing COVID19 adaption protocol for adherence support, ensuring that CFHH remains available for participants during the pandemic. |
| 10 | Addition of a sub-study to investigate possible adaptations and refinements to the BCI for young people with cystic fibrosis. This addition is briefly detailed in section 8 of the revised protocol, with a full study protocol included as Appendix 4.  Study Manager contact details updated. |
| 11 | Eligibility criteria for CFHH changed to allow patients not using chipped nebulisers to take part in the study. |
| 12 | Addition of 16-17 year olds to the Paediatrics sub-study to address the gap between sub-study and adult study, and will increase number of eligible patients. See Appendix 4.  Study Manager contact details updated (change in maternity leave cover) from Alex Scott to Liz Cross.  Change in Research Assistant at CTRU from Emma Young to Jamie Hall. |
| 13 | Change of research study title from “CFHealthHub Data Observatory” to “CFHealthHub Digital Learning Health System”.  Project Manager contact details updated from Liz Cross to Sophie Farrell  University of Sheffield CTRU details removed from study contacts, due to trial management handover to Sponsor (STH NHS FT).  Addition of Zhe Hui Hoo, Lana Lai, Matthew Sperrin, Lisa Watson and Sophie Farrell as contributors to revised protocol.  Lay Summary updated to ensure aims of Digital Learning Health System clear, and historical context of RCT and its findings provided to highlight accumulating evidence base supporting CFHH and its aims.  Introduction updated to provide information on CFTR modulators which are highly efficacious and have become important pillar of standard care for majority of PwCF (Section 1.1, 1.2).  Aims updated to provide more explicit description of pre-existing aims and clearly signpost all ongoing research projects (Section 2).  Terminology used to describe design of study has been updated to better reflect that used within current research streams of the CFHH Digital Learning System (Section 3).  Update to information on i-Neb data (Section 4.2.2) to clarify that consent is obtained to analyse existing i-Neb data.  Updated details of information technology infrastructure (Section 4.4) to more accurately reflect current CFHH infrastructure. Information regarding Bi-neb devices has been removed as no longer in use (Section 4.5, 6.2). Additional information regarding the new generation eTracks to be integrated for use within CFHH is provided (Section 4.6).  Centres currently participating in CFHH updated and reference to RCT, which is now complete, has been removed (Section 5.1, 5.3).  Consent documentation process updated as copies of CRFs are no longer required to be stored centrally (Section 5.5).  Clarification regarding consent/assent process for paediatric participants at Southampton Children’s hospital provided (Section 5.10).  Clarification regarding participant transfer process provided as due to increase in centres joining CFHH, participant transfer between sites has become more common (5.12).  Addition of Section 6.9 to provide information regarding NICE quality indicator research stream.  For the purpose of coherence, the protocol has been restructured to include summaries of ongoing CFHH sub-studies (Sections 7.1, 7.2, 7.3), the protocols of which are provided in Appendix 3-5. Within the Process Evaluation protocol (Appendix 5), changes made to reinforce that on-going process evaluation is critical aspect of quality improvement (Appendix 5, 1.1, 1.3, 1.3.2). Clarification is also provided regarding the approach and recruitment of participants (Appendix 5, 1.3.3.2, 1.3.4) and the type of data that is collected (Appendix 5, 1.3.1).  Section 8.1 updated to clarify data collection process and specify the routine clinical data collected. Sweat chloride added to be used as a surrogate for adherence to CTFR modulators. Prescription data included as data source.  Time frame on transition of CFHH to CIC updated (Section 8.3.2).  Statistical analyses (Section 8.4) streamlined and planned analyses made more explicit to reflect updated aims within protocol.  Section 9.4 updated to reflect increasing diversity in CFHH funding sources. |

## Lay Summary

Cystic Fibrosis (CF) is an inherited disease affecting 10000 people in the UK with an average age at death of 28 years in 2012. The lungs of people with CF (PWCF) are prone to infections. Daily physiotherapy and inhaled medications are needed to stay healthy. Around £30 million is spent annually on inhaled therapy but average adherence has been shown to be only 36%. Data suggest that adherence is better in younger children (71% in under 12s, falling to 50% in teenagers) but of the 10000 UK PWCF almost 6000 are now adults. PWCF who collect <50% of their medication cost the healthcare system significantly more than PWCF who collect more than 80% and most of the additional cost results from unscheduled emergency care and hospital admission. This unscheduled emergency care is distressing for PWCF and their families.

Current research investigating whether adult PWCF can build successful, self-management, treatment habits using dose-counting nebulisers to collect adherence data, displaying this data on a website (CFHealthHub) and using a behaviour change toolkit, supported by a health professional, is ongoing. (ACtiF study funded by the National Institute for Health Research, Programme Grants for Applied Research programme RP-PG-1212-20015).

The current study aims to develop CFHealthHub as a Digital Learning Health System. There are two over-arching purposes; first, adherence data from PWCF using dose-counting nebulisers will be shared with health professionals to explore how adherence data can be used within routine care encounters and within Quality Improvement (QI) projects to understand the quality of care; and to improve the quality and efficiency of care delivery. Second, collecting data from a large number of PWCF may support future CF research studies, focussing on the determinants of behaviour and understanding how to achieve sustained behaviour change. In addition, we will identify research and data analytic opportunities for learning health system to optimise long-tern condition care. This approach will include ‘Trials within Cohorts’ (TwiCs) to help CF researchers overcome the difficulties associated with conducting research in rare conditions such as high costs and un-representative recruitment. In addition, other methodologies that can be supported using the data will be used when appropriate.

Recruitment began in early 2017 when up to 140 participants in Sheffield were provided with chipped nebulisers as part of routine care. In late 2017 35 patients in Nottingham, and 35 in Southampton and Poole (Southampton and Poole is a single CF unit across two hospitals) who had been using chipped nebulisers as part of a pilot study completed the pilot and were invited to join the Digital Learning Health System and continue using the chipped nebulisers as part of standard care. From September 2017 a further 100 patients in Nottingham and a further 100 in Southampton and Poole were invited to join the Digital Learning Health System. CFHH is now open to all CF centres within the UK and currently 1442 patient across 17 centres are utilising the Digital Health Learning System within standard care. Over the next 10 years we will recruit as many as possible of the 6000 adults with CF in the UK.

With appropriate consent, adherence data and patient data from CF registry and patient notes are stored within CFHealthHub. CFHealthHub captures information related to their prescription, treatment habits, motivation and barriers for self-management and behaviour change, identified by patient’s personal details (name, DOB, contact details and NHS number).

CF is an archetypal long-term condition in which adherence to life saving therapy is an important indicator of the effectiveness of the support and empowerment provided by the local CF clinical team. Local QI projects, facilitated by a trained Microsystems Coach will explore how feedback of adherence data can support tests of change in which clinical teams attempt to make the care offered by the CF team more effective in supporting PWCF to succeed with the challenge of daily self-management. Two metrics are particularly important, the overall adherence measured at centre level (which uses anonymised aggregate data) and the proportion of patients who are willing to share individual identifiable data with the clinical team. The willingness of PWCF to share identifiable data is an indicator of the quality of relationship between PWCF and the clinical team. QI projects related to adherence data might for example test of change whereby teams change their working patterns to be available to support PWCF when PWCF get home from work. An increase in overall centre adherence would support this change in practice as an improvement in the quality of care provided by the CF team. The two metrics of adherence rate and the proportion of patients within a centre willing to share identifiable data with the clinical team will be made available as aggregate quality indicators of unit performance. These aggregate data will not contain patient identifiers and will allow CF centres to be compared.

The Digital Learning Health System establishes a cohort of patients providing a continuous stream of data about the metric of adherence behaviour and the metric of willingness to share individual data with the MDT and this data rich cohort provides a platform for learning. Data from PWCF may be used for future research which results in no changes to patient care but might for example provide data about the relative speed at which different nebulisers might allow treatment to be delivered. PWCF may also consent to being included in selection for future research which may result changes in care, for example, testing new treatments or testing new patterns of care delivery. Digital Learning Health System participants can consent to be involved or not in any of the possible combination of QI projects and pragmatic trials that the platform will support. Consent to ‘selection’ does not pre-determine nor mitigate the need for informed consent for future studies. Participants will of course be able to decline participation in future research with no impact on their inclusion in the Digital Learning Health System, and consent for the Digital Learning Health System can be changed or withdrawn at any time without reason.

Adherence data and QI data will be explored to investigate the importance of this data to measure the quality of care delivered by CF sites. As the Digital Learning Health System includes more of the patients in Southampton, Poole, Nottingham and Sheffield the data capture and feedback platform will be assessed and iterated so that it will be sufficiently robust the recruit more of the 6000 adults with CF in the UK when the 20 centre RCT which is being carried out in parallel with the Digital Learning Health System is complete. It is important to emphasise that the justification of the Digital Learning Health System does not depend on the success of the RCT. It is recognised that an adequate assessment of a PWCF involves measurement of lung function, weight and adherence to effective lifesaving therapy. The most basic but transformative function of the Digital Learning Health System is to deliver the IT infrastructure that ensures that adherence is available at every consultation. If the behaviour change intervention delivered within the RCT fails to support an increase in adherence, that will not be a reason not to measure adherence, but will instead provide even more reason to continue to measure adherence in a new trial with an improved behaviour change intervention.

The RCT was conducted between October 2017 and May 2018. 608 participants were recruited to the trial and randomised into either the intervention group (n=305) or control (usual care, n=303). The results showed no significant difference in FEV1 or exacerbations between the two groups. However, greater sustained improvement in adherence to inhaled medications, lower perceived CF burden and higher BMI were demonstrated amongst the intervention group. Patients living with long term conditions (LTCs) have lower adherence to prescribed medications and such medications are only effective when taken correctly, therefore the findings of the RCT are significant in highlighting the effectiveness of the Digital Health Learning System as a means of supporting increased adherence and improving quality of life for PwCF.

# Introduction

## Background

Cystic Fibrosis (CF) is a long term condition (LTC) in which poor adherence to high cost drugs shortens lives and increases NHS costs. CF is a LTC affecting 10,000 people in the UK with PWCF typically dying from lung damage at a median age of 28 years 1. The prognosis of PWCF has improved from around 6 months in 1938 due to evolving CF care and improvement in treatment options over time2. An example of new treatment in CF are CFTR modulators which directly target the underlying genetic defect in CF and are currently efficacious for around 80% of PWCF3,4.

One of the most important treatments in CF is preventative inhaled therapies that help to control chronic infection and promote more effective airway clearance. Randomised controlled trials show that preventative inhaled medications reduce exacerbations and/or preserve lung function5-11, however adherence is poor. A recent review of objective measures of adherence using medicine possession ratios (MPR: prescriptions collected over prescriptions issued) and instrumented medication monitors showed adherence ranging from 67% for oral antibiotics, 31-53% for inhaled antibiotics, 53-79% for mucolytics agents and 41-72% for hypertonic saline12. Accumulating evidence suggests poor adherence is associated with poor outcomes. PWCF collecting four or more courses of alternate month nebulised tobramycin per year were 60% less likely to be admitted to hospital than PWCF collecting one or less13. Lower composite MPR predicted exacerbations requiring intravenous antibiotics (IVAB)11 and over a 12 month period PWCF with an MPR of 80% had significantly lower total healthcare costs than PWCF with an MPR <50% with a cost difference $14,211 per patient and most excess costs related to hospital care14. Rescue therapy with IVAB can cause renal failure15. The total 2012 UK spend for CF was estimated to be £100 million of which £30 million was spent on inhaled antibiotics and mucolytics16. Although patient self-reported adherence to inhaled therapy was 80%, objective measurement showed median adherence was only 36% and the clinicians were unable to predict which PWCF were able to successfully adhere17 making adherence support difficult. In 2012, the UK CF population received 171,907 days of IVAB with the 93,455 of these that occurred in hospital costing an estimated £27 million18. It is recommended that adherence interventions should be targeted where adherence really matters19 and targeting support towards the high cost inhaled preventative drugs in CF (median adherence 36%) has the potential to impact on the 171,907 days of IVAB a proportion of which will represent rescue therapy necessitated by failed prevention.

## Rationale

Understanding patient adherence and supporting PWCF who find adherence to treatment regime difficult may lead to improvements in the quality of CF care delivered to individuals and across CF units nationally. The opportunity to explore the use of a ‘process’ metric (adherence data) in routine care and it’s utility as a measure of the quality of care is novel in the management of a chronic long term condition. Furthermore, understanding adherence data from CF centres across the UK, will enable researchers to benchmark and thus promote greater examination of the processes and service organisation which supports greater adherence with CF patients. Making adherence data visible to MDT’s at CF centres has the potential to influence regular routine encounters and deliver greater person- centred care. Quality improvement projects which also examine how adherence behaviours are developed and supported through care contacts may also influence service delivery and design to maximise opportunities to develop adherence behaviours. Sharing data and QI best practice, within a theoretical and reproducible QI programme may also be an important driver of care quality nationally.

Whilst pragmatically understanding and influencing CF care, the data collected via CFHealthHub will support the Trials within Cohorts (TwiCs) functionality. As the number of patient records within CFHealthHub increases the platform can be utilised to support research into CF, predominantly focussing on behaviour change research. The use of such cohorts as platforms for trials is now becoming common and is especially valuable for rare disease populations20. In particular, as CF care continues to evolve over time, on-going data collection is valuable to understand the role of existing treatments in the context of new medications such as CFTR modulators being widely used.

# Aims and Objectives

The over-arching aim of CFHealthHub Digital Learning Health System is to explore the use of adherence data for quality improvement and as behavioural data within a cohort for future CF studies.

The objectives of CFHealthHub are to:

1. Understand the determinants of adherence
2. Evaluate behaviour change techniques using appropriate methodologies including trials within cohorts (TWICs)
3. Sustain / embed CFHealthHub within centres and improving adherence by delivering behaviour change intervention within clinical practice and use CFHealthHub data to optimise clinical outcomes
4. Generate robust and replicable quality improvement processes in order to optimise recruitment, retention and data completeness within CFHealthHub and use this to determine the effect on centre level adherence
5. Understand, develop and optimise quality indicators (including the NICE quality indicators), so that they are useful and meaningful tools to support system optimisation across the CFHH Community
6. Embed behaviour change intervention within clinical practice by using the NICE Quality Indicator for centre comparisons
7. Improve health outcomes by extending the reach of the behaviour change intervention (including to adults who are ‘hard to reach’, to the paediatric population, and to outside of the UK)
8. Understand how to optimise medicine use (including improving local protocols for drug escalation) and medicine delivery
9. Understand the nature of effective and efficient care in the context of evolving health systems
10. Create appropriate analysis using CFHealthHub and routinely collected data to support on-going engagement with policy-makers and stakeholders

# Design

A pragmatic, development study which consists of;

1. an observational cohort study / Learning Health System with design elements supporting Trials within Cohorts
2. a platform for quality improvement projects across the NHS.

# Existing Interventions

## Overview

The CFHealthHub Digital Learning Health System will support quality improvement projects and Trial within Cohorts (TwiC’s) methodology studies utilising existing interventions, which can be defined as; (a) a microchipped device (nebuliser) for delivering inhaled medications; (b) the medicine possession ratio; (c) information technology infrastructure to capture and store adherence data from the nebulisers and display it to PWCF and the CF team; and (d) the CFHealthHub software as a behaviour change intervention. Details about these three existing interventions can be found below and the interaction of these interventions and the CF patient are outlined in figure 1;



Figure 1: Interaction of existing intervention and the CF patient

## Chipped nebuliser devices

Nebuliser adherence data will be automatically uploaded from a participant’s nebulisers in their own home. This will be collected via two different microchipped nebulisers, the eTrack nebuliser system and the i-neb AAD System. The device use will be determined by the different treatment strategies at the CF site.

### The eTrack nebuliser system (Pari GmbH)

The eTrack controller is a modified version of the eBase controller and can be used to operate both the eFlow rapid nebulizer or Altera nebulizer. Compared to the eBase controller the eTrack is equipped with a Bluetooth chip and has a monitoring function to allow the capture of inhalation adherence data. The eFlow rapid nebuliser with eTrack controller is a CE marked medical device to be used for inhalation therapy. The device allows medications (approved for inhalation) to be transported deep into the lungs.

### The i-neb AAD System from (Philips Healthcare)

The I-neb AAD system is a CE marked medical device which is intended for use to deliver aerosolised liquid medications for participants with cystic fibrosis.  The drug delivery device is a small battery powered device designed to deliver a precise dose of drug into patient’s lungs. The I-neb AAD system is designed to deliver liquid medications that are specifically approved for use with the I-neb AAD System. During the initiation of the I-neb AAD System, all users also consented to contribute data from their devices for the purpose of research.

## Medicine Possession Ratio

CFHealthHub (CFHH) is in use in 17 out of 26 adult centres in the UK and in many centres a large proportion of patients are now using chipped nebulisers in conjunction with CFHealthHub to support their adherence. However, there remains patients who take medication for CF that *cannot* transfer data to CFHealthHub. For example, the use of inhaled therapies via devices that are not chipped, and oral medications for CF in pill form (indeed, all CF patients take such oral medications). Therefore, in order to make full use of CFHealthHubs’ potential to monitor and improve adherence in CF, it is vital that CFHealthHub is able to accommodate medication use from non-chipped nebuliser devices. One way in which CFHealthHub can incorporate medications that cannot be tracked using a chipped nebuliser is to use the Medicine Possession Ratio (MPR), a measure commonly used in adherence research. The MPR will be entered onto CFHealthHub by the clinician, and is the ratio of the number of prescriptions collected from the pharmacy divided by the number of prescriptions written by the medical team. As such, the MPR allows the clinical team to understand the maximum amount of treatment a patient had access to over a period of time. Thus if a patient had only collected 60% of prescriptions, the maximum amount of treatment the patient could possibly have taken could only be 60% of the drugs the clinical team intended the patient to take.

It has become apparent that adding MPR data to the clinician facing CFHealthHub platform will widen participation of patients with CF within adult centres by allowing CFHealthHub to present adherence data on all patients attending a centre regardless of the type of medications used. This has become particularly important as the new generation Vertex modulators are now entering the UK. The vertex modulators cost in the region of £100K per patient; however, adherence data from a recent trial showed that adherence to the vertex modulator Ivacaftor was only 60%, and fell over 6 months21. Consequently, there is a clear need to monitor and improve adherence to medications that cannot (currently) be chipped and automatically transferred to the CFHealthHub platform. With the incorporation of MPR into CFHealthHub we will be in a position to monitor, and potentially improve adherence to more CF medications (e.g., vertex modulators), and therefore widen the impact of CFHealthHub as a digital health platform within the NHS.

## Information technology infrastructure

The information technology infrastructure for the Digital Learning Health System comprises;

1. The eTrack
2. The Qualcomm hub
3. The i-neb
4. CFHealthHub

## The i-neb data transfer system

The i-neb does not have automatic adherence data transfer to CFHealthHub currently. Instead, it requires a member of staff or the user to download a data file from the i-neb using a Phillips docking station and IT software. This can then be uploaded to CFHealthHub by a clinician or sent to the clinician for upload by the user.

## The eTrack and Qualcomm hub

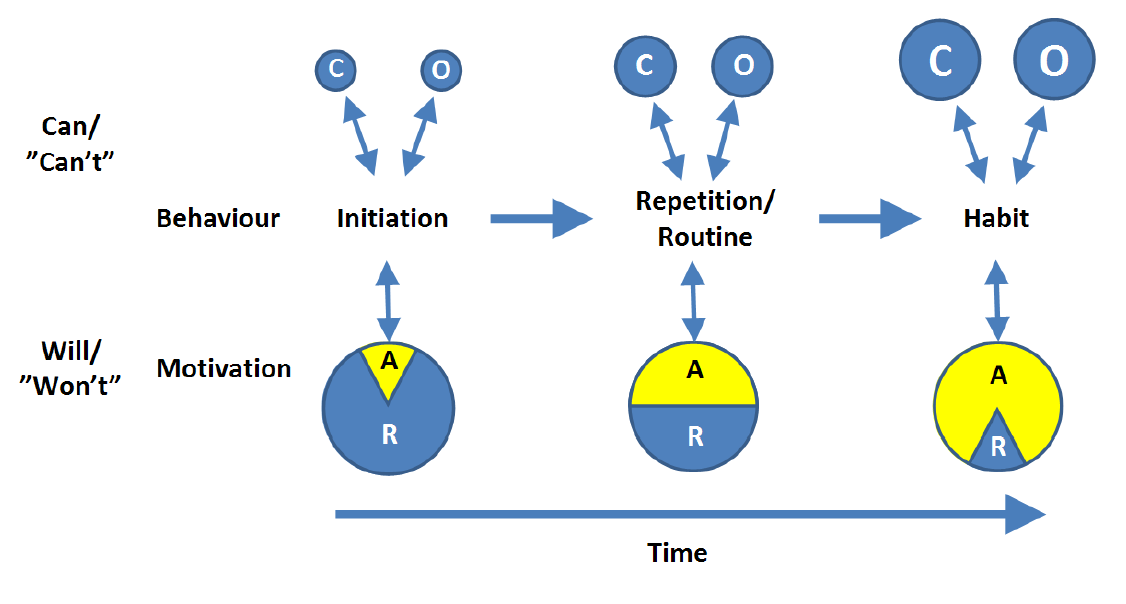
The Qualcomm hub (Qualcomm; Cambridge, UK) is a wireless device which acquires data from the eTrack nebuliser device and transmits it to a cloud-based data centre. It is a Class I MDD and CE registered in Europe. It is designed, developed and manufactured in accordance with a quality system compliant with ISO13485 standards, meaning it aligns with the quality requirements of international regulatory agencies in the health care industry.

We anticipate the integration of the new generation eTrack in late 2022. This new eTrack nebulizer device includes a built-in feature for adherence monitoring and therefore includes a Bluetooth® and Wi-Fi chip and an internal clock. Nebulisation data is transferred after each nebulisation either via Bluetooth to the PARI Connect app installed on a mobile phone device, or via Wi-Fi directly to PARI’s cloud. Transfer of nebulisation data from PARI’s cloud to the CFHealthHub platform can then be initiated by the patient within the PARI Connect app and is completed via a secure internet connection.

## CFHealthHub

CFHealthHub is an online portal which displays adherence data and provides behaviour change resources and tools for PWCF, these tools used alongside trained CF health professionals support changes in patient self-management (nebuliser adherence). It is available on-line via computers, tablets or mobile phones. Previous research has focussed on the development of an adherence intervention for PWCF (CFHealthHub) and is subject to ongoing evaluation. These work packages have been supported by an NIHR applied programme grants (Reference RP-PG-1212-20015).

The CFHealthHub modules which support behaviour change and habit formation for self-management are mapped to the COM-B theoretical framework are summarised in fig 2 and table 1. Yet, it is important to emphasise that the functionality CFHealthHub provides within the RCT is distinct from the functionality provided in the Digital Learning Health System. In the RCT the patient facing platform provides structured behaviour change to support adherence. Within the Digital Learning Health System CFHealthHub is providing a clinician facing data display of metrics which help clinicians understand the performance of the local unit in delivering high quality support for patients to self-manage their CF. Within the Digital Learning Health System the key metrics include a real time understanding of adherence across the unit and how this is changing and the proportion of patients in the centre willing to share identifiable data with the clinical team. CFHealthHub will also allow clinicians to look at all patients within a centre ranked by adherence rate and lung function decline to help identify the patients needing support. CFHealthHub also monitors clinician use. These metrics are fed back to clinicians and the research team as measures of engagement. This distinction is important as the utility of the Digital Learning Health System is not dependent on the success of the patient facing modules within the RCT. If the patient facing modules happened to be ineffective in supporting adherence the Digital Learning Health System would then provide a platform within which refined behaviour change modules might be tested in the future. In this way the utility of the Digital Learning Health System is independent of the results of the RCT.



A= Automatic, R= Reflective, C= Capability, O=Opportunity

Figure 2: Interplay between COM-B components during habit formation

**Table 1:** CFHealthHub modules, theoretical behaviour change (COM-B) and theoretical domains framework

| **Module** | **COM-B** | **Intervention functions** | **Behaviour Change Techniques** | **Mode of Delivery** |
| --- | --- | --- | --- | --- |
| ***Universal parts of the CFHealthHub*** | | | | |
| **Self-monitoring** | Psychological capability  Reflective Motivation | Education  Environmental restructuring  Enablement | * Self-monitoring of behaviour * Adding objects to the environment (CFHealthHub) | * Charts of objective adherence data presented within CFHealthHub |
| **Goal setting & review** | Psychological capability  Automatic motivation | Enablement  Incentivisation | * Goal setting (behaviour) * Feedback on behaviour * Discrepancy between current behaviour and goal * Review behavioural goals * Graded tasks * Social reward | * Discussion and agreement of goal with interventionist * Review of goal * Feedback on progress (through CFHealthHub and interventionist) * Visual reward if goal met on CFHealthHub |
| **Treatment plan** | Psychological capability  Physical Opportunity Social Opportunity  Automatic motivation | Training  Environmental restructuring  Enablement | * Action planning * Habit formation * Prompts/cues (tailored) | * Action planning tool within CFHealthHub * Option to set reminders |
| **Confidence building** | Reflective Motivation | Persuasion | * Focus on past success | * Interventionist encouraging focus on periods of higher adherence on charts |
| ***Tailored parts of CFHealthHub (based on baseline COM beliefs and barriers questionnaire (COM-BMQ)***[[1]](#footnote-2) ***and consultation with CFHealthHub researcher*** | | | | |
| **My treatment** | Reflective Motivation  Psychological capability | Education  Persuasion  Modelling | * Information about health consequences * Credible source * Salience of consequences * Demonstration of the behaviour * Vicarious consequences * Self-talk | * Q&A linked to information within CFHealthHub (tailored by baseline beliefs and prescription data) * Presentation though text, patient stories, 'talking heads' and animation * Credible sources including clinicians, PWCF and interventionist * Interventionist eliciting self-talk through focus on why motivation is not lower than rating given on pre-screening questionnaire |
| **Confidence building** | Reflective Motivation | Modelling  Persuasion | * Demonstration of behaviour | * 'Talking heads' videos of coping stories within CFHealthHub |
| **Problem-solving (including skills training)** | Physical capability  Psychological capability  Physical opportunity  Social opportunity | Training  Environmental restructuring  Enablement | * Instruction on how to perform the behaviour * Demonstration of the behaviour * Behavioural practice/rehearsal * Problem solving * Restructure the physical environment * self-talk * social support (practical) | * Tailored problem solving guided by interventionist * Solution bank within CFHealthHub. * Construction of if-then coping plans * Videos demonstrating correct use of nebulisers within CFHealthHub |

# Participants and Study Setting

## Locations

UK specialist CF units will be offered the NHS CQUIN funding which supports the CFHealthHub Digital Learning Health System. This funding initially supported CFHealthHub in Sheffield, Nottingham and Southampton and Poole however, it is now facilitating the use of the Digital Learning Health System in a further 12 centres across the UK – Birmingham, Blackpool, Bristol, Exeter, Lewisham, Newcastle, Norfolk and Norwich, Oxford, Plymouth, Stoke, York and Hull and Southampton Children’s.

## Participant Eligibility Criteria

### Inclusion criteria for participants

1. Diagnosed with CF and with data within the CF registry
2. Aged 16 years and above
3. Current taking, or willing to take inhaled mucolytics or antibiotics via a chipped nebuliser (e.g. eTrack or I-Neb), and/or taking any form of medication for CF from which a Medicine Possession Ration (MPR) can be calculated.

### Exclusion criteria for participants

1. Lacking in capacity to give informed consent

## Sampling

All CF centres will have the opportunity to accept the NHS CQUIN funding which will support the project activities. All patients using chipped nebulisers may join the Digital Learning Health System, resulting in a potential sample of up to 10,500 patients with CF in the UK.

## Recruitment and Screening

PWCF from CF units will be identified through the local site CF registry. The CF registry will apply the eligibility criteria to participants held on the unit registry data set and provide a pseudo-anonymised participant list to the site. The local CFHealthHub researcher or a member of the direct clinical team researcher will use this list to check the inclusion and exclusion criteria against information held in patient notes and where eligible will post an information sheet and consent form to invite the patient to participate in the study

## Informed Consent

The informed consent appointment will be conducted face to face with the local CFHealthHub Researcher, at the CF centre or at the patients’ home. An optional telephone call to the patient, from the local CFHealthHub researcher or a member of the CF clinical team, may be conducted to arrange the consent appointment after the postal invitation has been sent. Due to the COVID-19 pandemic, consent appointments may be conducted over the telephone to reduce the risk of unnecessary patient contact. The CFHealthHub researchers will use the audio consent form provided (which includes a telephone script).

Informed consent will be taken by the local CFHealthHub researcher or CF team member, in accordance with Good Clinical Practice, who will have received training on the consent procedures for the project and whom have been delegated informed consent duties on the local delegation log. The original consent form at each local site will be held in the local Investigator Site File (ISF) and the responsibility for the maintenance of the ISF will be that of the local site. The original consent form will be scanned and emailed to the central research team at Sheffield Teaching Hospitals via a secure NHS.net mailbox. Two copies of the consent form will be made, one to be given to the participant at the time of consent and a copy to be stored in the participant’s medical notes. The patient’s GP will be informed on their participation in Digital Learning Health System by letter. Where telephone consent has been conducted, a copy of the audio consent form will be posted to the participant.

Participants will be presented with a variety of options for consent to the study (table 2) and will be in control of their consent options throughout the study. These can be amended via a submission of a participant withdrawal form (see section 5.7) by the local CFHealthHub researcher. Throughout participation in the Digital Learning Health System, participants maintain their ability to turn on/off sharing identifiable data with their clinical team

Table 2: Consent requirements for the study

|  |  |  |  |
| --- | --- | --- | --- |
| **Activity supported** | **Consent statement** | **Consent required** | **Consent optional** |
| Quality Improvement ‘and’  Trial within cohorts (TWiCs) | Share data from my existing nebuliser, patient notes | \* |  |
| CF team to contact me via mobile phone (calls and texts), emails, and Skype to discuss the study and my adherence. | \* |  |
| Share their CF registry data and conversely allow for CFHealthHub data to be shared with CF registry | \* |  |
| Contribute existing data stored within CFHealthHub to be added to the CFHealthHub Digital Learning Health System project | \* |  |
| Quality Improvement | Allow CFHealthHub to record personal details, adherence data, CFHealthHub usage data, and other data stored within CFHealthHub such as behaviour change data | \* |  |
| Contribute pseudo-anonymised data to centre level aggregated data | \* |  |
| Allow the local CF clinical team to view patient identifiable data on CFHealthHub to be used for routine care |  | \*  (modifiable within CFHealthHub) |
| TwiCs | Contribute pseudonymised data for future non- randomised research studies related to CF |  | \* |
| Consent to be included in randomisation for future research studies |  | \* |

## Uncontactable participants

Where the local CFHealthHub researcher opts to call participants to discuss participation in the project and book consent appointments, approximately three attempts to contact the patient via telephone will be made. This can include a call outside of normal working hours and also permits the use of confidential voicemail message to a personal mobile number. Individuals who remain uncontactable will be offered a final opportunity to participate in the study when attending the CF centre for routine care.

## Re-approaching patients who decline or withdraw

Patients who are eligible to participate in the Digital Learning Health System may initially decline to participate, yet during routine care for CF the clinical team may decide to re-approach the patient where adherence support is required. These patients will be screened against the most recent local CF registry data and provided with an invitation letter, PIS and consent form, prior to taking informed consent (*see section 5.5*).

## Screening new patients

New patients who transition or are transferred to sites participating in the Digital Learning Health System will be screened on transition/transfer. In the absence of local CF registry data, the CFHealthHub researcher will contact the CF team responsible for previous care to obtain their most recent annual review data to complete screening. These patients will then be sent an invitation letter and follow consent procedures *(see section 5.5).*

## Participants from the CFHealthHub RCT

There will be a two phased approach for participants from the CFHealthHub RCT (IRAS 218519, REC reference 17/LO/0035).

**Part 1: Consent of RCT intervention and control arm participants**

CFHealthHub RCT intervention group participants will be screened and sent the study information (section 5.4) prior to a scheduled RCT study visit. The interventionist, who is already employed at each participating CF centre, will call the participant in advance to confirm their willingness to discuss participating in the Digital Learning Health System. At the scheduled RCT study appointment, the interventionist and patient will complete the tasks detailed in the Digital Learning Health System consent appointment (section 5.5). However, the participant will not receive a new device or any change to their CFHealthHub account. There will be no further action relating to the Digital Learning Health System for these participants until their involvement in the trial ends in June 2019.

At the end of their involvement in the trial, RCT intervention group participants will have their CFHealthHub accounts transferred from a ‘CFHealthHub RCT’ account to a ‘CFHealthHub MDT’ account. All existing data will be transferred automatically into the new account. The participant will keep the same account details (username and password) and continue to use their chipped nebuliser as normal; however they may notice some new features in CFHealthHub.

*RCT control participants*

Prior to the final RCT study visit (estimated around June 2019), the RCT control group will be screened and sent the study information as per section 5.4 of this protocol. If interested in participating in the Digital Learning Health System, their current CF centre interventionist will arrange to complete the consent appointment at the end of the final RCT study visit. It is important that this consent takes place after the final RCT data collection, so as to not bias the outcomes of the RCT. At the appointment the control group participant will be given access to CFHealthHub and offered adherence support as required. This group will continue to use their chipped device as normal.

**Part 2: recruitment of new study participants (June 2019 – onwards)**

From June 2019 (after RCT data collection is complete), new patients from transitioning RCT sites can be recruited into the study. Patients may use etrack or ineb devices. CF Centres will be able to purchase new etrack devices if their Trust is part of the national PSS CF Self-Care CQUIN funding, or self-funding. Specific project milestones for CQUIN centres are detailed in the PSS CF CQUIN document. The process for recruiting new patients is as detailed in this protocol (section 5).

Some Trusts may be unable to take up the CQUIN funding. In this situation will we endeavour to secure excess treatment costs to cover the interventionist salary and data transfer fees for etrack devices already in use at the centre. Trusts may also self-fund if they are able to cover the minimum costs.

## Participants from paediatrics substudy

CF patients aged 13-17 under the care of Southampton Children’s Hospital will be invited to join the Digital Health Learning System. The previously outlined informed consent procedure will be followed however, informed assent will be obtained from the participant in addition to informed consent from their parent/guardian.

## Participant withdrawal

Participants who choose to withdraw consent to any of the minimum consent requirements (see table 2) are considered as withdrawals from the study. Participants are not required to provide a reason. Site staff will complete a withdrawal form with the participant, over the telephone or in person. The withdrawal form will be uploaded onto the study database. Any data already collected in the Digital Learning Health System will be used in any analysis unless the participant explicitly states their data should be destroyed.

## Participant transfer between sites

When transferring participants between CFHealthHub sites, the participant will retain their current I-neb/eTrack and Qualcomm hub. The devices are unassigned from the participants CFHealthHub account, and the participant is marked as withdrawn on CFHealthHub at the previous site; a withdrawal form does not need to be completed. The patient will receive an appointment with the clinical team at their new site to set up their new account and log in details, and their device(s) will be assigned to their new centre. The patient does not need to be reconsented however, a copy of their original consent form will be sent to the new site and the original consent form filed at the old site, alongside a file note documenting the date of transfer and the participant’s new pseudonymised CFHealthHub ID.

If a participant transfers to a site which does not participate in CFHH, the full withdrawal process must be followed (see 5.12).

## Patient Stories

Pseudonymised participant data from the Digital Learning Health System will be used in CFHealthHub training packages, quality improvement work and dissemination to maximise the effectiveness of these activities. Participants will be purposely sampled and approached by a member of the CFHealthHub research team to contribute their data as a ‘Patient Story’. Due to the COVID-19 pandemic, consent appointments may be conducted over the telephone to reduce the risk of unnecessary patient contact. The CFHealthHub researchers will use an audio consent form. A participant information sheet will be provided either face to face, or via post if patient contact is not safe due to COVID-19, and informed consent obtained (either face-to-face, or over the telephone). Once consented, the participant’s data will be obtained by STH NHS FT and the University of Manchester, and pseudonymised. Patient stories will be uploaded to the CFHealthHub development server by the research team at the University of Manchester. The development server maintains the security features of the live serve but is used for technical development, training and demonstrative purposes.

As an additional option on the Patient stories consent form, participants will be asked if they consent to having an interview video recorded. These videos will ask participants about their experiences of using CFHealthHub, to be used for example for educational purposes, at conferences, or for quality improvement work. Information about these videos is included in the ‘Patient Stories’ participant information sheet, the ‘Patient Stories’ consent form, and there is an additional copyright agreement for participants to sign if they are participating in this. These forms detail the possible uses of the video recorded interviews. In addition to the optional items on the consent form, if taking part in a video recorded interview, there is also a copyright agreement for the patient to sign. By signing this copyright agreement, participants are agreeing to sign over the copyright of the material to Sheffield Teaching Hospitals.

Participants can withdraw their data at any time and this will not affect their participation in the Digital Learning Health System or the care they receive from their CF centre. Participants are made aware when signing the copyright agreement, that if they decide to withdraw their video recorded interview, whilst any copies in possession will be removed, it may not be possible to remove all copies that may be in circulation.

## Health Episode Statistics Data Linkage

Attempts to reliably collect participant attendance at hospital by site staff has been unfeasible due to the numbers of patients involved in the study and the frequency of hospital appointments and admissions in CF. Therefore, the central study team will obtain data on hospital attendance and admissions through Health Episode Statistics (HES), from the NHS information centre (NHS Digital). The purpose of this additional data collection is:

1. To provide a metric of the ‘engagement’ of the clinical team for quality improvement projects and process evaluation. HES data will provide attendance at clinic of study participants, and be linked with ‘click analytic’ data collected automatically by CFHealthHub. The data will be linked to understand whether CFHealthHub is being delivered in routine clinical encounters.
2. To reliably identify periods of admission to hospital for study participants. This will replace the collection of exacerbation data by the clinical team and allow future health economic analysis for the cost effectiveness of CFHealthHub use for the clinical team.

For new participants, an information sheet and consent form for HES data linkage will be provided alongside the study participant information sheet and consent form. Consent to HES data linkage is optional and does not impact the participant’s involvement in the study. Existing participants from phase 2 and 3, Southampton, Nottingham and Sheffield (see legacy diagram) will be sent the information by letter, along with the standard wording updates relating to the General Data Protection Regulation (GDPR). At a follow up clinical or intervention visit participants will be invited to complete the optional consent form.

Access to HES data will be through an application to the relevant NHS information centre. The purpose of obtaining participant consent is to demonstrate the acceptability of HES data linkage, without requiring a further application to the Confidential Advisory Committee (CAG). Future trials that use the Digital Learning Health System platform will be required to submit additional requests to NHS digital.

# CFHealthHub Digital Learning Health System

## Training for local CFHealthHub researchers and the CF team

The Local CFHealthHub researcher(s)[[2]](#footnote-3) will receive training related to CF care, CFHealthHub, Behaviour change methodology and Quality Improvement (section 6.5) to support the activities of the study and importantly support participants to self- manage their CF using the CFHealthHub software. We anticipate the training requirements will vary, depending on the background and previous experience of the individual undertaking the CFHealthHub researcher role. We will develop a bespoke training package to researchers at the first three sites, with a view to developing standardised training strategies as the project develops.

For a CF centre to provide greater adherence support to patients, it is necessary to cascade the CFHealthHub training across the wider team. This will be developed as part of the quality improvement paradigm but will be led by the local CFHealthHub researcher at each participating site and the central researchers.

## Participant ‘set up’ in the Digital Learning Health System

Once consent has been provided, the CFHealthHub researcher provides the equipment and access to for the participant to engage with CFHealthHub. This can occur at the consent appointment, or at a separate time, and set up occur in person, over the telephone and supported via written documentation (e.g. standard instructions provided by device manufacturer). Set up arrangements will be tailored to patient need and convenience.

Key activities within set up include:

1) Physically providing equipment and supporting the patient to use it

2) Supporting the patient to use CFHealthHub and personalising the content which is related to

3) Completing a behaviour change questionnaire (COM-BMQ with the patient) to populate the 'My toolkit' and ‘My treatment’ sections of CFHealthHub with tailored behaviour change information relevant to their motivational status and beliefs, and 4) Check pseudomonas status and enter current prescription.

All patients will be asked to complete the COM-BMQ, a single item on the automaticity of their adherence behaviour from the Self Report Behavioural Automaticity Index (SBRAI) and rate their effort to take their nebulisers on a 7-point Likert scale. This data will be added to CFHealthHub and allow a targeted adherence behaviour change information. Other data to add to personalise the adherence data views and content include, and prescription and pseudomonas status.

## Ongoing support/contact for Participants

Two months after participant set up the local CFHealthHub researcher, members of the CF team, or member of the CFHH central team trained to deliver CFHealthHub behaviour change support may work with the participant to support adherence. For new participants joining after 2019 there is no period between set up and delivery of adherence support. The contact with the CFHealthHub interventionist will be decided by the local participating site and may continue throughout the study;

### Delivering the Behaviour Change Intervention

The CFHealthHub researcher and trained members of the CF team will support participants to use CFHealthHub, for example update information resources, problem solve and develop action plans. This may involve supporting patients intensively (e.g during an acute period of being unwell) or over a long period of being unwell. The style of support will vary between centres, the context and preferences of the patient and clinical team. Ongoing support may require patients to repeat the data collection (see table 3).

### Troubleshooting

Participants mayexperience difficulties using the CFHealthHub and the associated technology during the project and may require support to resolve any issues. Queries may also arise from communication with the researchers (STH NHS FT and University of Manchester) which may require the local CFHealthHub researcher to follow up queries with the Participant in person or over the telephone.

## Development of the CFHealthHub platform

The development of the CFHealthHub software is led by programmers at the University of Manchester, and supported by the Project management group. Local CFHealthHub researchers may be invited to meetings which discuss the development of the software. Local researchers may also identify opportunities to feedback development opportunities as the result of their ongoing engagement with CFHealthHub in routine care or resulting from local quality improvement work.

## Quality Improvement (QI)

QI projects will support CF teams to use data within CFHealthHub as part of their routine care, in accordance with the conceptual idea that CF care and patient outcomes can be transformed with the availability of adherence data21. CF care is regarded as an exemplar healthcare context for QI22, where the dynamic, iterative changes in healthcare processes are supported by a healthcare system which obtains regular data on indicators of patient health, for example FEV1 and BMI23.

We will adopt a novel approach to QI within CF care adopting the process measure of adherence, usually unavailable to clinicians but collected within CFHealthHub, to understand the quality of care delivered by a CF centre. We hypothesise that CF centres where a greater number of patients self- manage their CF, achieving higher levels of adherence may experience fewer exacerbations resulting in fewer inpatient stays. This supports PWCF to stay well for longer and is more affordable to healthcare services (Fig. 3) Therefore QI projects focussed on understanding adherence behaviour and how to deliver healthcare which supports PWCF to self-manage, within an evidence based and replicable behaviour change framework (COM-B1) is highly valuable to the CF community.

We will obtain baseline information via a questionnaire from each participating site to understand their current adherence strategies with patients. Then CF teams led by the local CFHealthHub researcher will be supported by a team of QI coaches to undertake QI work throughout the project. As the number of sites participating in the Digital Learning Health System increases, we will adapt the delivery of QI work, supporting CFHealthHub researchers to continue with QI work and tapering the face to face input from the QI coaches. We will adopt a QI collaborative approach, utilised widely in healthcare contexts (Øvretveit 2002), where a network of CF centres will share change ideas for PDSA cycles and reflections on implementation, to generate best practice materials for future CFHealthHub QI projects.

### Microsystems Coaching

Quality improvement projects will utilise the Clinical Microsystem methodology developed by the Dartmouth Institute, USA (Nelson, Bataldan and Godfrey 2007) and adopted by the Sheffield Microsystem Coaching Academy (MCA). The Sheffield MCA (<http://www.sheffieldmca.org.uk>) has trained 143 microsystem coaches to deliver structured quality improvement based upon key quality improvement activities (figure 3). This approach advocates that complex health systems can be reduced to smaller building blocks called ‘microsystems’ where multidisciplinary teams deliver healthcare to patients. At each microsystem a number of QI projects may occur but the implementation requires the completion of four phases; Assessment, Diagnose, Treatment and Standardise, where tools such as assessment using the 5 P’s (Purpose, Patients, Professionals, Processes, Patterns) process mapping, time series measurements, Plan Do Study Act (PDSA) cycles are utilised until the change idea has been adapted or has become embedded into the microsystem24

### Metrics and tests of change

Quality improvement ideas will be generated by the CF centre team and developed with the QI coaches. However, we anticipate there are key metrics related to QI related to the overall adherence measured at centre level (pseudonymised aggregate data) and the proportion of patients who are willing to share individual identifiable data with the clinical team. We perceive the willingness of PWCF to share identifiable data is an indicator of the quality of relationship between PWCF and the clinical team. These aggregate data will not contain patient identifiers and will allow unit A to compare its performance with Unit B etc. The two metrics of adherence rate and the proportion of patients within a unit willing to share identifiable data with the clinical team will be made available as aggregate quality indicators of unit performance.

An example of QI projects might for example involve a test of change whereby teams might decide to change working patterns so that team members are available to support PWCF when at times which are more convenient to them, for example outside of normal working hours. An increase in overall unit adherence would support this change in practice as an improvement in the quality of care provided by the CF team.

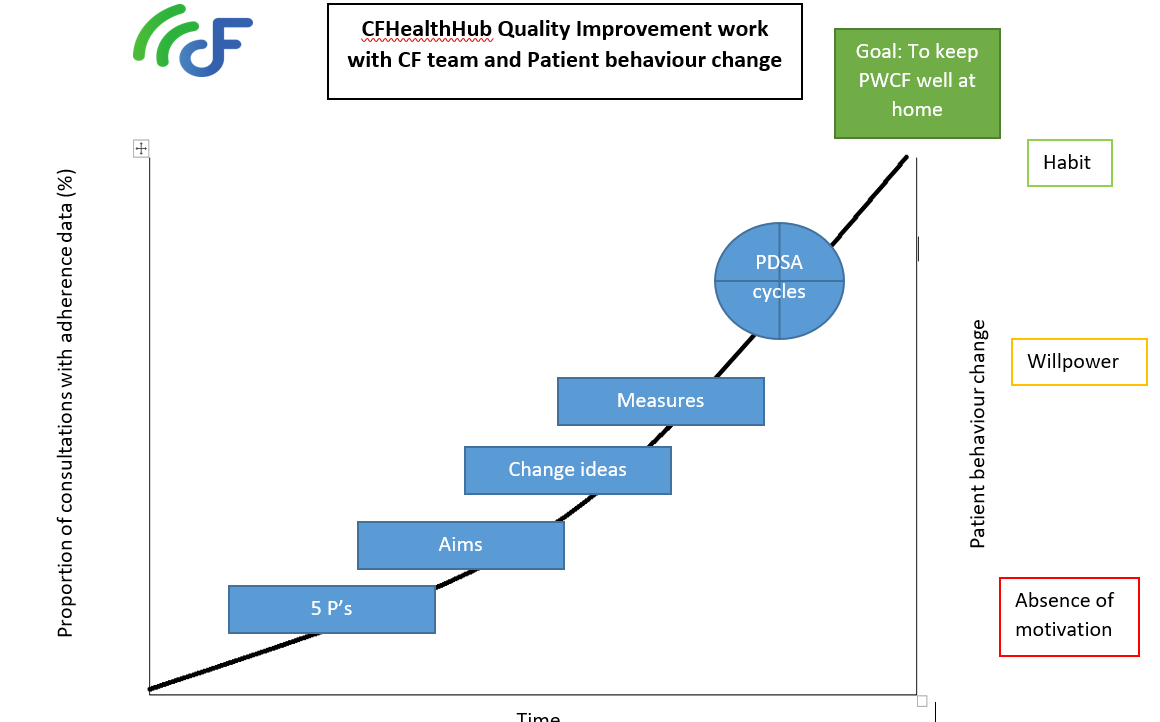


Figure 3. CFHealthHub and Microsystems coaching

## Trials within Cohorts (TWiCs) methodology

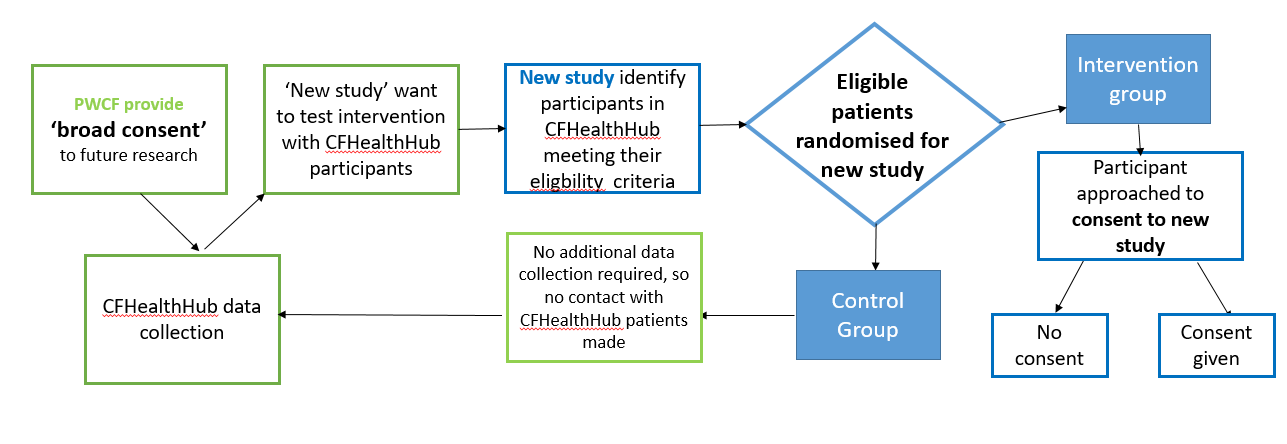
Data captured within CFHealthHub creates a cohort of CF patients to support future research via the adoption of a Trials within Cohorts methodology (also known as the cohort multiple RCT (cmRCT) design). The cohort will primarily support behaviour change research adopting a randomised design utilising data collected within the CFHealthHub Digital Learning Health System procedures, for example adherence data, clinical indicators, and behaviour change metrics. However, the CFHealthHub cohort can also support studies of non-experimental designs such descriptive studies (cross sectional and qualitative) and observational studies.

TWiC’s methodology is pragmatic, and may support researchers to overcome some of the traditional issues associated with conducting traditional RCT’s designs in rare diseases, such as a low number of eligible participants, poor recruitment resulting in sub-optimal statistical power, poor external validity, and reduce the distress and anxiety which can result from randomisation to usual care20,25,26. The context of CF as chronic condition may also lend itself favourably to the adoption of TWiCs designs fulfilling criteria from Relton et al, such as; PWCF are an ***easily defined and identified population, improvements to treatment is highly desired*** due to the early age mortality rate and high costs of care and finally, ***future pragmatic trials are likely to compare an intervention or treatment with ‘usual care’***26*.*

## Procedures for the CFHealthHub Cohort

### Participant Consent to future research

To perform the key function of TWiCs design which allows PWCF to be screened against study eligibility criteria and to be randomly allocated to the intervention or control group, PWCF will undergo a ‘two-stage’ consent process (figure 4). First, when consenting to the CFHealthHub Digital Learning Health System PWCF could agree to be selected for future research (see table 2), which we term ‘broad consent’. Second, if this participant meets the eligibility criteria for a hosted study and is randomised to the intervention group, they will be contacted by the CFHealthHub research team and provided with the new study invitation letter, participant information sheet and consent form. Consent to the new study must be provided to receive the intervention. Participants will be reminded throughout that they can decline participation to the new study with no impact on their chances to be selected for future studies. Participants can also decide to withdraw from the cohort for future research, without impacting their use of CFHealthHub or any other terms of consent.



**Figure 4**. TwiCs two-stage consent procedure

Some participants who consent to future research will be randomised to the control group. If participation in the control group requires no change to their data collection within CFHealthHub these participants will not be approached for consent and they will not be informed of their participation in the control group. This is consistent with other cohorts20,25, and on consultation with patient and public representatives was unanimously found to be an acceptable procedure. However a website will be maintained that publishes the results of studies carried out within the Digital Learning Health System and publicity will provided periodically to allow patients to view study findings.

### Quality assurance of supported research studies

Studies supported in CFHealthHub will be subject to a high level of appraisal which incorporates traditional research governance and ethical approval required for all studies and additional scientific appraisal from the CFHealthHub researchers. We envisage the CFHealthHub researchers will support research teams to develop high quality protocols, demonstrate a high level of scientific rigor, ensure the optimal security of the patient data, and are shaped by patient and public involvement. Researchers will then be required to obtain ethical approval from an NHS Research Ethics Committee, or other recognised Research Ethics Committee, along with other research governance requirements appropriate to the study design.

### Data security and supported research studies

Where participants have consented to take part in future research studies they are required to provide their contact details to the CFHealthHub researchers. If a participant is randomised to receive an intervention thus requiring new study information to be posted to the participant, or contacted via the telephone, the initial invitation and any subsequent contact to recruit the patient to the study can be made by a member of their local CF team or the CFHealthHub researchers. Contact details will not be transferred to the new research team unless permission is obtained from the participant.

Data which is transferred from CFHealthHub for supported research will be pseudonymised and encrypted prior to transfer. Details of how the data will be transferred and stored within the new study will form part of their study protocol and patient materials which will undergo assessment to ensure patient confidentiality and data security is respected at all times.

## Medicines Optimisation

The medicine possession ratio for high cost inhaled therapy in adults in the UK is reported as 63% whereas actual objectively measured adherence is reported as 36%. As homecare companies deliver a greater proportion of medicines there is the possibility of waste. The following work packages described here have been mandated as part of NHS England CQUIN funding for the Digital Learning Health System.

CFHealthHub will develop modules to support the use of time and date stamped drug use data to guide homecare deliveries so that the MPR approaches actual use thus avoiding waste. This CFHealthHub functionality will also support patients in the Lind alliance survey priority of simplifying the administration of medications to ensure just in time availability. Based on initial analysis with CF pharmacists participating in the Digital Learning Health System, the annual enduring saving is modelled at £708 per patient.

We will explore how CFHealthHub adherence data can support intelligent commissioning around new generation antibiotics. New generation inhaled antibiotics (Aztreonam and Levofloxacin) cost in the region of £12K per patient per year whereas colomycin costs in the region of £1.1K per annum. Specialised commissioning guidance suggests that patients should only escalate to the more expensive new generation inhaled antibiotics if patients cannot tolerate the first line antibiotics or are deteriorating.

However, given that median adherence to inhaled antibiotics is in the region of 36%, a significant amount of treatment failure is likely to result from non-adherence. In the context of non-adherence, escalation from a twice daily £2k per annum drug to a more complex thrice daily regime with £12k per year drug is unlikely to deliver patient benefit. Reducing inappropriate variation in the use of high cost third and fourth line medication might save hundreds of thousands per annum. CFHealthHub can automatically provide adherence data to support escalation decisions.

There will be a number of stages in the EMBRACE project.

1. **Understanding system waste**: local pharmacists working as part of their hospital CFHealthHub team, will use local hospital records to calculate Medicine Possession Ratio (MPR), for participants consented into the Digital Learning Health System. Objective adherence data will be available from CFHealthHub (if participants have data sharing switched on). Participant data will be only identifiable to the research team by their study ID. A cost comparison will be made between objective data and MPR, and an overall centre cost comparison will be reported.
2. **Developing ‘just in time’ drug delivery**: A sample of participants on ‘Dornase only’ prescriptions will be used to develop and test an algorithm for homecare delivery, based on objective adherence.
3. **Developing drug escalation protocols:** Local pharmacists working with the CF team will develop or adapt protocols for appropriate drug escalation using objective adherence data from CFHealthHub. A local PPI group will be consulted before this is implemented widely in the centre.

## Quality Improvement and embedding behaviour change intervention within clinical practice by using the NICE quality indicator for centre comparisons

NICE have approved 2 novel quality indicators using the process measure of medication adherence27,28. Previous work demonstrates how poor data quality can lead to inaccurate conclusions on quality of care29, so we want to develop confidence in the CFHH data quality. With only approximately 11,000 PWCF in the UK, over 99% of whom are registered with the CF registry30, and adults receive care at one of only 28 centres, we have accurate and accessible denominators. This allows us to investigate the reach of CFHH and provide accurate data on adherence within each centre. We hope to lay the groundwork for adherence measures, collected through CFHH, to deliver the NICE indicators and be sensitive to change, brought about by quality improvement programmes at centre-level.

There will be several aspects of the NICE indicator projects with the objectives of:

* 1. **Learning how to optimise recruitment and retention to CFHH for patients and clinical centres:** recruitment to CFHealthHub over time will be described, the reasons for the variation in recruitment levels will be explored and the factors associated with more effective recruitment and retention to CFHealthHub will be summarised
  2. **Learning to optimise adherence data completeness for those recruited:** the reasons for data incompleteness will be explored and an intervention to help increase data completeness will be designed
  3. **Developing exemplar centres with high adherence data completeness**, by iterating the intervention designed to increase data completeness: repeated ‘plan-do-cycle-act’ (PDSA) cycles31 of interventions will be carried out at a small number of centres (‘exemplar centres’) to improve data completeness and barriers encountered during the PDSA cycles will be addressed using (a) the capability-opportunity-motivation – behaviour (COM-B) structure mapped to Theoretical Domains Framework (TDF)32 (b) the Institute of Health Improvement (IHI) improvement ramp structure33.
  4. **Improving the adherence data completeness in other CFHealthHub centres** and demonstrate the reproducibility of the improvement processes undertaken in the exemplar centres: the data completeness work from the exemplar centres will be extended to other CFHealthHub centres (i.e. spread the PDSA cycles)
  5. **Determining the impact of adherence data completeness on centre-level adherence**: cohort and centre-level metrics pre- and post- optimisation of data completeness will be compared to test the hypothesis that parameter determination is unreliable with incomplete data
  6. **Understanding, developing and optimising quality indicators** (including the NICE quality indicators), so that they are useful and meaningful tools to support system optimisation across the CFHH Community: the impact of the different methods to quantify data completeness will be explored, the impact of charting Mean and Median on statistical process control (SPC) charts34, and different methods of imputing missing data (e.g. imputing 0% for those without up-to-date adherence data +/- 0% for non-recruitment) will be determined and system indicators will be iterated with input from all CFHealthHub centres.

# Sub-studies

## 7.1 Using the CFHealthHub digital learning health system to support preventative self-care for patients with Cystic Fibrosis (CF) during the COVID-19 emergency

During the COVID-19 pandemic, the way in which healthcare services were provided and accessed changed. This sub-study explores the emergency measures implemented within the CFHealthHub infrastructure to allow CF teams to continue to provide flexible adherence support to PwCF. Modifications to service provision made during this sub-study are still relevant within current CF care and continue to be implemented throughout, and in conjunction with, the CFHealthHub Digital Health Learning System. The study protocol can be found in Appendix 3.

## 7.2 Refining the CFHealthHub Behaviour Change Intervention (BCI) to help young people with CF manage treatment adherence: Paediatrics Acceptability Sub-Study

The Paediatrics sub-study aims to explore the possible refinements and adaptations that might be required to deliver the Behaviour Change Intervention (BCI) administered as part of the main Digital Learning Health System study to Young People with Cystic Fibrosis (YPWCF). This sub-study will be conducted at a single site, the Children’s Cystic Fibrosis Service within the University of Southampton NHS Foundation Trust. A full study protocol that details background and rationale, aims/objectives, as well as the study method can be seen in Appendix 4.

## 7.3 Process evaluation sub-study

The process evaluation sub-study aims to highlight potential sources of failure in the implementation of the Digital Learning Health System by providing an overview of the experience and views of staff and participants at all participating sites. This data is to be integrated with process data already collected in order to inform large scale change. The study protocol can be found in Appendix 5.

# Data Collection and Management

## Data collection sources

To ensure CFHealthHub is a useful tool for the CF team from the outset of the study, data will be collected retrospectively from CF Registry and patient medical records by the local centre on a standardised spreadsheet. Examples of the types of clinical data will include month and year of birth, sex, ethnicity, height, pancreatic and diabetic status, FEV1, body mass index, date of starting and stopping (if applicable) Kaftrio, Pseudomonas status, medications, comorbidities, healthcare utilisation (oral and intravenous antibiotic days), adherence to Kaftrio (measured by medication possession ration) and effective adherence to preventative inhaled therapies. Existing patient data within CFHealthHub will also be retained and adherence data from existing nebuliser devices (including data prior to participants’ consent date) will be added to CFHealthHub for the purpose of analysis. In addition, prescription data including which and how medications are used will be collected to ensure nebuliser use data can be analysed appropriately and to determine the number of doses used.

Table 3. Sources of patient Data within CFHealthHub Digital Learning Health System

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | **When will data be obtained?** | | |
| **Data Source** | **Data recorded** | **Screening** | **Consent/ Baseline** | **Review** |
| CF Registry | Pseudonymised ID, patient data; prescription, lung function, Body Mass Index, number of IV days, pseudomonas status diabetes status, deprivation index, lung transplant status) | x | x | x |
| Patient medical records | Personal data; name, contact details, NHS number, DOB. |  | x | x |
| Lung function, prescription data, Height and weight, pseudomonas status, exacerbations, sweat chloride (as a surrogate for adherence to CFTR modulator, based on the clinical commissioning policy of NHS England35), medication possession ratio |  | x | x |
| Existing nebuliser devices | Number of inhalations, date and time of inhalations |  | x | x |
| Prescription data | Including which and how medications are used |  | X | X |
| CFHealthHub | Behaviour change data, usage metrics, adherence data. |  | x | x |
| Patient reported | COM- BMQ, habit score and effort score, participation in other research |  | x | x |
| Health Episode Statistics | NHS identifier, clinic appointment date and attendance, hospital admission date, length of stay. |  |  | x (if optional consent has been obtained) |

## Data handling and record keeping

The University of Manchester and the STH NHS FT will oversee data collection, management and analysis and ensure the study is undertaken according to Good Clinical Practice Guidelines and STH NHS FT standard operating procedures. Data will be collected and retained in accordance with the Data Protection Act and General Data Protection Regulations. Patients will be reassured that all data which are collected during the course of the research will be kept strictly confidential

Data will be collected directly from the participants, CFHealthHub software, source documents (e.g. patient notes), or external sources (e.g. CF Registry). Pseudonymised screening and recruitment data will be collected for all participants, with patient contact details collected for those who consent to participation. Screening and recruitment data collected on CRF’s will be entered into CF HealthHub. All other data collected in the Digital Learning Health System will be captured in CRF’s and entered into CFHealthHub directly.

Health Episode Statistics (HES) data will be stored securely at STH NHS FT in accordance to data protection laws and requirements set out by NHS information centre (NHS digital). Data linkage procedures will be outlined in the data request application.

The Data Monitoring and Management Plan for the study will provide further guidance on the types and levels of data and how these will be monitored and verified. Some essential documents may be posted to the central team to facilitate this e.g. participant consent forms in which case this will be detailed in the appropriate participant PIS and consent forms.

Data capture will be monitored indirectly both by the local CFHealthHub researcher, CF team and central researchers at the University of Manchester. We envisage that where a patient treatment plan involves CFHealthHub they receive more intensive support to utilise the functionality or receive prompts for to review their data, outside of routine care encounters.

## Data Management

### University of Manchester

All participant data is held within CFHealthHub, and The University of Manchester shall provide and maintain the CFHealthHub software and CFHealthHub databases containing participant data. Software and personal data within CFHealthHub may be hosted within a secure environment at the University of Manchester site or storage may be sub-contracted to a third party with authorisation from the sponsor and under the terms of the Agreement. CFHealthHub complies with the Data Protection Act and follows best practice guidelines on security and information governance and has been subject to rigorous security testing. Encrypted channels are used to transfer any data to and from the web and mobile application platforms. All user interaction with the CFHealthHub server and each action performed by a user will be logged. An audit log contains the username of the user performing the action, the date & time of the action, and a short description of the action performed. All users are authenticated via a secure password with access to the system restricted on a role basis.

### Not-for-profit CFHealthHub Company

In order to ensure the legacy of CFHealthHub is secured for the future, it is hoped that the CFHealthHub platform will transition from the University of Manchester and Sheffield Teaching Hospitals to a standalone Community Interest Company (CIC) which will function on a not-for-profit basis. The community interest company is required to ensure that all the staff needed to maintain CFHealthHub are employed into the future and extensive work with NIHR has led to the conclusion that the optimum strategy to ensure implementation is via a not-for-profit CIC. The CIC ensures that any revenues that accumulate must be used for the community which is defined at the time the CIC is set up. For which, the CF community have been defined as the beneficiaries of the CIC. CFHealthHub board members responsible for the oversight and day to day running of the CIC will ensure the future of the platform. The CIC will be governed by exactly the same data security and protection arrangements as within the period prior to the establishment of the CIC and operational functions will be contracted to the University of Manchester with a board and governance arrangements that will ensure resilience and continuity.

## Data Analysis

The analysis will be performed at regular intervals by a statistician from the University of Manchester under the supervision of the senior study statistician who will develop a statistical analysis plan with the input of the CI and the wider research team.

The data analysis will consist of two components, 1) quantitative and 2) qualitative. The quantitative component will involve using objective nebuliser data to explore the process of habit formation with the delivery of the adherence intervention36-41, explore the determinants of adherence and to determine the association between adherence and health outcomes. In addition, we will explore the relationship between system features and system optimisation. The analyses will include:

1. Description of patient characteristics, including age, gender, Pseudomonas status, socioeconomic status etc
2. Description of treatment characteristics, including number of doses, duration of doses etc
3. Exploratory analyses to understand the utility of various measures (e.g. the various definitions of Pseudomonas status) within the Digital Learning Health System
4. Generating objective habit scores by taking into account data and time of nebuliser use
5. Using statistical process control (SPC) to identify when periods of stability are achieved
6. Time-series methods, including cross-correlation between habit scores and adherence
7. Examining the independent effects of predictor variables (patient and institution factors) on adherence and system optimisation using random-effect multi-level model
8. Comparing FEV1 decline, intravenous (IV) use and other health processes & outcomes among people with differing levels of adherence
9. Comparing the costs of medication supplied (as measured by MPR) with the costs of medication consumed (objective adherence)

The qualitative aspect of this project include understanding, developing and optimising quality indicators to support system optimisation across all CF centres within the Digital Learning Health System. We will also be conducting literatures reviews to understand the impact of complex behavioural interventions on behavioural process measures, as well as clinical outcome measures. Part of the qualitative work will also include semi-structural interviews with patients to improve adherence, e.g. explore possible issues with long treatment durations. Our qualitative initiatives will be based on the Theoretical Domains Framework and “Plan, Do, Study, Act (PDSA)” cycles will be applied to optimise quality indicators, which will in turn improve patient care and quality of life.

Both our qualitative and quantitative analyses will be performed for the entire cohort (i.e. every individual in the Digital Learning Health System analysed as a single group) and also at a centre-level for the purpose of comparing the different CF centres within the Digital Learning Health System. Data will be reported and presented according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) and Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0) statements42,43. Where relevant, the detailed plan for data analysis will be pre-specified as a 'Statistical Analysis Plan' (SAP) for the individual projects.

# Monitoring and Oversight

## Management of the study

A Data Monitoring and Ethics Committee will not be convened in this study due to the low risk nature. Sheffield Teaching Hospitals NHS Trust and the sponsor of the study, have overall responsibility for the study and are the study data controller.

At each participating site, the PI local Principal Investigator (PI) will be responsible for the study, which will be registered and approved by each R&D department. The study will be conducted in accordance with the protocol, GCP and STH NHS FT Standard Operating Procedures

The Project Management Group (membership listed on the p3) will govern the conduct of the study on a day to day basis. The Manager will be jointly supervised by the CI via the form of regular meetings (face to face and telephone calls). The Manager will be responsible for liaising with the whole project team.

Monitoring procedures will be assessed based on the level of risk of the study. The Site Monitoring Plan will outline the types and frequency of site monitoring activities for the study and this will be agreed with the Sponsor prior to the start of the study.

## Harms (safety assessments)

It is not anticipated that there will be SAEs related to the use patient use of CFHealthHub, the collection of their data in a Digital Learning Health System.

## Auditing

The sponsor will permit monitoring and audits by the relevant authorities, including the Research Ethics Committee. The investigator will also allow monitoring and audits by these bodies and the sponsor, and they will provide direct access to source data and documents.

## Finance and indemnity

The study has received funding from a number of sources. Most recently, the project has been financed by NHS England CQUIN funding. Details have been drawn up in a separate agreement. This is an NHS sponsored study. If there is negligent harm during the clinical trial when the NHS body owes a duty of care to the person harmed, NHS Indemnity will cover NHS staff, medical academic staff with honorary contracts and those conducting the trial. NHS Indemnity does not offer no-fault compensation and is unable to agree in advance to pay compensation for non-negligent harm. Ex-gratia payments may be considered in the case of a claim.

# Ethics and dissemination

## Approvals

The project will be conducted subject to Health Research Authority and Research Ethics Committee favourable opinion. The approval letter from the ethics committee and copy of approved patient information leaflets, consent forms and any ethically approved questionnaires will be present in the site files before initiation of the study and patient recruitment. Local research governance approvals will be sought from all participating research sites. The project will be conducted in accordance with Good Clinical Practice Guidelines and STH NHS FT standard operating procedures.

## Amendments to the project

The categorisation of amendments as substantial or non- substantial will be guided by the Sponsor, and implemented in accordance with the HRA amendment classification. It will be agreed with each local R&D whether a letter of permission to continue is required prior to the date of amendment implementation as recommended by the HRA. The local PI and researchers will be updated following an amendment to the ethical approval, protocol or study documents. The new documents, REC approval, R&D approval and any other appropriate documentation surrounding the amendment will be sent to the site via a “site file update”. Local researchers will be required to fulfil the implementation of the amendment per guidance provided by the STH NHS FT.

## Consent procedures

Please refer to ‘Informed Consent’ in section 5.5 and section 6.7.1

## Confidentiality

Participant confidentiality will be respected at all times. Access to personal details and identifiable data will be highly restricted to key members of the study team, with all other researchers using pseudonymised data. All data transfer and will be pseudonymised.

Trial documents (paper and electronic) will be retained in a secure location at the local participating site during and after the trial has finished. All source documents will be archived for a period of 5 years following the end of the project. Each site is responsible for ensuring records are archived, in accordance with their local procedures and STH NHS FT Archiving procedures.

## Declaration of Interests

There are no interests to declare.

## Dissemination policy

A dissemination plan will be developed with the CI and STH NHS FT appropriate to needs of the wider research programme.

# References

1. Michie S, van Stralen M, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 2011;6(42)

2. De Boeck K, Amaral MD. Progress in therapies for cystic fibrosis. Lancet Respir Med. 2016;4(8):662‐674.

3. Lopes-Pacheco, M. CFTR Modulators: The Changing Face of Cystic Fibrosis in the Era of Precision Medicine. Frontiers in Pharmacology. 2020;10:1662

4. Habib AR.R, Kajbafzadeh M, Desai S. A Systematic Review of the Clinical Efficacy and Safety of CFTR Modulators in Cystic Fibrosis. Sci Rep. 2019;9:7234.

5. Parham R, Thomas S, Mills R, Al E. CF patient’s beliefs about nebuliser treatment: implications for adherence to treatment. J Cyst Fibros. 2012;11 (Suppl(S9).

6. Bucks RS, Hawkins K, Skinner TC, Horn S, Seddon P, Horne R. Adherence to treatment in adolescents with cystic fibrosis: The role of illness perceptions and treatment beliefs. J Pediatr Psychol. 2009 Sep;34(8):893–902.

7. George M, Rand-Giovannetti D, Eakin M, Borrelli B, Zettler M, Riekert K. Perceptions of barriers and facilitators: self-management decisions by older adolescents and adults with CF. J Cyst Fibros. 2010;9:425–32.

8. Dziuban E, Saab-Abazeed L, Chaudhry S, Streetman D, Nasr S. Identifying barriers to treatment adherence and related attitudinal patterns in adolescents with cystic fibrosis. Pediatr Pulmonol. 2010;45:450–8.

9. Bregnballe V, Schiøtz P, Boisen K, Pressler T, Thastum M. Barriers to adherence in adolescents and young adults with cystic fibrosis: a questionnaire study in young patients and their parents. Patient Prefer Adherence. 2011;5:507–15.

10. Modi A, Quittner A. Barriers to treatment adherence for children with cystic fibrosis and asthma: What gets in the way? J Pediatr Psychol. 2006;31:846–58.

11. Abbott J, Dodd M, Bilton D, Webb A. Treatment compliance in adults with cystic fibrosis. Thorax. 1994;49:115–20.

12. Abbott J, Dodd M, Webb A. Health perceptions and treatment adherence in adults with cystic fibrosis. Thorax. 1996;51:1233–8.

13. Abbott J, Dodd M, Gee L, Webb K. Ways of coping with cystic fibrosis: implications for treatment adherence. Disabil Rehabil. 2001;23:315–24.

14. Conway S, Pond M, Hamnett T, Watson A. Compliance with treatment in adult patients with cystic fibrosis. Thorax. 1996;51:29–33.

15. Jones S, Curley R, Wildman M. 345 Systematic review of qualitative studies investigating barriers to adherence in patients with cystic fibrosis using framework analysis structured by a conceptual framework of behaviour change. J Cyst Fibros. 2013;12 (Suppl(S136).

16. Kettler L, Sawyer S, Winefield H, Greville H. Determinants of adherence in adults with cystic fibrosis. Thorax. 2002;57:459–64.

17. Lask B. Non-Adherence to Treatment in Cystic Fibrosis. J R Soc Med. 1994;87 (21 Sup:25–7.

18. Latchford G, Duff A, Quinn J, Conway S, Conner M. Adherence to nebulised antibiotics in cystic fibrosis. Patient Educ Couns. 2009;75:141–4.

19. Horne R, Weinman J, Barber N, Elliott R. Concordance , Adherence and Compliance in Medicine Taking: Report for the National Co-Ordinating Centre for NHS Service Delivery and Organisation R & D (NCCSDO). 2005.

20. Kwakkenbos L, Jewett L, Baron M, Bartlett S, Furst D, Gottesman K, et al. The Scleroderma Patient-centered Intervention Network (SPIN) Cohort: protocol for a cohort multiple randomised controlled trial (cmRCT) design to support trials of psychosocial and rehabilitation interventions in a rare disease context. BMJ Open. 2013;3(e003563).

21. Wildman M, Hoo Z. Moving CF care from rescue to prevention by embedding adherence measures in routine care. Paediatr Respir Rev. 2014;15(sUPPL 1:16–8.

22. Quon BS, Goss CH. A story of success: continuous quality improvement in cystic fibrosis care in the USA. Thorax. 2011;66:1106–8.

23. Schechter MS, Fink AK, Homa K, Goss CH. The Cystic Fibrosis Foundation Patient Registry as a tool for use in quality improvement. BMJ Qual Saf. 2014;23(Suppl 1):i9.

24. Sheffield MCA. 2016.

25. Uher R, Cumby J, Mackenzie LE, Morash-Conway J, Glover JM, Aylott A, et al. A familial risk enriched cohort as a platform for testing early interventions to prevent severe mental illness. BMC Psychiatry. 2014;14:344.

26. Relton C, Torgerson D, O’Cathain A, Nicholl J. Rethinking pragmatic randomised controlled trials: introducing the “cohort multiple randomised controlled trial” design. BMJ. 2010;340:c1066.

27. NICE. Adherence to nebulised therapy in cystic fibrosis 2020 [Available from: https://www.nice.org.uk/standards-and-indicators/nlindicators/adherence-to-nebulised-therapy-in-cystic-fibrosis.

28. NICE. Normative adherence to nebulised therapy in cystic fibrosis for patients with chronic pseudomonas acquisition 2020 [Available from: https://www.nice.org.uk/standards-and-indicators/nlindicators/normative-adherence-to-nebulised-therapy-in-cystic-fibrosis-for-patients-with-chronic-pseudomonas-acquisition.

29. Mohammed MA, Stevens AJ. A simple insightful approach to investigating a hospital standardised mortality ratio: an illustrative case-study. PLoS One. 2013;8(3):e57845

30. CF Trust. UK Cystic Fibrosis Registry 2021 [Available from: https://www.cysticfibrosis.org.uk/the-work-we-do/uk-cf-registry.

31. Berwick DM, Developing and testing changes in delivery of care. Annals of Internal Medicine, 1998. 128(8): 651-6.

32. Atkins L, Francis J, Islam R. A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. Implementation Sci. 2017. 12(77).

33. Langley GJ, Moen R, Nolan KM, et al. Changes that result in improvement. In: The improvement guide: a practical approach to enhancing organizational performance. 2nd edn. San Francisco: Jossey-Bass, 2009:15–25

34. Mohammed, M.A., et al., Bristol, Shipman, and clinical governance: Shewhart's forgotten lessons. Lancet, 2001. 357(9254): 463-7.

35. NHS Commissioning Board. Clinical Commissioning Policy: Ivacaftor for Cystic Fibrosis. 2012 [Available from: https://www.england.nhs.uk/wp-content/uploads/2013/04/a01-p-b.pdf]

36. Hoo Z, Gardner B, Curley R, Wildman M. Part I : Understanding the variation in adherence with nebulised treatment in Cystic Fibrosis. J Improv Sci. 2013;9(1–10.3).

37. Hoo Z, Gardner B, Curley R, Hinchliffe C, Wildman M, Zhe A, et al. Part II: Methods to Deliver a “Personalised” Behaviour Change Intervention to Support Adherence with Nebulised Treatment. J Improv Sci. 2013;10:10.

38. Hoo Z, Gardner B, Curley R, Wildman M. Part IV: Using Process Behaviour (XmR) Charts of I-neb Adherence Data to aid the “Personalisation” of a Behaviour Change Intervention. J Improv Sci. 2013;13:1–12.

39. Hoo Z, Wildman M, Curley R, Hinchliffe C, Gardner B. Part V: Time of Nebuliser Use and the Process of Habit Formation. J Improv Sci. 2014;16:1–10.6.

40. Hoo Z, Wildman M, Curley R, Gardner B. Part VI: Delivering a “Personalised” Behaviour Change Intervention to Support Adherence with Nebulised Treatment with the “PDSA cycle” at an Individual Level. J Improv Sci. 2014;17:1–7.5.

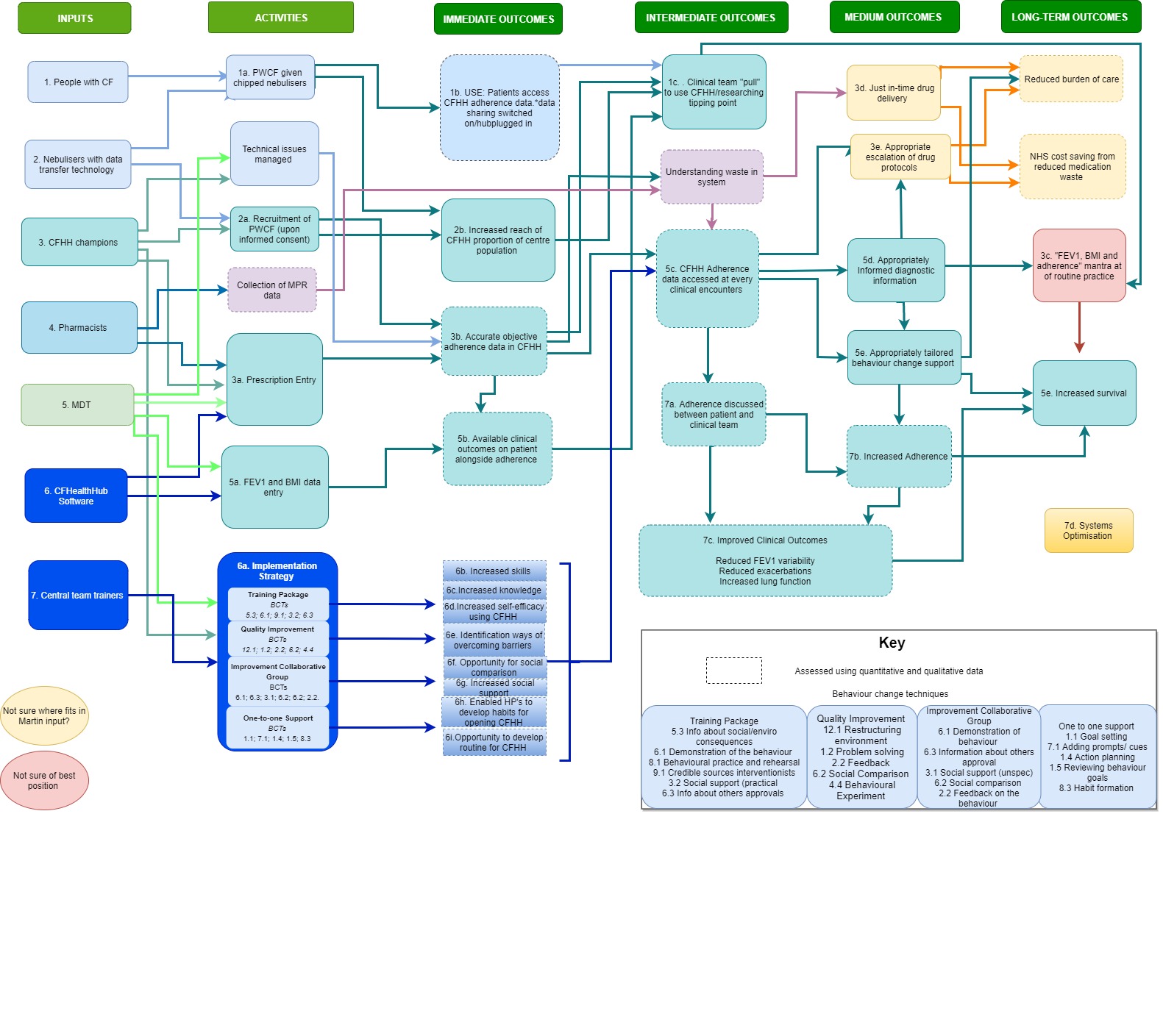
41. Hoo Z, Gardner B, Curley R, Wildman M. Part III: constructing a process behaviour (XmR) chart with I-neb adherence data for people with cystic fibrosis. J Improv Sci. 2013;12:1–12.4.

42. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet (London, England). 2007;370(9596):1453.

43. Ogrinc G, Davies L, Goodman D, Batalden P, Davidoff F, Stevens D. SQUIRE 2.0 (Standards for QUality Improvement Reporting Excellence): Revised Publication Guidelines from a Detailed Consensus Process. Can J Diabetes. 2015;39(5):434–9.

# Appendices

# Appendix 1. Logic Model



# Appendix 2. Implementation Strategy (publication submitted for review)

|  |  |  |  |
| --- | --- | --- | --- |
| Module | COM-B | Intervention functions | Proposed BCTs |
| Training package: CFHH training and adherence support training: Training resources, refresher training, shadowing, fidelity assessment by lead interventionist | Physical capability  Psychological capability  Social opportunity | Training  Education  Persuasion | * 5.3 Information about social/enviro consequences * 6.1 Demonstration of the behaviour * 8.1 Behavioural practice and rehearsal * 9.1 Credible sources * 3.2 Social support (practical) * 6.3 Information about others approval |
| Quality Improvement work: PDSA cycles and continuous metrics feedback | Physical opportunity  Reflective motivation  Automatic motivation | Education  Environmental restructuring  Enablement | * 12.1 Restructuring physical environment * 1.2 Problem solving * 2.2 Feedback on behaviour * 6.2 Social comparison * 4.4 Behavioural experiments |
| Improvement Collaborative group: Peer support, multicentre events, share success stories, problem solve together | Reflective Motivation  Social Opportunity | Persuasion  Modelling  Enablement | * 6.1 Demonstration of behaviour from influential figures * 6.3 Information about other approval * 3.1 Social support (unspecified) * 6.2 Social comparison * 2.2 Feedback on the behaviour * 1.2 Problem solving * 15.3 Focus on past success |
| One to one support from trained interventionist: Goal setting, identifying prompts/cues, action planning | Psychological capability  Reflective motivation | Training  Enablement  Environmental restructuring | * 1.1 Goal setting * 7.1 Adding prompts/cues * 1.4 Action planning * 1.5 Review behaviour goals * 8.3 Habit formation |

# Appendix 3. Using the CFHealthHub digital learning health system to support preventative self-care for patients with Cystic Fibrosis (CF) during the COVID-19 emergency

## Background

* During the COVID-19 pandemic, optimum adherence to preventative inhaled medication will reduce exacerbations and, in the event of COVID-19 infection, likely improve outcomes.
* During the COVID-19 pandemic, clinic visits will be minimised and CFHealthHub (CFHH) provides a tool that offers an alternative to clinic visits which is proven to significantly increase self-care to inhaled preventative therapies. This can be delivered via web and app.
* This protocol outlines how the CFHealthHub infrastructure will be reconfigured to provide bespoke support to individual CF teams across the UK. This is intended to allow the provision of uninterrupted self-care support throughout the pandemic, despite local teams managing high emergency workloads & staff sickness.
* Central resource will be configured in such a way that even when an individual CF centre has minimal staff availability, people with CF (pwCF) will continue to see accurate self-care data and receive self-care support as needed.

## Aim

* To support pwCF to maintain and optimise lung health via potent inhaled preventative medication throughout the COVID-19 emergency.
* To support pwCF to monitor medicine supply and ensure medications are always available.
* To provide encouragement to maintain motivation and to ensure pwCF using CFHH feel supported in the daily challenge of staying well.
* To input patient prescriptions on CFHH for expected treatment regimens for the next 3-6 months.
* To deliver a robust and well-supported digital platform that can be refined to meet the changing needs of pwCF and clinical teams during the COVID-19 emergency.

## Objectives

* Central team[[3]](#footnote-4) to take on the task of ensuring that data within CFHH is as accurate as possible.
* Central team to work with local teams to provide flexible support to patients who are not taking optimal treatment.
* Central team to work with local teams to facilitate the delivery of inhaled medications to pwCF using CFHH.
* Central technical team to ensure the ongoing stability and maintenance of the CFHH digital platform and deliver software refinements and updates as needed.

## Description of revised CFHH support

### Initial phase

Excess COVID-19 admissions remain low & CF teams not pulled to other duties.

* All participants will be contacted to inform them of the changes to CFHH relating to COVID-19 and how we plan to continue managing their care. We will explain how their data will be managed and that they may be contacted by a member of the central team where the local team are unavailable. All participants will be offered the opportunity to opt out of being contacted by the central team. Participants who opt out will be recorded on CFHealthHub.
* Local interventionist to continue to support CF patients using CFHH.
* Support provision of nebulised preventative medication to the patient.
* Endeavour to ensure prescriptions outlining expected treatment are inputted for the next 3 to 6 months.
* Local teams develop strategies to continue to provide CFHH support as the emergency escalates (e.g. could team members self-isolating deliver CFHH input with coaching as required from the Central team).
* Central team establish a cascade of contacts with local CF centres so that the Central team have a robust communication strategy if local teams need to pass CFHH support on to them. The aim is to have 1 local CF centre team member & 2 ‘buddies’ who are able to commit 3 hours per week in total “whatever happens”, with contact arrangements with the central team in place.
* Interventionists to prioritise recruitment of pwCF to CFHH, ensuring the maximum number of pwCF access CFHH throughout the COVID-19 emergency.
* Central team will support interventionists in providing:
  + CFHH technical support
  + CFHH recruitment support
  + Regular CFHH support for patients to develop habits and routines for treatment-taking that emphasises the benefits of preventative self-care during the COVID19 emergency.
* Identify and implement all software refinements to support pwCF throughout the COVID-19 crisis, and to support the work of the Central team (e.g. delivering COVID-19 clinical dashboards for the Central team that enables prioritisation of pwCF with greatest need).

### Intermediate phase

COVID-19 admissions start to impact clinical teams with cross-cover & self-isolation reducing resource.

* Central team will liaise with local teams and likely start to take on tasks such as prescription checking and identifying pwCF in local centres with falling or low adherence.
* Central team may pick up the task of checking CFHH inhaled therapy stocks for pwCF on CFHH.
* Hospital teams may move to “emergency CFHH delivery” in this phase so that only 3 hrs of “local CFHH time” is available.
* Any Central team contact with patients will be recorded in the Summary page on CFHH.
* Data of patients not engaging with the Central team for adherence or prescription purposes will be recorded centrally. CFHH pseudonym identifiers will be used. Identifiable information will not be recorded, as per usual data protection guidance.

### Peak phase

COVID19 admissions are at the peak and hospital services are only just coping. There will be major concern in the population at this time. Local teams may no longer have any resource to support CFHH, though they may have team members at home self-isolating.

* Central team will take on the responsibility for ensuring data accuracy, technical and adherence support for the entire CFHH collaborative, including updating prescriptions.
* Any Central team contact with patients will be recorded on the Summary page on CFHH, with relevant information fed back to the local CF MDT by email. Identifiable information will only be shared between secure nhs.net email addresses.
* Central team will continue to aim to deliver adherence support to patients not managing to take optimum treatment.
* Central team will support data accuracy, reviewing CFHH prescriptions and reacting to prescriptions alerts.
* Patients will be identified for a CFHH call if:
  + They are not taking optimum treatment, prioritising those who are taking the least treatment.
  + There is a prescription problem.
  + There is a request for support from the local team.
* Where prescriptions require updating, this will be undertaken by the central team.

### ‘Hand back’ Phase

There will be a period of transition of CFHH back to the local team once the epidemic calms and interventionist duties return to their normal activities. We may need to potentially address training needs at this point.

## Patients using I-neb nebuliser devices

It is anticipated that the visibility of adherence data on CFHH for patients using I-neb devices will reduce and potentially cease during the COVID-19 emergency, as patient-clinician face-to-face contact diminishes and clinicians will be unable to download adherence data from patient I-nebs. I-neb patients will receive prescription and technical support from the central team depending upon local team resource as outlined above. Patients will also have to opportunity for adherence support telephones calls from the Central team, although this will be limited in the absence of any recent adherence data. Options for patients to download ineb data from home will be explored. Guidance will be updated as this progresses.

## Setting up of new participants

Consent visits have been face-to-face as approved by our ethics. We will move to amend this protocol to enable remote consent and set up of new participants. Sites will also move to an opportunistic approach, consenting and setting up if or when new potential participants are seen (e.g. as inpatients or at home).

## Functions of the Central team

* To be a point of contact for sites to relay information regarding their ability to carry out CFHH activities and duties.
* To support sites to continue with their current CFHH duties for as long as possible.
* In the event that the interventionist(s) at a site are no longer able to carry out their CFHH duties, the Central team will assume control of prescription updates, technical support, and providing remote adherence support to patients.

## Central team resilience strategy

We will build a team with the resources, knowledge and experience to move fluidly in response to rapid changes in roles and responsibilities at site-level. All scheduled face-to-face meetings amongst the Central team will now take place over teleconference.

## Resources

### Central team

* Protected time for a Central team of people who are experienced with CFHH to optimise data accuracy and deliver adherence support interventions.
* All central team members will:
  + Be experienced or trained in delivering adherence support interventions
  + Be GCP trained
* Include a technical support team at University of Manchester to maintain the digital platform throughout the crisis, provide updates to the platform as required, and provide technical support to pwCF and the clinical teams. The technical team will also act as liaison with third party suppliers for nebuliser and spirometer devices, ensuring on-going data transfer from devices.

### Local CF centres

* Aim for protected time for each site interventionist of around 3 hours per week for essential communication with the central team for patient adherence support purposes.
* Clinical, administrative and technical support will be offered from the Organisational Development team at Sheffield Teaching Hospitals to support data collection or analysis.

## Equipment

* If working from home, the central team will require:
  + Laptop with internet access
  + Mobile phone, ideally with speaker function or headphone
  + Phone line for Central team communication to avoid face to face meetings, to allow multiparty teleconferences
  + Contact log access for mobile and emails accounts

## Risks

What are the risks if CFHH is not available?

### Context

* Cystic Fibrosis is an inherited life-limiting disease in which the lungs are damaged by repeated infections, making pwCF a critically vulnerable group in whom COVID-19 will be especially dangerous, since respiratory reserve is already reduced.
* Randomised controlled trials (RCTs) and meta-analyses of RCTs show that inhaled preventative therapy can protect the lungs of pwCF, improve lung function and reduce infectious exacerbations. However, median adherence to inhaled therapies is around 30%.
* The CFHealthHub platform was built and designed to support adherence to inhaled therapies and is currently in use across >60% of adult Cystic Fibrosis centres in the UK, reaching a major portion of the overall adult CF population.
* The ‘Digital Learning Health System Platform’, an ongoing collaborative research project (supported by University of Manchester CFHealthHub platform) and digital learning health system, is continuing to recruit and support patients across >60% of adult CF centres.
* During the COVID-19 pandemic, the platform will be supported by NHS England and by a national coordinating CFHH central group.

The evidence we draw upon to understand the risks come from a 19-centre RCT involving 608 pwCF which was completed at the end of December 2019. This trial was led by Martin Wildman (Chief Investigator and Principle Investigator at Sheffield Teaching Hospitals), and the CFHH digital platform was developed by the Centre for Health Informatics, Digital Health Software team (leads: Prof John Ainsworth & Dr Pauline Whelan). This was the largest CF trial ever conducted in the UK and provides the most recent evidence-base to draw on.

### Why is CFHH valuable to pwCF?

* CFHH was developed by clinicians and pwCF to provide feedback (objective adherence data) to pwCF about their use of inhaled therapies. It also provides a comprehensive behaviour change intervention which has been proven to significantly increase the use of preventative inhaled therapy compared to a control group not using CFHH.

### What are the risks if CFHH is not available?

* If pwCF are not supported by CFHH, their adherence to inhaled preventative therapies will fall and their lungs will deteriorate, making them at greater risk if they contract COVID-19. They will also be more likely to have a “standard” exacerbation leading to hospital admission which will almost certainly increase the risk of COVID-19 exposure.
* PwCF have used CFHH for the past couple of years and for it to fail during the COVID-19 emergency can be expected to create panic and anxiety, and reduce resilience at a very difficult time.

### Levels of distress to patients and the clinical team

* Frontline CF teams have worked hard over the past 3 years to create CFHealthHub as a potent tool to support vulnerable patients and they have come to depend on it as a way of keeping patients well.
* Frontline teams have felt incredibly reassured that CFHH will help them to support patients virtually in the most challenging circumstances any healthcare team has ever faced. If CFHH was taken away when it was most needed, it would create a sense of betrayal and increased anxiety as clinicians feel unable to support pwCF when they most need that support.
* Where patients require general guidance on COVID19 they will be directed to their local care team and the care team alerted if possible, to the query. All notes will be recorded on the summary review page.

12.14 Central team

The central team will be made up of a core of staff who have experience working with CFHH and/or working in a CF clinical environment. These staff members will sign a central delegation log, have GCP training and be specifically trained for the task by the CI. Their role in the study will be to provide a number of the following roles to sites:

* Adherence support
* Prescription checking
* Triaging data
* Technical support

# Appendix 4. Refining the CF HealthHub Behaviour Change Intervention (BCI) to help young people with CF manage treatment adherence: Sub-study protocol

## Background and rationale

This protocol describes the processes and procedures for conducting a study that follows from and replicates the main CFHealthHub Digital Learning Health System study (based on Actif NIHR programme grant: work package (WP) 2.2B) but with young people and their parents or guardians instead of adults. This study will allow researchers to **refine** the behaviour change intervention (BCI) including CFHealthhub and manual for use with young people.

There is a need for systematic development of interventions to improve adherence in People with Cystic Fibrosis (PWCF). Developing theory-based methods to improve adherence is an NHS research priority (1) because non-theory based adherence interventions have limited effectiveness due to a lack of personalisation resulting from inadequate diagnosis and a tendency to use uni-modal, superficial “one size fits all” solutions to address poorly defined problems (2). CFHealthHub has been developed to understand and evaluate the use of BCI in people with Cystic Fibrosis.

Adherence is often reported as higher in young people with CF (YPWCF) than in adult populations. This might be because of the influence of parents or guardians in prompting and controlling care. Nonetheless, supporting adherence behaviours at this age could protect lung health by creating good habits for self-care as YPWCF become more independent. This study follows from the Digital Learning Health System and focuses on the adaptations that need to be made to allow CFHealthhub to be refined so that it meets the needs of young people and their parents and guardians, who were otherwise not considered in the adult Digital Learning Health System study.

### 

### Aims and objectives

To understand how the CFHealthHub website and BCI can be used with young people with CF. Specifically, we will:

1. Use qualitative interviewing and audio recorded data from BCI sessions with young people and their parents/guardians, to develop and refine the CFHealthHub BCI and website.
2. Use qualitative interviewing and field notes from the research physiotherapist to develop and refine the BCI.

## Method

### Study design

This is as single group, non-randomised intervention study to investigate possible adaptations required to tailor a BCI and the CFHealthHub website towards YPWCF.

### Study setting

The proposed study will be conducted at the Children’s Cystic Fibrosis service within the University of Southampton NHS Foundation Trust, who have received funding from NHS England CQUIN to support the study.

### Sample size

The goal of this study is to explore possible refinements to a behavior change intervention to support adherence in YPWCF, and not to provide definitive conclusions around effectiveness/efficacy. Therefore, a formal power calculation is not required. Instead, recruitment will be limited by the number of dose counting eTrack nebulizers (required to monitor objective adherence) that are available for participants. As part of the CQUIN funding, twenty eTrack nebulizers are available, therefore we will aim to recruit *n* = 20 participants in total.

### Eligibility criteria

#### Inclusion:

1. Diagnosis of Cystic Fibrosis
2. Aged 13-17 years
3. Able to complete consent form, and whose parent or guardian is able to give informed consent.

#### Exclusion:

1. YPWCF who are post lung transplant or on the active lung transplant list or are in the palliative phase of disease.

### Recruitment

A research physiotherapist based within the Children’s CF team will cross reference the study eligibility criteria with local hospital records. Where a potentially eligible participant is identified, the research physiotherapist will post a participant information sheet (PIS) to both the young person and their parent/guardian, along with a covering invitation letter. After no more than one week later, the research physiotherapist will telephone the parent/guardian of the YPWCF to discuss the study over the phone and answer any questions. If the potential participant and their parent/guardian is happy to take part, the research physiotherapist will arrange an appointment to gather written or telephone informed consent, give participants their chipped eTrack nebuliser, and explain the intervention. For any participants who are not interested in taking part, a reason for refusal will be recorded. Where telephone consent has been conducted a copy of the completed ‘audio’ consent form will be posted to the participant. As per the main Digital Learning Health System protocol, the local CFHealthHub researcher, taking consent, will do so in accordance with Good Clinical practice, will be recorded on a delegation log and will have received training on consent procedures. The research will follow the main Digital Learning Health System study procedures for uncontactable participants. Participants who refuse will not be re-approached.

### The Behaviour Change Intervention

The intervention uses the same principal components as the main Digital Learning Health System study. These components interact together to help improve participant adherence to medication. The various components of the intervention include:

* CFHealthhub - the website/mobile application which will display routinely collected adherence data to PWCF and modules to educate and motivate them to adhere
* An Initial Assessment with the Research Physiotherapist to identify the needs of the PWCF and tailor their use of CFHealthhub
* PWCF using CFHealthhub with additional consultations with the Research Physiotherapist
* A manual to help physiotherapists deliver the intervention

### Study procedures

The proposed study is divided into three stages: (1) an initial research process phase where participants are identified, recruited and consented to the study; (2) an intervention phase consisting of a total of 3 interactions with the interventionist (i.e., study visits 2, 3, and 4); and (3) a final assessment phase involving participants, parents/guardians, and the clinicians delivering the intervention where feedback is gathered. Table 1 describes an overview of each of the five study visits to be conducted as part of the proposed research, alongside the types of data collected

**Table 1**

*An Overview of Each Study Visit and the Types of Data Collection*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Study visit/contact** | **When?** | **How long?** | **Where?** | **Visit type** | **What?** | **Data collected** |
| **Initial contact** |  | 5-10 mins | Post | Research process | * PIS & cover letter posted to (potential) participant | * None |
| **Follow-up telephone call** (1 week from initial contact) |  | 10 mins | Telephone | Research process | * Call potential participant to discuss study, answer any questions and, if interested, invite to come in for consent visit. | * If applicable, reasons for refusal to participate |
| **Study visit 1** | 1-3 weeks from telephone call | 40-60 mins | At clinic or in patients home or via teleconference / video conference | Research process/intervention | * Take written or telephone informed consent, including consent for audio recording. * Initial assessment (Screening Tool). An initial session with the physiotherapist, gathers data and provides the chipped nebuliser. Research physiotherapist will input the prescription details into CFHealthhub. * Completion of COM-BMQ screening tool to assess motivation, capability and opportunity. | * Participant consent form * COM-BMQ screening tool * Patient medical records (see section 8.1, Table 3 of main study protocol) * CFHealthHub account set-up and consent procedure |
| **Study visit 2** | 4 weeks after intervention visit 1 | 40-60 mins | At clinic or in patients home or via teleconference / video conference | Intervention | * Review captured adherence data within CFHealthhub with PWCF. * Explain CFHealthhub including the modules and other aspects of the website. * Discuss issues of capability, opportunity and motivation as indicated by initial assessment. * Direct PWCF to specific modules in CFHealthhub based on the information provided in intervention session 1. | * Audio recorded session |
| **Study visit 3** | 4 weeks after intervention visit 2 | Up to 30 mins | Telephone or video conferencing | Intervention | * Short review session to check how participant is engaging with CFHealthhub and to review goals, adherence plans, motivation, and problem solving. | * Audio recorded session |
| **Study visit 4** | 1-4 weeks after intervention visit 3 | Up to 30 mins | Telephone, video conference, or face-to-face, or home | Assessment | * Semi structured interview with YPWCF and their parents / guardian to discuss *participant’s* experience of intervention and CFHealthhub over the phone. * Interviews with parent/guardian to discuss website content, design, data display, manual and supporting documents. | * Audio recorded qualitative interviews |
| **Study visit 5** (clinician interviews) | After intervention delivery is complete | 20-40 mins | Clinic or via telephone / video conferencing. | Assessment | * Written consent obtained from clinician. * Interview to discuss *clinician* views of CFHealthhub and acceptability of BCI. | * Audio recorded qualitative interviews |

### Study visit 1 – Consent and initial assessment visit

At this visit, the research physiotherapist will explain the purpose of the study and obtain written or telephone consent from participants if they are happy to proceed. A parent or guardian will be present and will complete the relevant consent form. Parents/guardians may be invited to take part in an interview at visit 4. The following key elements will be covered at visit 1:

* 1. The research physiotherapist will gather data from participants about their medical history and assess issues and barriers using a screening tool (COM-BMQ). This may be revised over the subsequent sessions (e.g. with additional problems that have been identified) to ensure that it is collecting the correct information to enable appropriate tailoring and support.
  2. Participant will complete COM-BMQ and the CFHealthHub consent set up procedure (baseline data collection in section 8.1 table 3 of the main Digital Learning Health System protocol).
  3. The research physiotherapist will provide their chipped nebuliser (by post if not able to meet face to face) and set this up to allow adherence data to be captured in CFHealthHub. The research physiotherapist will provide a description of how data from the nebuliser is uploaded to CFHealthHub to ensure participants and their parent/guardian are clear on how this works.

### Study visit 2 – intervention session 1 and participant assessment

The following key elements will be undertaken at visit 2:

1. The participant will be provided with their own log in details, shown how to navigate and use CFHealthHub.
2. Informed by the measures taken at visit 1 (i.e., the COM-BMQ), the research physiotherapist will review data captured within CFHealthhub with the participant at visit 2 and direct individuals to relevant parts of the website to aid behaviour change and discuss motivation, confidence and barriers to adherence following the intervention manual procedures. They will also support download of the CFHH app onto the participant’s smartphone.
3. As the session is audio recorded, participants are able to feedback on the website in terms of the modules within CFHealthhub and how the data was accessed, in real time.

### Study visit 3 – Intervention session 2 (review) and audio recording

Short follow up visit to check how participant is engaging with CFHealthhub and to review goals, adherence plans, motivation, and problem solving. The researcher may conduct this over the phone. This session will be audio recorded.

### Study visit 4 – data collection around intervention feedback

As part of study visit 4, we will interview both the participants receiving the intervention, and a sub-set of their parents/guardians. The information collected will complement the audio-recorded interventions session themselves and allow further refinement of CFHealthHub and the BCI.

#### Interviews with YPWCF

All participants will be asked to feedback, via interview, on the intervention, including CFHealthub and interactions with the physiotherapist. A semi structured topic guide will determine the acceptability of the intervention, focusing on strengths and weaknesses and also consider any aspects of adherence which participants feel were not addressed during the intervention. Interviews will be conducted either face to face, by telephone or videoconference dependent on participant preference and government guidelines on interactions during COVID19.

#### Interviews with the parent/guardian of the YPWCF

Ten of the parents or guardians of the YPWCF recruited into the study will be purposively sampled (i.e., based on sociodemographic characteristics, sex, age etc.) and asked to feedback on the intervention, including CFHealthub and interactions with the physiotherapist. A semi structured topic guide will determine the acceptability of the intervention, focusing on strengths and weaknesses and also consider any aspects of adherence which participants feel were not addressed during the intervention. This will be via interviews conducted either face to face, by telephone or videoconference dependent on participant preference and government guidelines on interactions during COVID19. All Interviews will be audio recorded on encrypted Dictaphones, transcribed and analysed to identify themes to aid the development of the intervention.

### Study visit 5 – researcher physiotherapist interviews

Study visit 5 will not focus on the participants and/or their parent/guardians. Instead, in study visit 5 the research physiotherapist delivering the intervention will be interviewed after delivery of the intervention to all participants, to assess the ease of and acceptability of delivery and determine any suggested adaptations to the intervention materials and manuals. This interview will help capture what the research physiotherapist is learning, what is missing from the manual/CFHealthhub and what training might be needed for the research physiotherapists when the intervention is used in a wider setting.

## Data management and analysis

### Data handling and record keeping

University of Southampton NHS Trust (UHS) will be responsible for all data collection and ensure the study is undertaken according to Good Clinical Practice Guidelines. Support will be available from STH NHS FT Digital Learning Health System Project Manager, University of Manchester technical leads, and other CFHealthHub central team members. Data will be collected directly from the participants, CFHealthHub software and source documents (e.g. patient notes). Screening and recruitment data will be stored securely at UHS and transferred securely to University of Sheffield researchers. Research data will be entered directly into CFHealthHub. All research data will be pseudonymised. Interviews and BCI sessions will be recorded on an encrypted Dictaphone and transferred securely to the study team at the University of Sheffield for transcription and analysis by the CFHealthHub central study team. Data will be stored for 5 years from the end of the study, following the main Digital Learning Health System protocol procedures.

### Data Analysis

Interviews will be audio recorded on encrypted Dictaphones and field notes will be taken during the interview by the interviewer, to facilitate analysis and feedback into the intervention development. Interview data and field notes will uploaded to NVivo (QSR 12) for analysis. Intervention session audio recording will not be transcribed immediately they will be stored securely for 5 years and may be transcribed in that time using an approved, GDPR compliant third party transcription service.

### CFHealthHub data collected

CFHealthhub will store participants’ adherence data (measured via use of the chipped nebulizers) and treatment prescriptions, as per the main Digital Learning Health System protocol. The CFHealthHub database is stored on an AWS cloud service managed by the University of Manchester (see section 8.3.2 of main Digital Learning Health System protocol). All access to the CFHealthhub website is secured over https and requires a unique username and password. Each user (clinician or patient) interaction with the CFHealthhub server will be logged by the system for auditing and research purposes. This auditing will include data on the action performed by the user (e.g. ‘edited prescription dosage’), the username of the person performing the action and details of any changes made to the stored data. Researchers will have access to view the data within the CFHealthhub website and/or to export the data to CSV files to enable further analysis outside the CFHealthhub system. The software team at the University of Manchester will have access to the data for critical server maintenance tasks. All members of software team are GDPR trained.

## Monitoring and Oversight

See section 10 of main Digital Learning Health System protocol.

## Ethics and dissemination

See section 11 of main Digital Learning Health System protocol.

## 

## References

1. National Institute for Health and Clinical Excellence. Medicines adherence: Involving patients in decisions about prescribed medicines and supporting adherence. NICE Guidel [Internet]. 2009;(January):1–31. Available from: https://www.nice.org.uk/guidance/cg76

2. Horne RW, Barber N, Elliot R, Morgan M. Concordance, adherance and compliance in medicine taking: A conceptual map and research priorities. National Co-ordinating Centre for NHS Service Delivery and Organisational R&D (NCCSDO). 2005.

# Appendix 5. Process evaluation sub-study: substudy protocol

## Background and rationale

The Digital Learning Health System was initially being used to drive up quality, in three NHS Trusts: Sheffield Teaching Hospital NHS Foundation Trust; University Hospital Southampton NHS Foundation Trust; and, Nottingham University Hospitals NHS Trust. However, process evaluation is now being implemented using CFHH across all participating sites to facilitate quality improvement.

The success of this multi-centre quality improvement exercise requires two steps:

1. NHS England-funded 'interventionists' work in centres to recruit participants to the Digital Learning Health System and influence multi-disciplinary teams to use adherence in their day-to-day practice.
2. Multi-disciplinary teams access data to benchmark their centre's performance and to inform the care of individual patients.

To inform that large scale process of change, we need to understand the potential sources of implementation failure based on activity across centres which are already initiated. The current process evaluation will provide that understanding, using the MRC Process evaluation framework1.

The evaluation will involve interviewing health professionals and triangulating their views and experiences with quantitative data, already collected as part of the Digital Learning Health System.

## Aims and objectives

We aim to answer the question: “What are the potential sources of failure for: (a) the implementation interventionists and site PIs; and, (b) for the uptake of adherence data in the management of people with CF by multidisciplinary teams?”  
  
The objectives are:

1. To provide an overview of the experiences and views of site staff on this question; and,
2. To integrate those views with process data already collected by the Digital Learning Health System project.

## Study design

The evaluation will use a mixed methods approach, following MRC process evaluation guidelines2 to explore the activities and outputs documented on the logic model (appendix 1), specifically to identify the barriers and pathways to implementation. To capture the changing implementation of the Digital Learning Health System this process evaluation will be repeated at yearly intervals.

### Quantitative process data

1. **Study set up**

Collected by the central study team from study records. Data will include

* Date ethical and HRA approval was received.
* Critical path analysis of site set up using study manager notes

1. **Number and characteristics of eligible patients approached for this study**

Collected by centres in screening logs

1. **Reasons for refused consent or ineligibility**

Collected by centres in screening logs and stored of CFHealthHub.

1. **Reach**

Collected by screening and consent form. This will include the number of participants consented into the study, sub-grouped by socio-economic status (from CF Registry), as a proportion of:

* Those approached, expressed quantitatively, based on ‘pre-screening’ logs;
* Those known to be eligible, expressed quantitatively based on CF registry.

1. **Participant attrition rate and reasons for attrition**

Collected by centres in screening logs

1. **Consent to optional statements relating to future research**

Collected by centres on consent forms

1. **CF registry data accessed**

Collected by the central study team from study records.

1. **Encounter based CFHealthHub Data Entry**

Encounter based data entry points are automatically collected and will be compared against clinic information provided by the local administrators. Comparing the number of collected forms, versus the number of actual attended clinic visits will provide an understanding of the accuracy of data collected in the study, and identify any systematic patterns in missing data.

1. **Expertise at centre**

Collected in training records kept by the central study team. These records will be used to identify the number of staff and corresponding job role, at each centre, trained in:

* Quality improvement;
* Adherence support;
* CFHealthHub software.

1. **Number of delivered adherence sessions to participants, frequency of access to adherence data**

Evaluation of ‘click analytics’ exported from CFHealthHub for the:

* Completed ‘Summary Review’ page, used to record all adherence sessions with participants;
* Clicks onto ‘How am I doing?’ for each interventionist account.
* Other related CFHealthHub pages that indicate use of CFHealthHub / delivery of adherence support

1. **Engagement with other research and TwiCs**

Data collected in central study records, including details of the request to use the Digital Learning Health System platform, and the study design.

1. **PDSA cycles embed the use of adherence data in routine care**

Collected on a standardised PDSA recording form by interventionists and MCA coaches.

1. **Capability, Opportunity and Motivation barriers for CF Healthcare Professionals**

Collected by way of questionnaire using the Theoretical Domains Framework and questions developed from the qualitative interviews in 2018. Health professionals at every CFHealthHub Digital Learning Health System centre will be invited (by email) to take part on an online survey about their experience of implementing CFHealthHub in their centre. It is important to understand which elements of the CFHealthHub implementation strategy impacted on the overall implementation of CFHealthHub at each centre (see appendix 2). Implied consent will be obtained as part of the online survey. If participants provide their contact details, they may be selected for an in depth interview, within 12 months of completion of the questionnaire.

1. Reasons for non-engagement of patients with therapy in CF aside from extreme deprivation or severe mental illness

### Qualitative process data

Logic model components (appendix 1) will be evaluated using data from semi-structured interviews with centre staff. We anticipate that qualitative evaluation will be repeated at intervals as iterative developments within the Digital Learning Health System impact system performance.

### Sampling

#### Sampling of Staff

We aim to sample at least six staff members from each of the Cystic Fibrosis Centres already initiated. These will be selected for maximum variation3 based on their role (consultant, physiotherapist, nurse). Consent to be interviewed will be sought by the research team. Spontaneously-offered reasons for non-participation will be recorded. The eligibility criteria are as follows:

**Inclusions:**

1. Member of staff employed by a CF centre involved in delivering the CFHealthHub Digital Learning Health System (London-Brent REC 17/LO/0032) improvement collaborative study.

**Exclusions:**

1. unavailable or unwilling to consent

#### Sampling of participants with CF

Participants will be purposively sampled according to their adherence level on CFHH. Around 40 participants who the clinical team deem to not have extreme deprivation or severe mental health illness but has adherence level 0-25% will be invited to participate in a semi-structured interview to explore reasons for non-adherence.

**Inclusions:**

1. Participants of CFHH who have consented to be contacted for future research

### Interview procedures

**Identification of participants:**Potential participants are study funded interventionists and healthcare professionals working in a Digital Learning Health System study centre, or patients with CF already recruited to CFHH who consented for future research, who will be known to and identified by the study team. Invitations will be made face-to-face, by letter or by e-mail, by the Chief Investigator, study manager or research assistant. Invitations are made by letter or email, will be followed up by a telephone call from a member of the study team to ascertain interest, and where possible, arrange an appointment.

Centres part of the phase 4 platform (previously in the RCT) will be purposively sampled based on responses of the Theoretical Domains Framework (TDF) questionnaire at baseline in 2019.

**Timing and setting:** Interviews will take place at a time and place convenient for consenting participants. Where it is not possible to conduct the interview face-to-face, interviews will be conducted over the telephone.

**Informed Consent:**Written or telephone (audio recorded) informed consent will be obtained from every participant. Those who agree to be interviewed will be met at a place convenient for them, by one of the study team who will read the information sheet through with them. If the participant is happy to continue they will be asked to sign the interview consent form. Those involved in taking consent and collecting data will have up-to-date training in Good Clinical Practice (GCP). Participants will be reassured that all data which are collected during the course of the research will be kept strictly confidential. Spontaneously offered reasons for non-participation will be recorded.

**Interview guides:** As the interviews aim to understand the potential barriers to implementing a multicentre quality improvement project, interviewers will follow a topic guide that draws upon the TDF4,5. In addition, interviewee’s professional background, their role in the CFHealthHub Digital Learning Health System project will be collected.

**Recording:** Encrypted digital recorders will be used and recordings sent securely to the research team for analysis. Once saved, recordings will be permanently deleted from the digital recorder. All interviews will be fully transcribed. At the end of the study audio recordings will be destroyed.

**Field notes:** Will be taken during and after interviews as required.

**Duration:** Interviews will last up to one hour. Transcripts will not be returned to participants for correction. Participants will be invited to participate in the interviews at future time points; there is no obligation to participate again. Different members of staff may be recruited at each time point.

**Safety of the participants:** Interviews will be treated as confidential; information that identifies individuals will not be disclosed.

### Analysis

Transcripts will be coded using the latest version of NVivo (QSR International). The theoretical framework for understanding intervention adherence is the Theoretical domains framework within the COM-B system4. This will be used within the thematic framework for this evaluation. We will use the process evaluation functions of context, mechanisms and implementation to frame the analysis. We will compare and contrast findings from each centre as the different contexts in which care is provided in each CF unit may affect implementation and acceptability of the intervention. We will use the logic model (Appendix 1) as a framework for summarising information at the programme level6.

Summary statistics will be produced, the detail of which will be available in the Digital Learning Health System Statistical Analysis Plan (SAP).

Using a modified triangulation protocol7, we will integrate qualitative and quantitative datasets, summarising information based on logic model constructs at the programme level6. We will use a joint display table8 to summarise data sets for logic model constructs in the Inputs. The fit of data integration will be categorised as: ‘confirmation’ (quantitative and qualitative data provide similar findings, enhancing credibility); ‘expansion’ (the datasets diverge, expanding insights/ addressing different or complementary aspects the phenomenon); or, ‘discordance’ (the datasets are contradictory)9. We will summarise closeness of fit between data sets and differences in their contribution to the research question.

**References**

1. Moore G, Audrey S, Barker M, Bond L, Bonell C, Hardeman W, et al. Process evaluation of complex interventions UK Medical Research Council (MRC) guidance. [cited 2017 Nov 10]; Available from: http://decipher.uk.net/wp-content/uploads/2014/11/MRC-PHSRN-Process-evaluation-guidance.pdf

2. Moore GF, Audrey S, Barker M, Bond L, Bonell C, Hardeman W, et al. Process evaluation of complex interventions: Medical Research Council guidance. BMJ. 2015 Mar;350(mar19 6):h1258–h1258.

3. Coyne IT. Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries? J Adv Nurs. 1997;26(3):623–30.

4. Atkins L, Francis J, Islam R, O’Connor D, Patey A, Ivers N, et al. A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. Implement Sci [Internet]. 2017;12(1):107–12. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0895435604002562

5. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implement Sci [Internet]. 2011;6(1):42. Available from: http://implementationscience.biomedcentral.com/articles/10.1186/1748-5908-6-42

6. Yin RK. How to Start Your Analysis , Your Analytic Choices , and How They Work. Case Study Res Des Methods [Internet]. 2013 [cited 2017 Dec 11];127–64. Available from: https://www.sagepub.com/sites/default/files/upm-binaries/24737\_Chapter\_5.pdf

7. Farmer T, Robinson K, Elliott SJ, Eyles J. Developing and Implementing a Triangulation Protocol for Qualitative Health Research. [cited 2017 Dec 11]; Available from: http://journals.sagepub.com/doi/pdf/10.1177/1049732305285708

8. Guetterman TC, Fetters MD, Creswell JW. Integrating Quantitative and Qualitative Results in Health Science Mixed Methods Research Through Joint Displays. Ann Fam Med [Internet]. 2015 Nov 1 [cited 2017 Dec 11];13(6):554–61. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26553895

9. Fetters MD, Curry LA, Creswell JW. Achieving Integration in Mixed Methods Designs—Principles and Practices. Res Quest Mix Methods Heal Serv Res [Internet]. [cited 2017 Dec 11]; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4097839/pdf/hesr0048-2134.pdf

1. Incorporating the Beliefs about Medicines Questionnaire (BMQ-specific nebuliser treatment) Horne, 2010 [↑](#footnote-ref-2)
2. During the COVID-19 pandemic, members of the CFHealthHub central team, that are NHS employed and/or allied health professionals, will act as the local CFHealthHub researchers supporting patients with adherence behaviours. All relevant employment checks and approvals from individual Trusts will be gained prior to this change. [↑](#footnote-ref-3)
3. Central team who are either NHS employed or trained in a healthcare role e.g. Allied Health Professional [↑](#footnote-ref-4)