An Evidence-Based Approach to Quality Improvement for COVIDoximetry@home

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Introduction

Robust data-driven insights are critical for the design, adaptation, and improvement of clinical and operational management policies governing care pathways and resource models. However, understanding the requirements for data and analysis can be challenging when faced with disruptive innovations that offer new or reconfigured services such as COVIDOximetry@Home (NHS England and NHS Improvement, 2020), and when such change impacts multiple providers in an Integrated Care System (ICS).

In this report we outline measurement, monitoring and analysis of COVIDOximetry@Home using evidence-based practice as the underpinning foundation for PDSA quality improvement[1]. Many operational and clinical decisions should be considered, and it is the purpose of the data and analytics to offer decision makers with insights necessary to design, assessment and implement of policies for better care.

- **Clinical**: predict patient outcomes; understand the efficacy of interventions at different COVID patient disease stages and associated clinical care settings
- **Operational**: understand how clinical services respond to workload and resources for planning, optimisation, and reconfiguration; identification and validation of processes
- **Compliance**: understand the degree to which services are operating according to procedures and practices
- **Programme Evaluation**: deliver evidence as part of programme evaluation and for sustainability investment decisions

Whilst the COVID-19 Virtual Wards Data Provision Notice (NHS Digital 2020-1) mandates the “data to be collected for the evaluation of the Virtual Wards pilot”, our work puts data into the context of digital systems, and ongoing clinical and operational quality improvement. We describe the COVID19 Virtual Ward concept and clinical setting, and then elaborate the clinical, operation, compliance, and evaluation requirements. Finally, we summarise a system view from an exemplar ICS, outlining the relation between structure and data.

COVID-19 Virtual Wards within Integrated Care Systems

Virtual Wards in England were introduced in Croydon Primary Care Trust in 2005. Its original definition was a model for delivering multidisciplinary case management to people who are at high predicted risk of unplanned acute care hospitalisation (Lewis, Wright, & Vaithianathan, 2012).

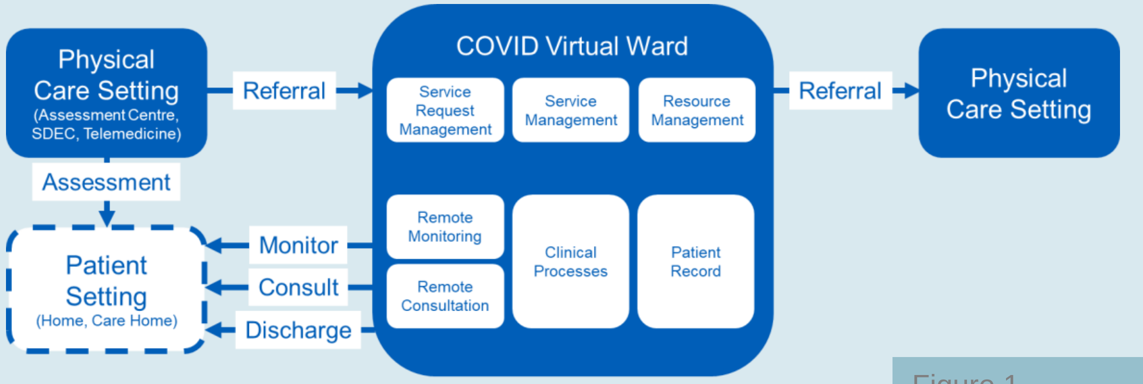


Figure 1

[1] https://improvement.nhs.uk/documents/2142/plan-do-study-act.pdf

In its original definition, a Virtual Ward model consisted of two fundamental components: (1) using a predictive model to identify individual patients in a population who are at high risk of future unplanned hospital admission; and (2) offering these people a period of intensive, multidisciplinary, case management at home using the systems, staffing and daily routines of a hospital ward (Lewis et al., 2013).

This model copies the strengths of hospital wards: the Virtual Ward team shares a common set of notes, meets daily, and has its own ward clerk who can take messages and coordinate the team (Lewis, 2006). The term 'virtual' is used because there is no physical ward building: patients are cared for in their own homes. The only way in which patients are admitted to a Virtual Ward is if their name appears at highest on a predictive algorithm (Billings, Dixon, Mijanovich, & Wennberg, 2006) (Lewis, 2010).

The concept of Virtual Wards has also been used in primary care. In 2013, The King's Fund published a case study exploring community Virtual Wards based in GP practices within South Devon and Torbay Clinical Commissioning Group (CCG) (Sonola, Thiel, Goodwin, & Kodner, 2013).

Since then, the concept of Virtual Wards have been used across the country and have emerged as a critically important service for remotely monitoring and consulting patients with known COVID-19 and high risk of deterioration, to ensure early warning of deterioration, and to allow us to act promptly and reduce mortality from silent hypoxia, whilst limiting hospital attendances and admissions (Stockly, 2020).

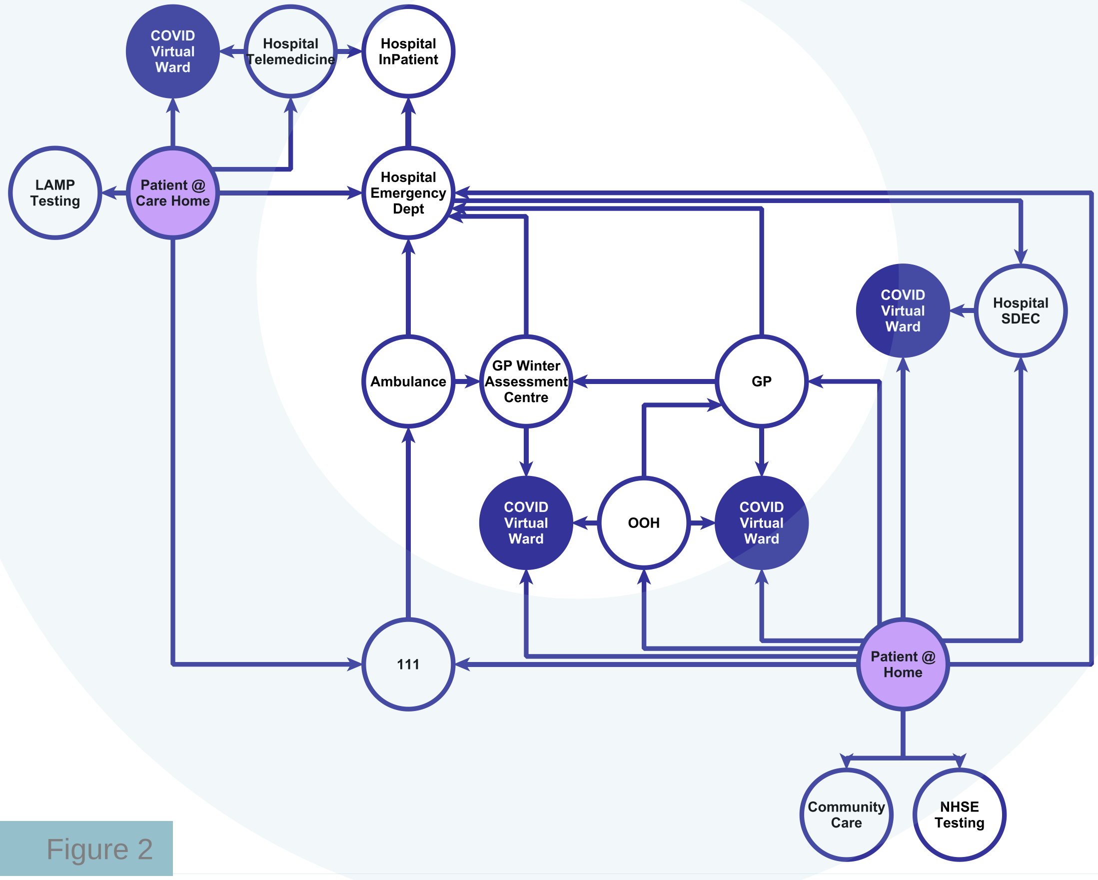


Figure 2

National guidelines have been established (NHS England and NHS Improvement, 2020), whilst business processes implemented in specific care settings considering referral, admission, patient monitoring, and discharge, along with initial guidelines for service management and resourcing (i.e. space, workforce, equipment, and digital solutions).

Patients are referred by clinical services responsible for operating COVID-19 Virtual Wards (CVWs), then triaged prior to admission to ensure that the CVW offers an appropriate level of care. The assessment of patients highlights the important relationship between physical and virtual services in the overall delivery of care. Even though a CVW is entirely virtual, physical care is still needed for patient assessment (e.g. COVID testing and initial observations). Examples of physical services that operate CVWs include GP practices, Primary Care Assessment Centres, Same Day Emergency Care or Care Home Telemedicine implemented by collaborations between hospital staff and community care workers.

A clinical service making a referral to a CVW retains responsibility for patient care. In Primary Care the GP retains clinical responsibility for the patient, and the only exception for this is when they are admitted to a hospital. Multiple clinical services of the same type (e.g. GP practices) may collaborate and federate delivery of the same service, for example, establishing a Winter Assessment Centre with a CVW supporting a Primary Care Network (PCNs) or an Integrated Care Partnership (ICP).

CVWs are implemented at different disease stages across an integrated care pathway. Primary care will use CVWs for early identification of patients at risk of deterioration in communities, whilst a hospital would use CVWs to step down patients at high risk of adverse complication events and readmission to hospital, e.g. frail, elderly and vulnerable patients with multiple long-term conditions.

Finally, CVWs interact with a complex network of clinical services (as shown in Figure 2) who collaborate to implement national guidelines for green, amber and red pathways to escalate patients according to patient acuity and risk factors in response to patient demand from 111, General Practices, Out of Hours Services, and Emergency Departments.

Evidence-Based Practice for Quality Improvement

Quality improvement requires a clearly articulated set of goals and measurement criteria for success. In general terms, COVIDOximetry@Home aims to deliver better healthcare outcomes for COVID19 patients through early detection of deterioration using remotely monitoring at home rather than through hospital admission, whilst maximising the utility of scarce health system resources. The expected patient benefits are:

- Earlier identification of patient deterioration
- Reduction in conveyances, admissions, length of stay and deaths
- Increased appropriateness and timeliness of assessment and escalation
- Increased reliability of referral, transfer, clinical assessment, and management of COVID19 illness presenting across the care pathway
- Better use of interventions (e.g. dexamethasone, anticoagulation)

At the heart measuring benefits is evidence-based practice where knowledge is derived from research (i.e. evidence), audit and routinely collected data (i.e. statistics) and experience of patients/service users and professionals (Brun 2013). Evidence is collected, analysed, and presented to different stakeholder groups (see table below) to support operational and clinical decisions.

Operational Management may be concerned with monitoring service activity and planning capacity against expected demand, where clinical policy makers are concerned with assessing patient trajectories and its association with organisational resources. Programme teams such as NHSX would be interested in aggregate data for population-level public health and evaluation of impact.

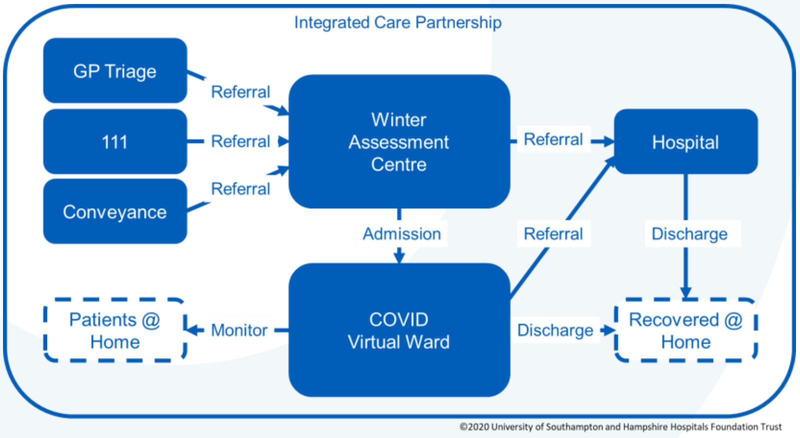
Stakeholder	Why	What	When
Change Programme Management	Impact evaluation, funding decisions	Activity, Capacity, Demand, Patient	Weekly, monthly
Regional and National Policy Makers	Policies, capacity, and demand planning. Clinical pathways	Activity, Capacity, Demand, Patient	Weekly, monthly
Operational Management	Capacity and demand planning	Activity, Capacity, Demand, Compliance	Daily, weekly, monthly
Service Management	Service requests, resourcing	Activity, Capacity, Demand	Immediately
Research	Scientific publications for operational and clinical research	Activity, Capacity, Demand, Patient	On demand

Data needs to be aggregated within the entities of the system under analysis and provided for business intelligence and more complex predictive analytical models for capacity, demand planning and patient related risk stratification and decision support (Inada-Kim, M 2020). Entities can be physical, i.e. patient physiological observation, or conceptual, i.e. workforce made up of a set of physical team members. Entities can form hierarchies, i.e. have composition relations, and data and respectively insights can be propagated along this hierarchy. Entities can also form chains, i.e. have dependency relations such as a patient pathway, and data insights can be co-related along these chains.

For accurate interpretation of the data analysis needs to consider the boundaries and the size of the parts of the system that generates the data. Accurate insights and knowledge transfer can be achieved only when the system generating the data is accurately quantified and results are normalised explicitly by the analytics' tools or by the decision maker. Thus, when collecting data for supporting evidence-based decision making, it is important to understand both structure and the size of the system.

Figure 3

The example shown in Figure 4 is based on a Winter Assessment Centre (WAC) and CVW deployed supporting community patient monitoring as defined by North and Mid Hants Integrated Care System. The WAC is a physical care setting responsible for assessing patients and deciding on treatment, including admission to a CVW on a "Green" pathway.

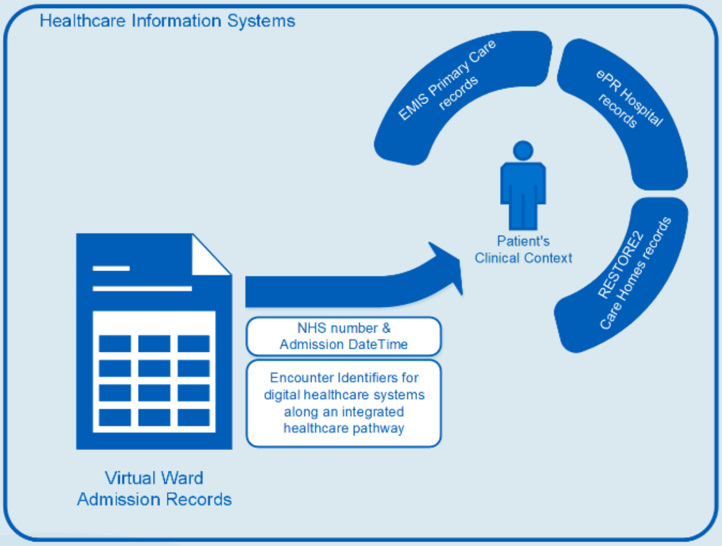


Patients can be referred for assessment by several other care services and quantifying these services would enable better CVW demand predictions and operational planning. Furthermore, patients can be referred for hospital care whilst admitted to a CVW, if their condition deteriorates, or discharged to the community in the case of observed recovery. Being able to link hospital information or primary care information after discharge would enable better clinical pathways and policies to be developed.

For patients admitted to the CVW, alongside the monitored observation data (e.g. oxygen saturation, symptoms, etc.), additional data needs to be recorded for patient level analyses that is fed into the operational and clinical evidence-based decision making. This additional data should include time referenced significant clinical events and references for linking with a patient's clinical data outside the boundaries of the CVW (see Figure 4). Having this additional data will ensure that patient's clinical context can be digitally recreated for establishing the accurate current clinical condition and for retrospective data analyses

Figure 4

At its minimum, this information shall include the NHS number of the patient and a timestamp of patient's admission in and discharge from the CVW. However, for recreating patient's clinical context from these minimal data, timestamps across different digital healthcare systems will need to be used for what will be moderately complex inference, hence prone to errors. So, to ensure a simple and reliable reference scheme across the different digital systems, records of the identifiers of the encounters of the patient with the different healthcare providers along an integrated healthcare pathway.



Evidence data is categorised into activity, capacity, demand, patient trajectory, pathway compliance and programme evaluation (see table below). In Appendix A, we provide a check list for practitioners to determine the completeness of data coverage for CVW's in relation to reporting requirements, and hence the ability for implementation teams to support evidence-based analysis. In addition, such can be linked to existing Data Provision Notices to provide full trajectory analysis, e.g., the COVID-19 Daily NHS Provider SitRep (NHS Digital 2020-2)

Category	Description	Reporting Requirements
Activity	Monitoring service usage and resource availability	• Patients ○ Number of patient appointments by referral source per day ○ Number of patient attendances by referral source per day ○ Number of patient admissions by referral source per day ○ Number of patients diagnosed with COVID-19 by referral source per day ○ Number of patient referrals to amber by referral source by destination per day ○ Number of patient referrals to red by referral source by destination per day ○ Number of patient discharges per day ○ Average, Min, Max length of stay for patients discharged by referral source each day • Resources ○ Number of staff available by band by type at 08:00 ○ Number of staff absent through sickness by band by type at 08:00 ○ Number of oximeters available at 08:00 ○ Number of oximeters provisioned at 08:00 ○ Number of oximeters decontamination at 08:00 ○ Number of oximeters missing at 08:00
Capacity	Quantifying maximum amount of service that can be delivered from a set of resources.	• Workforce ○ Number of staff by band by type per patient population • Equipment ○ Number of oximeters per patient population ○ Number of testing devices per patient population

Category	Description	Reporting Requirements
Demand	Estimating the future need for service from a defined patient population	• Population ○ Size of catchment population ○ Size of population per clinical service ○ Size of population by referral sources to clinical service ○ Size of population by demographics • Structure ○ Number of referral sources (e.g. homes, care home, GPs) per clinical service ○ Number of referral destinations (e.g. hospitals) per clinical service ○ Local area identifiers for clinical service, e.g. Postcodes (so connection to ONS population level data can be done)
Patient Trajectory	Monitoring the pathophysiological process of a patient's disease state and the total organization of work done throughout all clinical and patient interactions and refers to the impact of patient care processes on those interactions and the organization" (Alexander 2007).	• Individual ○ patient physiological observations ○ patient risk factors ○ patient demographics ○ patient clinical pathway events ○ patient clinical intervention events (drug, oxygen, ventilation) ○ patient acuity on pathway event (presentation, referral admission, discharge, etc) ○ rate of deterioration and recovery ○ length of time in care setting ○ patient outcomes • Aggregate ○ Number of patients by care setting by patient characteristic ○ Proportion of patients by care setting by patient characteristic
Pathway Compliance	Checking conformity to an agreed standard for care delivery, clinical audits, and continuous quality improvement	• Tests for correctness of decisions against clinical pathway events • Tests for completeness, accuracy, consistency, validity of patient record
Programme Evaluation	Measuring the socio-economic impact of change programmes and investments.	• Does home based remote monitoring of oxygen saturation levels lead to improved health outcomes for people with COVID-19? • Is home based remote monitoring of oxygen saturation levels equally accessible to those who experience health inequalities? • Has the pathway been implemented in line with the standard operating procedure?

Data-Driven Systems Thinking

The digital system supporting CWDs within an integrated care pathway consists of a set of interoperable digital components:

- **Patient Devices** for report remote measurements and diaries
- **Patient Platforms** for remote interaction (e.g. consultation and monitoring) between with patients and care workers
- **Healthcare Information Systems** for implementation of clinical processes and storage of patient records
- **Information Exchanges and Service Buses** for exchange information between systems within single institution or between multiple institutions

Solutions must be constructed supporting both real-time dataflows for direct care, where data is typically passed through processes of requests and response, as well as offline dataflows where reported data is collected, analysed and presented to operational and policy decision makers.

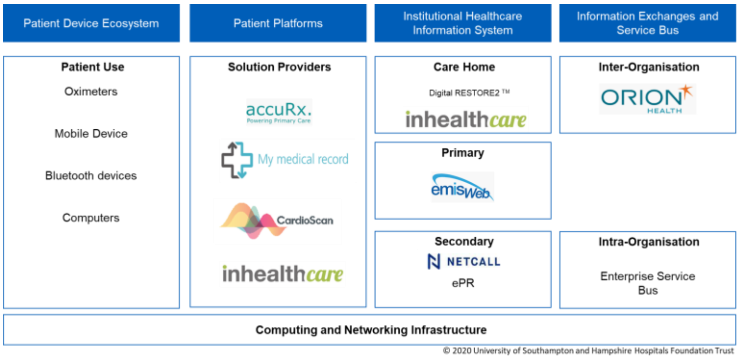


Figure 5

COVIDOximetry@home is deploying the primary digital innovation of remote oximetry monitoring implemented in CWDs. In North and Mid Hants this includes patient platforms (Accurx, MyMedicalRecord, inhealthcare, CardioScan) offering real-time data to primary care (EMIS), secondary care (NetCall, ePR), and community care (inhealthcare, DigitalRestore2) as shown in Figure 5. These digital components when integrated together provide the structure for the ICS under analysis and the source of data required for evidence.

Digital components should include data directly related to the processes they implement but also relationships with processes implemented by other digital entities. This chaining of references allows for trajectories to be reconstructed through direct data linking, beyond inferential linking of timestamps and patient identifiers. For example, if Hospital Same Day Emergency Care refer a patient to a CVW, the SDEC clinical encounter identifier should be included in the referral to allow the CVW to report observation data within the context of the patient and the specific clinical encounter.

Figure 6 outlines how digital components can be integrated to implement COVIDOximetry@home within an ICS where multiple independent providers must consider individual situations and legacy constraints. Selecting a single solution is rarely feasible or even desirable in complex systems considering the need for local adaptation and integration with clinical processes and technology, workforce training, and even innovation potential. Standardisation and interoperability will by the key to long term success, however, the pace of change required to deliver COVIDoxiemtry@home means that pragmatic solutions must be found that allow for the system change in ways that are understandable to those responsible for management and governance.

Data-driven systems thinking introduces rigour into service design and helps build evidence for change impacts within quality improvement. Stakeholders will have a better understands of the system they are operating and how different sources of data can underpin insight and decisions Capturing evidence in such a way will ensure that we increase the learning from COVIDoximetry@home for long term sustainability of solutions and best practice in future change programmes.

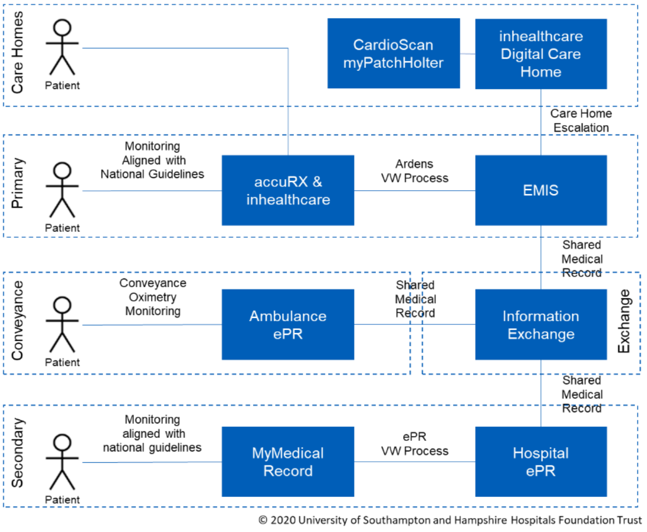


Figure 6

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Data Mapping Checklist (1 of 2)

Checklist	Entry		`			
Clinical Service Name						
Checklist Completed By						
Affiliation						
Role						
Version						
Date Completed						
Activity Reporting: Patient	Available [Y/N]	Frequency	Data Source [System ID]	Clinical Service Reference		
Number of patient appointments						
Number of patient attendances						
Number of patients without COVID-19						
Number of patients diagnosed with COVID-19						
Number of patient admissions as green						
Number of patient referrals to amber on assessment						
Number of patient referrals to red on assessment						
Number of patient referrals to amber on CVW						
Number of patient referrals to red on CVW						
Number of patient discharges from CVW						
Activity Reporting: Staff	Available [Y/N]	Frequency	Data Source [System ID]	Staff Type Reference	Clinical Service Reference	
Number of staff available						
Number of staff absent						
Activity Reporting: Equipment	Available [Y/N]	Frequency	Data Source [System ID]	Equipment Type Reference	Clinical Service Reference	
Number of oximeters available						
Number of oximeters provisioned						
Number of oximeters decontamination						
Number of oximeters missing						
Number of testing machines available						
Capacity Reporting: Workforce	Available [Y/N]	Frequency	Data Source [System ID]	Staff Type Reference	Staff Band Reference	Population Size
Number of staff by band by type by patient population						
Capacity Reporting: Equipment	Required [Y/N]	Frequency	Data Source [System ID]	Equipment Type Reference	Population Size	
Number of oximeters per patient population						
Number of testing devices per patient population						
Demand Reporting: Population	Required [Y/N]	Frequency	Data Source [Document ID]			
Size of catchment population						
Size of population per clinical service						
Size of population by referral sources to clinical service						
Size of population by demographic						
Demand Reporting: Structure	Available [Y/N]	Frequency	Data Source [Document ID]	Source Clinical Service Reference	Destination Clinical Service Reference	Clinical Service Reference
Number of referral sources for clinical service				N/A		
Number of referral destinations for clinical service					N/A	

Data Mapping Checklist (2 of 2)

Patient Reporting: Baseline	Available [Y/N]	Frequency	Data Source [System ID]	Patient Reference	Clinical Encounter Reference	Clinical Service Reference
Patient demographics						
Patient comorbidities risks						
Patient social risks						
Patient Reporting: Trajectory	**Available [Y/N]**	**Frequency**	**Data Source [System ID]**	**Patient Reference**	**Clinical Encounter Reference**	**Clinical Service Reference**
Patient physiological observation on assessment						
Patient physiological observation on CVW						
Patient clinical pathway events on assessment						
Patient clinical intervention events (medicine, etc) on assessment						
Patient clinical pathway event on CVW						
Patient acuity on pathway event (presentation, referral admission, discharge, etc)						
Rate of deterioration and recovery						
Length of time in care setting						
Patient Reporting: Outcome	**Available [Y/N]**	**Frequency**	**Data Source [System ID]**	**Patient Reference**	**Clinical Encounter Reference**	**Clinical Service Reference**
Patient outcomes from assessment						
Patient outcome from encounter						
Pathway Compliance Reporting	**Available [Y/N]**	**Frequency**	**Data Source [Document ID]**	**Clinical Encounter Type**	**Clinical Service Reference**	
Tests for correctness of decisions against clinical pathway events						
Tests for completeness						
Tests for accuracy						
Tests for consistency						
Tests for validity						

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