



Research Article

Community Virtual Ward (CVW+cRR) Proof-of-Concept Examining the Feasibility and Functionality of Partnership-Based Alternate Care Pathway for COPD Patients- Empowering Patients to Become Partners in their Disease Management

Antoinette Doherty^{1*}, Vera Keatings², Gintare Valentelyte³, Myles Murray⁴, Des O'Toole⁵

¹Donegal Community Healthcare and Letterkenny University Hospital, Donegal, Ireland

²Letterkenny University Hospital and University of Galway Medical Academy, Donegal, Ireland

³RCSI University of Medicine and Health Sciences, Dublin, Ireland

⁴PMD Solutions, Cork, Ireland

⁵HSE Digital Transformation and Innovation, Dr Steeven's Hospital, Dublin, Ireland

*Corresponding author: Antoinette Doherty, ¹Donegal Community Healthcare and Letterkenny University Hospital, Donegal, Ireland

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Abstract

Background: Individuals with exacerbating Chronic Obstructive Pulmonary Disease (COPD) display a pattern of exacerbations and illness culminating in repeated hospital admission. In an effort to empower people living with COPD to self-manage their illness and to avoid hospital admission a Community Virtual Ward + continuous Respiratory Rate (CVW+cRR) with a bespoke platform that incorporated respiratory rate (RR) trends was designed and implemented in Co Donegal. The proof of concept took place from May to August 2022 with 15 eligible individuals living with COPD. **Pathway:** Patients with moderate-severe COPD (Gold Scale D) were admitted to the CVW+cRR for remote monitoring, with optimisation of existing care plans and provision of rescue prescriptions for the patient's use. The objective and subjective patient data was reviewed daily by a Registered Advanced Nurse Practitioner (RANP). **Results:** Data from 10 patients was eligible for inclusion. Hospital avoidance was achieved in 100% of the eighteen (18) identified exacerbations in patients admitted to the CVW+cRR with cRR. The average cost per patient reduced from average €19,384.00 to €3,376.44, with a 96.7% probability of being both cost saving and cost effective at a €45,000 willingness to pay threshold. Several patient-reported measures also indicated improvement between admission and discharge, including Self-Management (increase of 29.1%), Understanding of COPD (increase of 35.3%), and Quality Adjusted Life Years (QALY) (increase by 0.15 of a QALY). **Conclusion:** The COPD CVW+cRR offered individuals an alternate care pathway and facilitated early intervention and management of infective exacerbation. The CVW+cRR provided the option to remain at home while receiving care, resulting in avoided hospital admissions with the use of both personalised objective trigger thresholds and patient feedback as to their wellbeing.

Keywords: Chronic Obstructive Pulmonary Disease; Advanced Nurse Practitioner; Partners; Treatment; Respiratory; Respiratory Rate; Community Virtual Ward; Virtual Community Ward; Hospital at Home.

Background

Respiratory disease treatment requires significant healthcare resources. In Ireland during 2021, there were 10,417 respiratory disease admissions to hospital for Moderate and Severe COPD. The average per admission cost ranged from €2,902 to €5,776 with an averaged range of length of stay between 5 to 11 days. In the UK, respiratory disease accounted for the highest proportion of inpatient hospitalisations and bed days compared to other diseases between 2009- 2016. In 2016, there were 92,391 hospitalisations and 578,319 in-patient bed days [1]. Diseases of the respiratory system are one of the main causes of death in the European Union (EU)¹. The majority of admissions with respiratory disease are classified as emergencies. Chronic Obstructive Pulmonary Disease (COPD) is the main reason for admission to the respiratory ward as some individuals have multiple admissions and become well known to all members of the respiratory team during their final years of life [1].

Nationally and internationally, the rising prevalence of COPD is responsible for significant healthcare use and patient morbidity and mortality [2,3]. The economic and social burden of COPD in Ireland is quite substantial. Relative to other Organisation for Economic Co-operation and Development (OECD) countries, Ireland continues to have highest rates of COPD hospitalisations of the recorded countries in 2020 [4]. Although the exact prevalence of COPD in Ireland is unknown, it is medically accepted that there is a very large number of undiagnosed COPD cases within the Irish population. It may be as high as 10% of the adult population with COPD, both diagnosed and undiagnosed [3,5]. Nationally pre-pandemic 15,000 patients were hospitalised with COPD with a predicted mortality rate from COPD in the region of 1,500 annually [5]. Acute exacerbations are the key drivers of direct costs for COPD, accounting for over 70% of COPD-related costs for hospitalisations including emergency visits [3]. The cycle of readmission is very common with a third of patients hospitalised for acute exacerbation COPD returning to the hospital within ninety days [1]. As per Letterkenny University Hospital In-Patient Enquiry (HIPE) data COPD admissions demonstrated that 35% of patients with COPD were readmitted within 90 days. In addition, longer inpatient stays demonstrated a correlation with readmission and death among this patient group.

The challenge that exists within hospitals nationally is to find a way to break this cycle and develop an ability to predict

1. [Eurostat. Respiratory diseases statistics](#)

readmission and offer an alternate care pathway. This was the key motivation for designing a Community Virtual Ward (CVW+cRR) proof of concept to examine the feasibility and functionality of an alternate care pathway for COPD patients in this cycle of care.

The target population consisted of individuals with a pattern of repeated illness culminating in hospital admissions due to COPD exacerbation(s). The increasing frequency of presentation is associated with a declining state of health and can increase the burden on resources [1]. A CVW+cRR with a bespoke platform that incorporated the novel use of cRR trends was designed, implemented, and offered as an alternative to inpatient care in Co Donegal from May to August 2022 to a cohort of eligible individuals with severe COPD.

With an alternate pathway these hospitalisations are avoidable once substantial provision and access to specialist community care is established [4]. This community model is the primary focus of the Irish national health policy “Sláintecare”, aimed at developing and progressing an integrated model of care across all health settings [6,7]. Recent challenges of the COVID-19 pandemic and the Health Services Executive (HSE) cyber-attack of 2021 [8] have focused the need for flexibility in patient care delivery.

Outcome Measures

The key objective of the CVW+cRR is to deliver innovation in healthcare with a primary care focus that will support and treat individuals with COPD allowing them to remain at home to receive their care. Exacerbations were assessed based on a mixed method of objective scoring using eMRCO extended MRC dyspnoea method and qualitative observations during verbal communication. It was anticipated that the CVW+cRR should improve patient care through early detection of exacerbation, offering a choice for patients and their families, respiratory physicians, nurses, and General Practitioners (GPs) to progress integrated respiratory care.

The design of the model of care did not focus on economies of scale but rather about the right care at the right time in the right place. If such a model of care proved to be cost-effective, it should be considered for standardisation.

The key patient-specific outcomes of the CVW+cRR were to:

1. Reduce attendance to Emergency Department or out-of-hours general practitioners (GPs) services.
2. Improve patient outcomes by offering an alternate care pathway.
3. Empower people with COPD to become a partner in the management of their health.
4. Reduce hospital admissions.

5. Reduce the length of stay for in-patients if applicable.

The CVW+cRR should improve channels of communication through well-established systems with GPs and ambulance teams to help avoid hospital admissions. The CVW+cRR should provide equipment, which will support patients to monitor their oxygen saturation levels, RR, and heart rate. It is anticipated that patients will be able to manage their exacerbations with rescue medications. Additional support where necessary will be provided through multi-disciplinary team (MDT) referrals, to support patients to reduce anxiety and improve their coping skills.

Development of the CVW+cRR

A preliminary proof-of-concept audit was undertaken by the RANP prior to the pilot commencement. This was used to establish a needs analysis to determine the consumption of acute hospital resources by patients living with COPD in Letterkenny University Hospital. The findings showed that nine (9) patients had a total of five hundred and forty (540) bed days over the previous year (an average of sixty (60) bed days per patient) with seven (7) average number of admissions per patient.

A Design Thinking Approach to Pathway Creation

The Digital Transformation Team of the Health Service Executive (HSE) is mandated to Empathise, Define, Ideate, Prototype, Test upon solutions that meet the quadruple aim of improvements in the quality of care, in quality of life, reduction in costs, and improvement in the clinician/patient experience. Working in partnership with industry to deploy “Design Thinking” methodologies with a patient centric approach, underpinned by a ‘Why Statement’. Design-thinking workshops were undertaken with a project team consisting of hospital respiratory consultants, community clinical leads, both regional and senior directors of nursing, GP’s, industry, and patient representatives.

Workshops involved multidisciplinary problem statement exercises and patient interviews to identify a patient persona, and their pains and gains within the existing area of COPD care locally.

Internationally CVW+cRR has become an alternative way of providing care to high-risk patients using a combination of specialist care and telehealth, employing “systems, staffing, and daily routines of a hospital ward...” in a community-based care

model [9,10]. However, as we attempted to answer the challenge statement - “How might we empower people with exacerbating COPD to become a partner in the management of their health and ensure that they receive the right care at the right time as close to home as possible?” - we realised that we would require a bespoke solution as there were no digital solutions available currently in the market place to meet the project needs.

The CVW+cRR provides delivery of acute medical care in the home of patients, who would otherwise require admission to hospital [11-14]. Previous studies have reported significant reductions in hospital admissions [11,15, 16] and improvements in quality of life [15,17] among patients with chronic diseases treated in a CVW+cRR. A recent Irish study has reported significant improvements in symptoms and health status among patients admitted to a CVW+cRR with chronic respiratory disease [18]. Similarly, the CVW+cRR model has been adopted recently to support mild COVID-19 patient infections at home [19-22]. The introduction of remote monitoring equipment to record oxygen saturation has relieved the strain on overburdened acute hospital services by allowing patients to be discharged while also ensuring the development of respiratory failure in these community-based patients is detected and treated early [12].

The design, implementation, and evaluation of CVW+cRR for individuals with a history of exacerbating COPD started with a comprehensive assessment of the patient’s journey through the health service using existing care pathways. This challenged the pains and gains associated with developing an innovative solution to patient care in the home setting. This project was designed with continuous monitoring of RR as an essential predictive clinical observation in the care and management of this patient group.

The unique approach to monitoring the RR in conjunction with a digital platform with active caseload management by a RANP represented, as showing in Figure 1, a world first in primary care. The vendor, PMD Solutions, who offers a unique RR monitoring technology, worked in partnership with HSE Digital Transformation. This secured a partner that would provide a remote management platform which integrates with RespiraSense™, Oximetry, and other tools such as spirometry. This allowed for gathering other assessments, patient education, and patient collaboration, through a health platform myPatientSpace™.

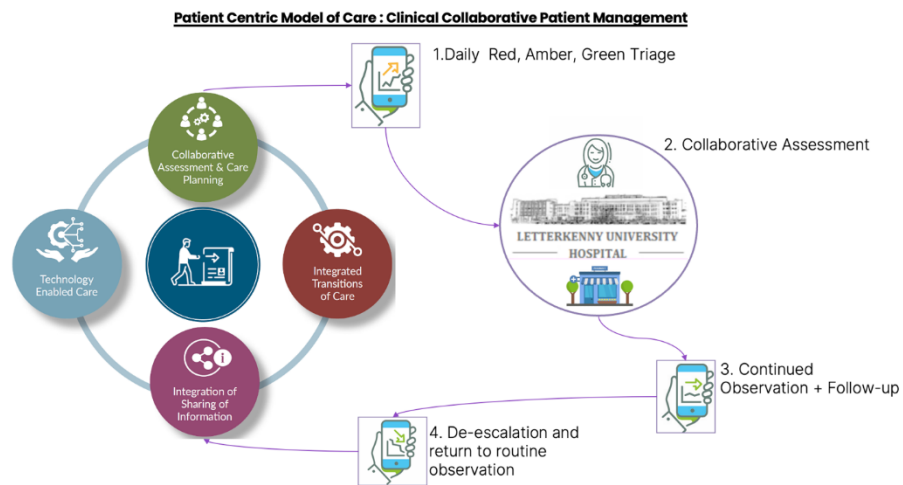


Figure 1: Interconnected patient centric process of linking patient accessible technology with collaborative clinical oversight to empower all stakeholders to improve outcomes.

Key responsibilities of the RANP

The CVW+cRR for individuals living with severe COPD was led by a RANP, an integrated nurse based in Community Healthcare, Co Donegal affiliated with Letterkenny University Hospital. The RANP was responsible for providing a choice to assist patients to remain at home, supported by technology as opposed to previous care options. Specifically, the RANP was responsible for:

- Reviewing and assessing patient’s status each day, using a Red-Amber-Green risk based approach for identification of intervention using both patient-reported and objective physiological data.
- Acting as a case manager, where a full episode of care included a complete respiratory assessment of physical health and current medication, breathlessness management, a home visit if indicated to assess equipment, and family supports.
- Identifying any barriers to better self-care and addressing these with actions wherever possible and within the scope of practice.
- Using the data promptly to implement a management plan or intervention.

- Establishing a pathway to medication such as steroids and antibiotics faster for the patient group by providing a rescue prescription if indicated by and in collaboration with the GP.
- Delivering patient information and education, face-to-face presentation, patient focus groups and the development of written information and videos to support upskilling throughout the project.
- Acting as an identified champion driver which involved weekly meetings with all key stakeholders throughout the process.
- Assessing, planning and implementing care, advice and patient-specific education as required throughout the process.

Patients selected for the CVW+cRR were identified from the caseload of high healthcare users identified by Letterkenny University Hospital In-Patient Enquiry (HIPE) data. Eligibility for the study was determined from a review of patient HIPE data. Patients demonstrating frequent exacerbations and those enrolled in a pulmonary rehabilitation clinic with advanced levels of COPD were deemed eligible. The inclusion and exclusion criteria are summarised in Table 1.

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Community Virtual Ward Inclusion and Exclusion Criteria & Pathway	
Inclusion Criteria	Red Flags - Hospitalisation Criteria
<ul style="list-style-type: none"> • Over 16 years of age • No active addiction or members of household with active addiction • Known to one of the Letterkenny University Hospital respiratory consultants • Spirometry diagnosed COPD • Physical examination completed by RANP • History of exacerbation or ongoing decline from baseline • Optimal home care supports in place, to support activities of daily living • Does not require an intensive programme of case-management • Tested negative for COVID-19 and no clinical suspicion of same 	<p style="text-align: center;">Depending on baseline of clinical observation:</p> <ul style="list-style-type: none"> • Stridor • HR >120 pm, RR>30 pm, SpO₂<88% <ul style="list-style-type: none"> • Worsening resting dyspnoea • Unable to complete sentences • Distress and elevated RR for prolong periods causing concern • Desaturation from normal oxygen levels and associated signs of hypoxia <ul style="list-style-type: none"> • Acute respiratory failure • Onset of new physical signs (cyanosis, peripheral oedema) • Failure of exacerbation to respond to initial medical management • Evidence of de-compensation of a long-term condition (e.g., heart failure, arrhythmia) with acute symptoms that requires acute hospital direct interventions and monitoring due to the presence of serious co-morbidity (heart failure, new occurring arrhythmias, etc.)

Table 1: Summary of patient inclusion and exclusion criteria.

Partnership with Technology Providers

The implementation of the CVW+cRR was aided by the monitoring device, RespiraSense™ and the digital health platform was developed and supported by myPatientSpace™. The pilot had one trained nurse who supported patient enquiries, enrolment sessions, and troubleshooting from PMD.

Figure 2 illustrates how industry supports the on-boarding, off-boarding, and the curation of data, as led by the RANP with assistance from the PMD trained nurse. This assistance facilitates the healthcare provider to focus more time on clinical assessment while removing the burden of technology.

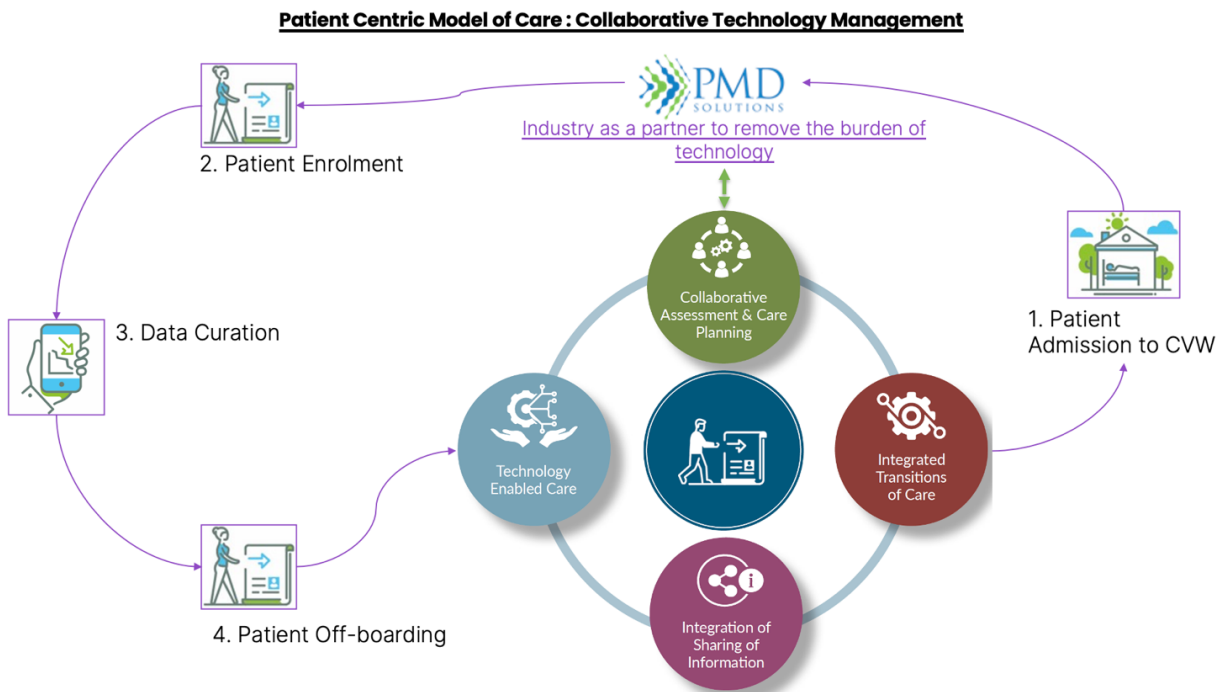


Figure 2: Infographic illustrating the position of technology providers in the care pathway, designed to remove technology burden from both clinician and patient.

RespiraSense™ - Continuous Respiratory Rate (cRR) monitoring

The novel respiratory rate (RR) monitor used was designed and produced by PMD Solutions, an Irish company, based in Cork. The advantage of the device is that it continuously monitors the RR in a motion-tolerant manner which enables accurate readings even if patients are ambulatory. The technology is National Institute for Health and Care Excellence (NICE) reviewed² in the UK and is CE, UK Conformity Assessment (UKCA) and Food and Drug Administration (FDA) approved.

Published evidence demonstrates that cRR was able to predict patients who became de-saturated ($SpO_2 < 92\%$) and those who developed a fever (38°Celsius) 12 hours earlier when rates stayed elevated above 24 breaths per minute for 30 minutes or longer [10].

In addition, preliminary evidence indicates useful features in the cRR, that if deviating from normal personalised trends, are an indicator of physiological distress (Figures 3 and 4).

² <https://www.nice.org.uk/advice/mib299> RespiraSense™ for continuously monitoring respiratory rate.



Figure 3: RespiraSense™ demonstrated by being worn in a home setting.



Figure 4: Illustration of RespiraSense™ showing thoracic and abdominal sensors with a connected electronic unit

It can be shown that everybody has a unique personalised profile of cRR trends (Figures 5 and 6), which if abnormal, indicate a shift from stable to unstable health status. Features of interest in cRR trends include:

1. The nominal minimum and maximum range of cRR over 48hrs;
2. The difference between the day-time average cRR and the night-time average respiratory rate;
3. The slope of 48hrs moving average cRR.

Combining the evidence of early indications of worsening respiratory performance can be observed by varying rates of breathing, in addition to increased effort of breathing compensating for poor gas exchange, deviations from personalised norms of respiratory trends can give objective and early evidence for the need to intervene and support rehabilitation. For example, during the study, when a trend of cRR deviated from either Nocturnal or Diurnal norms became apparent the patient was assessed and necessary support was provided virtually. If applicable their rescue prescription was dispensed.

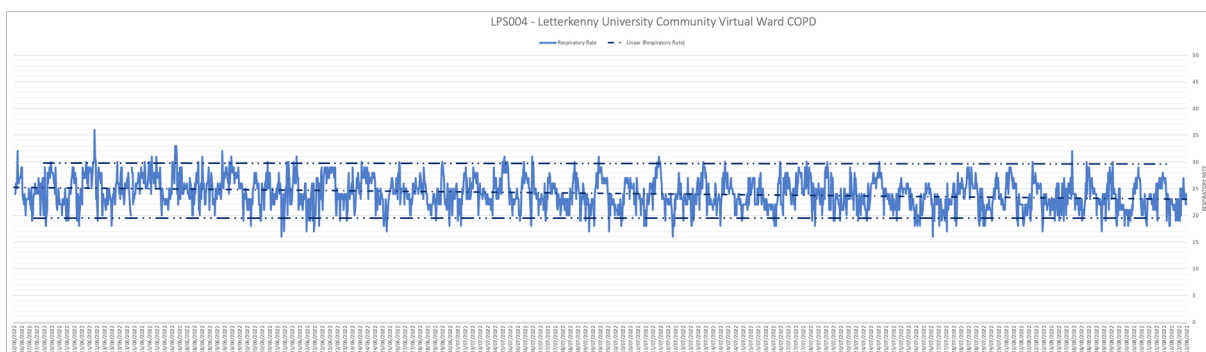


Figure 5: cRR Trend from a study participant for over 71 days with dashed lines to indicate max and min RR and a dashed trendline to indicate the slope of the mean RR.

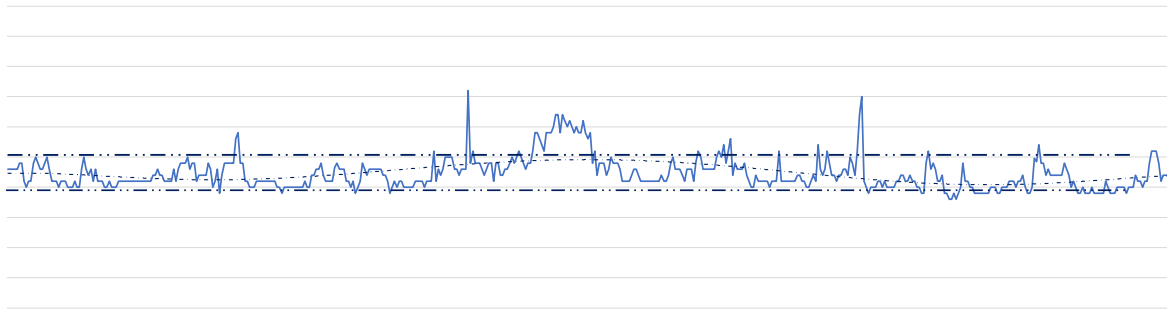


Figure 6: An abstract from one participant ranging from 8th July - 18th July. Features of abnormal Maximum and Minimum range of RR, including a dashed trendline slope of mean cRR can be observed which correlated with an exacerbation event.

MyPatientSpace™

myPatientSpace™ is a Digital Health Platform, an Irish digital and therapeutics company providing a remote management platform that integrates with RespiraSense™, Oximetry, and other tools such as spirometry and allows for gathering other assessments, patient education, and patient collaboration.

A non-invasive pulse oximeter was also used to monitor patients. The intervention gave additional information that could improve care. Clinical observations that require an escalation of care will be displayed on a portal and are colour coded by Red, Amber, and Green.

Targeted approach to healthcare

This is a targeted approach to care it is necessary to identify the following:

- Patients with COPD who have a history of acute exacerbation that has resulted in an individual having one or more presentation to the following GP/Out of hours services/ED or acute hospital.
- Patients who are suspected of having COPD but never diagnosed and who have a history of repeated respiratory tract infections resulting in an individual having one or more presentation to the following GP/OOH/ED or acute hospital.

- The learnings of this study, the CVW+cRR experience, resources and budget can be released throughout the HSE when implemented to the target group of patients at national scale.

Patient Enrolment

The patients were selected as described above, were admitted to the CVW+cRR for remote monitoring, for the optimisation of existing care plans. Patients were on-boarded with the digital technology and the health platform that would be the basis of the information reviewed daily. This data allowed the RANP to use the data to make clinical decisions to care for the patients in the CVW+cRR.

The patient data was reviewed daily at the start of each shift by the RANP. When an abnormal trend was observed patient contact was initiated and appropriate virtual support provided. If applicable the rescue prescription was activated.

Once an abnormal cRR trend became apparent the patient was contacted and self-care management was assessed, and support was provided virtually. If applicable, the rescue prescription was activated.

The process flow illustrated in Figure 7 shows the enrolment and volume of data points per patient during the study period.

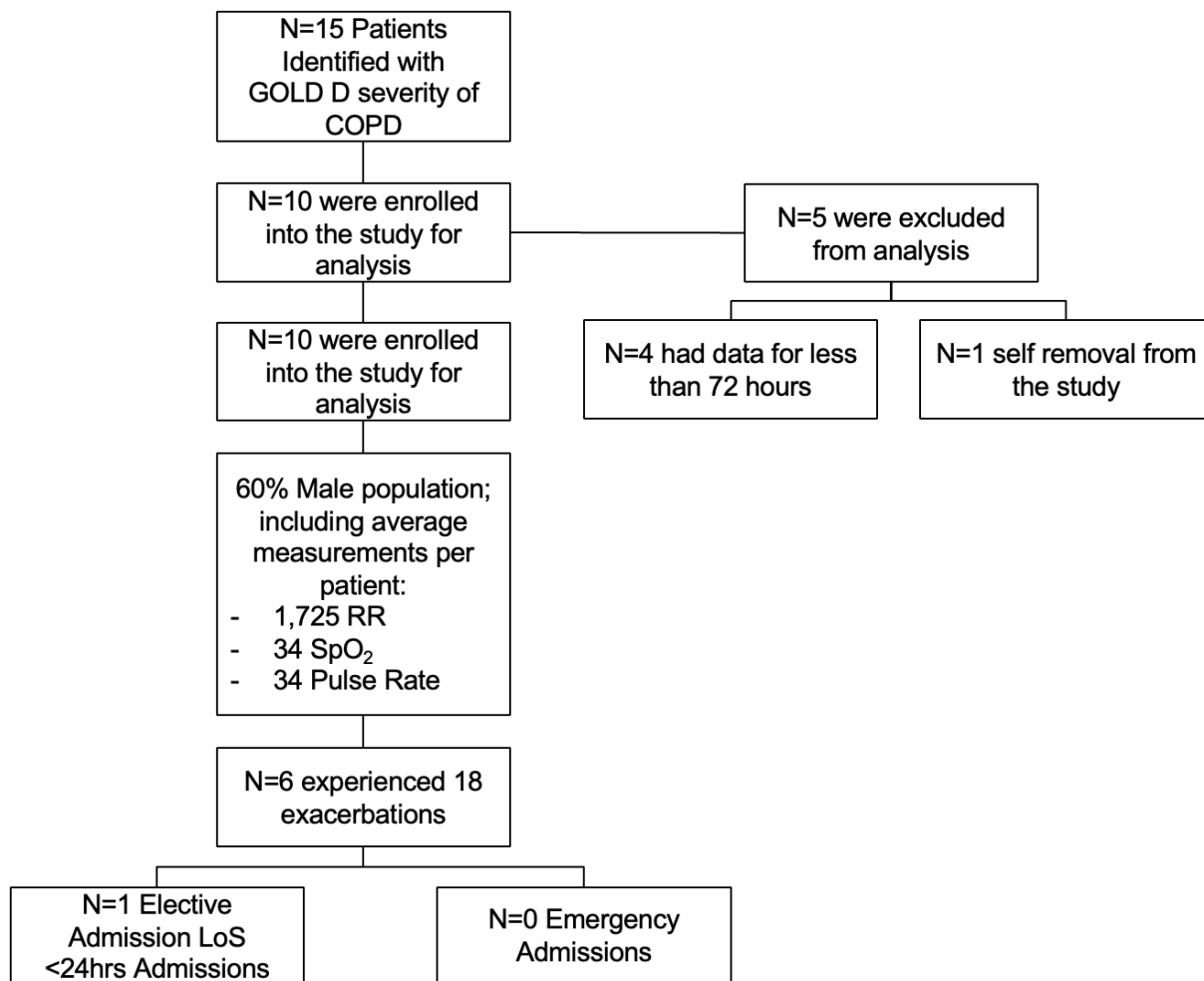


Figure 7: Flow chart of the enrolment of patients into the study and the volume of data per participant.

Statistical analysis

Economic evaluation

The technique of economic evaluation explores cost-effectiveness by relating the mean difference in cost between alternative treatment options to their mean difference in effectiveness, and by quantifying the uncertainty surrounding these incremental point estimates. The economic evaluation consisted of a cost-effectiveness analysis which estimated the incremental costs and benefits of the CVW+cRR compared with usual care (i.e., hospital admission) for the group of COPD patients. The proof of concept allowed for the evaluation of a new approach to healthcare inclusive of technologies and establish clinical feasibility.

The evaluation was undertaken over a 13-week time horizon (the duration period of the CVW+cRR pilot). The baseline

information on outcomes and costs was collected before patient admission to the CVW+cRR and collected again continuously over a 13-week period.

Health outcomes were expressed in terms of clinical effects and generic health status. The outcome data used in this analysis were collected and recorded routinely via an interactive bespoke app. Both patient-reported outcomes (generic health status) and objective outcome measures (clinical outcomes) were captured. The objective outcome measures were captured *via* RespiraSense™, non-invasive, wireless, body-worn motion-tolerant RR monitor. Data for all patients who spent between 30 to 90 days in the CVW+cRR were analysed.

Costing was based on the perspective of the publicly funded health and social care system (HSE) for intervention provision. This perspective was chosen as any savings would be in the acute sector

and costs in the intermediate/community care sector.

Individual patient healthcare expenses were also collected. Considering the duration of the CVW+cRR, neither the costs nor the outcomes were discounted. The evaluation followed the recommended national guidelines³.

Cost analysis

The cost components consisted of the following:

- Cost of implementing the CVW+cRR and relevant resources: patient recruitment, data collection, equipment, application, and educational equipment.
- Costs of primary and secondary health services over the course of the CVW+cRR: the costs of running the CVW+cRR (i.e., the RANP), cost of other relevant staff, medication, acute hospital length of stay, (additional treatments/tests).

Effectiveness analysis

Health outcomes were expressed in terms of clinical and generic health status. Clinical outcomes included RR, pulse oximetry, pulse rate and were recorded continuously over the 13-week period.

Generic health status was expressed in terms of Quality Adjusted Life Years (QALYs) gained, calculated based on patient responses to the EQ-5D-5L instrument for Ireland. The EQ5D scores at baseline and at discharge from the CVW+cRR were used to calculate patient-specific QALYs gained over the 13-week period⁴. The QALY is used in economic evaluations (which combines the quality and quantity of life) to quantify the overall health effects of interventions.

Outcomes from the patient-reported COPD Assessment Test

3 [Health Information and Quality Authority. Guidelines for the Economic Evaluation of Health Technologies in Ireland 2020](#)

4 EQ-5D-5L is an instrument which evaluates the generic quality of life. It was developed in Europe and is widely used. The EQ-5D descriptive system is a preference-based HRQL measure with one question for each of the five dimensions that include mobility, self-care, usual activities, pain/discomfort, and anxiety/depression

(CAT)⁵ and Understanding COPD Questionnaire were also analysed.

In economic evaluation, a treatment is considered as more cost-effective than its comparator based on one of the following conditions:

- (1) If it is less costly and more effective.
- (2) If it is costlier and more effective, but its additional cost per additional unit of effect is considered worth paying by decision-makers; and
- (3) If it is less costly and less effective, but the additional cost per additional unit of effect generated by the comparator is not considered worth paying by decision-makers.

The incremental analysis approach was adopted, which combines both the costs and effectiveness and their correlation into a single variable for each individual, to determine which of the three conditions applies. The incremental net benefit (INB) statistic was calculated, which takes into account the cost-effectiveness threshold value per additional benefit gained. A positive INB indicates that the intervention is cost-effective, and if INB is negative, the intervention is not cost-effective, relative to the usual care provided.

Analysis was performed using Stata v.17 with statistical significance set at $p < 0.05$.

Results

Hospital avoidance was achieved in 100% of the eighteen (18) identified exacerbations in patients admitted to the CVW+cRR with cRR. The average (range) of admission to the CVW+cRR was 74 days (30-94) days. All patients who were admitted to the CVW+cRR were successfully managed at home. The chart in Figure 8 and results in Table 2 summarises the patient-reported outcomes of the study.

5 The COPD Assessment Test (CAT) is a questionnaire for people with COPD. It is designed to measure the impact of COPD on a person's life, and how this changes over time.

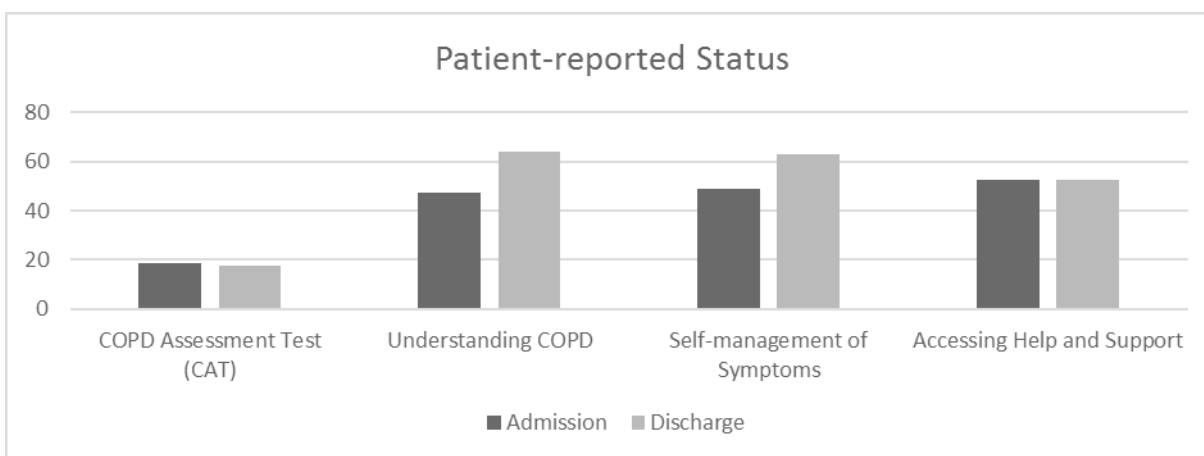


Figure 8: The chart illustrates an improvement in reported CAT score by 0.8 points; Improvement in the understanding of COPD by 16.7 points, an improvement in the self-management of symptoms by 14.2 points, and the same level of access to help and support between admission and discharge.

Outcomes	Admission	Discharge	Overall change	Significance
Understanding about COPD	47.3 (4.8)	64.0 (4.9)	16.7 (8.5)	p=0.05
Managing symptoms of COPD	48.8 (6.6)	63.0 (3.1)	14.2 (6.3)	p=0.03
Accessing help and support	52.6 (5.9)	52.6 (4.7)	0 (8.4)	p=0.99

Table 2: Summary of COPD Questionnaire Scores at CVW+cRR admission and discharge with noted statistical significance.

Six individuals had one or more exacerbations with a total of 19 courses of antibiotics and eight courses of oral corticosteroids being dispensed to participants during the study. This medication was used to treat infective exacerbations of COPD as prompted by the physiological data and patient assessment.

Patients with acute exacerbations were supported with eight RANP interventions by activating a rescue script of antibiotics and steroids. In practice, patients exercised caution and only dispensed the rescue script following consultation with the RANP.

Over the course of the duration of the CVW+cRR, the mean (SD) COPD Assessment Test (CAT) score fell by 0.8 ($p = 0.74$) from an average score of 18.5 (SD: 4.8) at admission to an average score of 17.7 (SD: 7.3) at discharge. Sixty per cent of patients reported improvements in CAT, and all of these exceeded the minimal clinically important difference of two points [23].

Understanding the COPD Questionnaire scores showed a statistically significant improvement at discharge from the CVW+cRR (Table 2). The mean score related to understanding COPD (‘About COPD’) increased by 16.7 ($p = 0.05$). Similarly managing symptoms of COPD among patients improved by a mean score of 14.2 ($p = 0.03$). No change in the score for accessing help

and support was observed. Standard errors reported in parenthesis in Table 2.

The EQ-5D-5L quality of life instrument reported significant improvements for ‘usual activity’ for 36% of patients ($p = 0.05$) after discharge from the CVW+cRR. Similarly, 40% of patients reported having ‘no problems’ ($p = 0.03$) across all dimensions (mobility, self-care, daily activity, pain and discomfort, anxiety and depression). Overall health status improved slightly whilst on the CVW+cRR, with a mean discharge score of 58.4 (SD: 4.2) ($p = 0.77$), however, this was not statistically significant which was consistent for this patient group who had ongoing exacerbations and significant levels of respiratory disease.

Resource Use and Costs

The CVW+cRR was delivered by the RANP within normal working hours (8.00-16.00) at Errigal CDM Hub Letterkenny. During admission to the CVW+cRR a total of 18 exacerbations among six patients during admission were recorded. Nineteen courses of antibiotics and eight courses of steroids were dispensed during the CVW+cRR stay. A total of eight GP visits were used by half of the patients. This resulted in a total cost of €777.76 for all patients which included medication, GP visits, prescriptions and government fees.

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Hospital admission was avoided by all patients admitted to the CVW+cRR. This represented eleven hospital admissions avoided among three of the patients admitted to the CVW+cRR based on their previous inpatient history. This resulted in significant cost savings of €820 per in-patient day bed at Letterkenny University Hospital.

Before admission to the CVW+cRR (i.e. usual care by hospital admission) the average cost per patient (to the HSE) came to €19,384.00. In contrast, the average cost per patient at discharge to the CVW+cRR was €3,376.44 (Table 3).

This demonstrated the strength of patient selection with the right patients being enrolled in CVW+cRR and greater resource and cost savings potential.

Description	GP visit + prescription	Medications	Staff	Equipment and Technology
Number of Uses	8	19 + 8 +27	2	-
Total Cost	€520	€257.76	€6,809.70	€22,800
Source	Local GP	Community Pharmacist	HSE Employee Scale	Study Records

Table 3: Summary of key resources used during admission to the CVW+cRR.

Potential cost savings

Substantial cost savings, due to avoided hospital admissions, were achieved during the implementation of the CVW+cRR. To estimate the potential costs savings (to the HSE) from a reduction in patient hospital admissions, the average cost of COPD patient hospital admissions during 2021 (before the CVW+cRR pilot) was estimated. Additionally, ambulance transfer costs were also calculated. HIPE data from Letterkenny University Hospital were used to capture the number of inpatient admissions and their duration of hospitalisation (Table 4).

A total of 46 COPD patients were admitted to hospital in 2021, with an average number of bed days of 19.39 per patient. The average cost per patient (including ambulance transfers) was estimated at €16,900. The total cost savings to the HSE, if the CVW+cRR would have been implemented at the beginning of 2021 would have resulted in €777,440 for these patients. This represents 1.3% of the Sláintecare Community enhancement Fund, which allocated €60 million in 2021 for enhancing community care [20].

Number of COPD admissions (two or more)	46^a
Total number of bed days used	892
Ambulance transfers^b	92
Cost per inpatient stay	€820
Cost per ambulance transfer	€500
Total potential cost savings in 2021	€777,440

Table 4: Summary of COPD patient hospital admissions and costs in 2021; (a) COPD admissions in 2021 were reduced on average by 50% nationally due to multiple factors associated with the COVID-19 pandemic care pathways through acute services; (b) With no available data of actual cost for an ambulance transfer, this was estimated at €500 per journey. Two journeys were assumed for each admitted patient.

Economic evaluation

The total cost of implementing the CVW+cRR was €30,387.97, giving a mean cost per patient of €3,376.44. The CVW+cRR was, on average, less costly and more effective than usual care (Table 4 and Figure 7). The CVW+cRR was associated with a reduction in mean costs of €14,999 (p-value: 0.09; 95%CI: -€30,941, €943) per patient. In terms of QALYs gained at discharge from the CVW+cRR, this was associated with an increase in mean QALYs of 0.15 (p-value: 0.32; 95%CI: -0.13,0.43) per patient as illustrated in Figure 8. The expected cost-effectiveness result indicated that at the willingness to pay threshold value of €45,000, the probability of the intervention being cost-effective was estimated to be at 0.967 (96.7%).

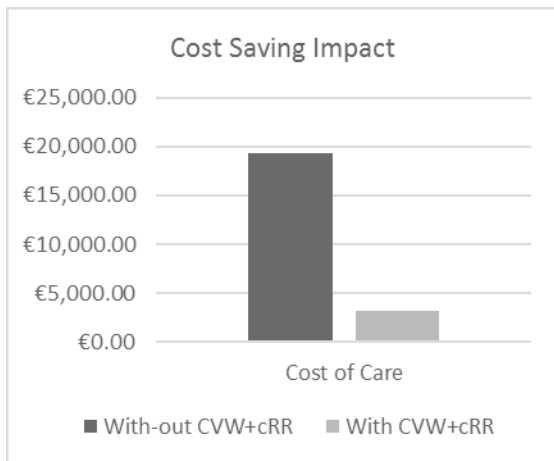


Figure 9: Summary of an average cost saving of €14,999 per patient based on the implementation of CVW+cRR.

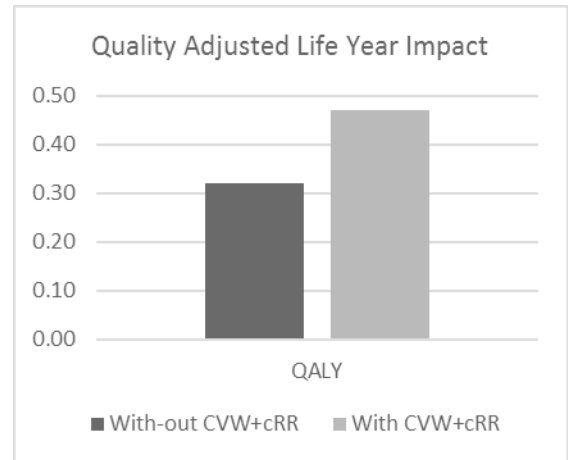


Figure 10: Summary of an average increase of 0.15 per patient in terms of Quality Adjusted Life Years based on the implementation of CVW+cRR.

Additionally, the incremental analysis suggested that relative to the usual care provided (i.e. hospital admission), the CVW+cRR was cost-effective, as reflected by a positive Incremental Net Benefit (INB) value of €21,648 (95% CI: €2,920.60 - €40,375.73) (at the threshold value of €45,000). (Table 5).

Variable/analysis	Incremental analysis (CVW+cRR minus usual care)
Cost analysis	
Difference in mean total cost (95% CI) [p-value]	-€14,999 (-€30,941, €943) [0.09]
Electiveness analysis	
Difference in mean QALYs (95% CI) [p-value]	0.15 (-0.13,0.43) [0.32]
Probability (%) that the CVW+cRR is cost-effective for threshold value of €45,000 ^a	0.967 (96.7%)

Table 5: Incremental cost-effectiveness results.

(a) The expected cost-effectiveness analysis probabilities were estimated using nonparametric bootstrapping technique based on 1,000 bootstrapped resamples

Discussion

The CVW+cRR facilitated the delivery and provision of specialist care to COPD patients in their own homes. This model of care delivered by the RANP provided a combination of specialist and general care, all with the aim to empower individuals to become more confident in the management of their COPD. Despite the small number of patients enrolled, the CVW+cRR led to significant improvements in patient care from their own home. Significant improvements in knowledge and understanding of their condition suggested the success of adopting a digital platform for remote monitoring of these patients to empower and improve their ability to manage their health. Additionally, the economic evaluation of the CVW+cRR suggested significant cost savings to the Irish public healthcare system as a disease-specific small-scale CVW+cRR has the potential to manage individuals with two or more acute hospital admissions with COPD from the system. "Respiratory rate elevation has been shown to be predictive of impending chronic obstructive pulmonary disease (COPD) exacerbation" [24].

Limitations

The economic evaluation focused on a pilot proof of concept project and does not reflect the full and final cost-effectiveness analysis of the CVW+cRR. It is important to note that the sample size of 10 patients is small. However, the reported findings warrant for the CVW+cRR to be conducted at a larger national and multi-site scale, with recruitment of more patients. This would further strengthen the evidence to support the successes of adopting an integrated community care model driven by digital technology for COPD patients in Ireland.

Conclusion

The COPD CVW+cRR offered an alternate pathway to individuals and facilitated early intervention and management of infective exacerbation. The option to remain at home while receiving care was achieved where previously a hospital admission was the standard of care given to these cohort of patients. Outcome measures demonstrated an improvement in quality of life, knowledge and understanding of their condition and increased ability to manage their health when supported through the digital platform, remote monitoring and access to the RANP. The cost-effectiveness of the CVW+cRR suggested significant savings were achieved for this patient group. The principles of the model using this bespoke platform and novel monitoring of RRe are transferable to other chronic respiratory conditions to improve

overall health outcomes and serve as an alternative to emergency and hospital care.

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