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Telehealth and CFTR modulators: Accelerating innovative models of cystic fibrosis care

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ABSTRACT

Better health and longer survival for many people with cystic fibrosis (PwCF) compels the continued evolution of the CF care model. Designed to deliver specialized care for a complex chronic condition, the model is organized around interdisciplinary healthcare teams at dedicated care centers. Introduction of CFTR modulators and the COVID-19 pandemic have catalyzed the model's evolution. Many PwCF on modulator therapies are experiencing better health and considering changes in their daily care routines. Some of the growing number of adults with CF are experiencing age-associated co-morbidities, requiring coordination with new specialists. The pandemic accelerated the use of telehealth, revealing tradeoffs from new configurations of care delivery. Herein we review the implications of these recent shifts and offer recommendations to improve the quality of care coordinated across the interdisciplinary teams and an expanding field of subspecialists, while supporting the ability of the patient to take on greater responsibility in disease management.

1. Introduction

Cystic fibrosis (CF) is the result of genetic mutations in the gene coding for the cystic fibrosis transmembrane conductance regulator (CFTR) protein. The clinical manifestations of a missing or malfunctioning CFTR protein can be severe and complex, affecting nearly every organ system and resulting in reduced life expectancy. To address the various challenges that persons living with CF (PwCF) face, CF care centers comprised of expert interdisciplinary clinical teams have been established. Supported by clinical studies and data registries, clinical practice guidelines have been developed and standards of care established for the purpose of learning and driving best practices. This model of care has served the CF population well with improving life expectancy and a growing adult population [1].

For decades, therapies developed and approved for PwCF were primarily directed at the downstream consequences of CF lung disease (i.e., infection, obstruction, and inflammation) and other manifestations (e.g., pancreatic insufficiency). These therapies have played a key role in the improvement in clinical outcomes [2]. The advent of novel therapies, notably CFTR modulator therapy, has produced amazing results for many PwCF, and we anticipate they will be available to more PwCF in the years ahead. The full impact of CFTR modulators was becoming evident when the SARS-CoV-2 (COVID-19) pandemic (https://www.cff.org/medical-professionals/patient-registry) necessitated immediate changes to the care model, specifically the rapid adoption of telehealth. These two landmark transformational changes, namely widespread availability of CFTR modulators and the COVID-19 pandemic, have stimulated interest in a re-evaluation of the current and anticipated needs of the CF population and potential adaptations to the care model to meet those needs effectively and efficiently [3]. Herein we offer a perspective on current challenges and opportunities.

2. The traditional CF chronic care model

CF care across much of the world adheres to standards of care guidelines, although some national and regional health systems are better resourced than others [4]. To facilitate the interdisciplinary approach and meet guideline standards, most care is de-

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Abbreviations

CF:	cystic fibrosis
CFTR	cystic fibrosis transmembrane conductance regulator
COVID-19	SARS-CoV-2
EMR	Electronic Medical Record
PRO	Patient Reported Outcomes
PwCF	people living with cystic fibrosis

livered through dedicated care centers. National health care systems and patient advocacy organizations like the U.S. CF Foundation accredit care centers through a peer-review process to periodically review staffing, operations, and quality of care [5]. Care teams are expected to deliver proactive, preventative care as well as provide treatment for complications, such as pulmonary exacerbations, with the goal of ensuring the best clinical outcomes for PwCF. They are encouraged to improve clinical care by engaging clinicians, patients, and families in the use of data and quality improvement methodologies [6,7]. This has been a hallmark of CF centers with a longstanding history of innovation driven by key patient outcomes and the dissemination of best practices.

Most CF care is provided in an outpatient clinic setting staffed by a core team of interdisciplinary professionals consisting of physicians, program coordinators, nurses, respiratory therapists, dietitians, and social workers. These teams are trained in pediatric and/or adult medicine and have a process for transitioning age appropriate PwCF from a pediatric to adult care setting. Many centers have added members to their core team such as pharmacists, physical therapists, mental health providers, and genetic counselors, while others access them through consultation [8,9]. CF care teams have also built a referral network to access expertise in inpatient care (e.g., hospitalists) and subspecialty care (e.g., gastroenterology and hepatology, endocrinology, otolaryngology, and obstetrics-gynecology). Although CF care is considered specialty care, the CF team often takes on primary care responsibilities as well.

To further encourage centers in building referral networks, the U.S. CF Foundation has supported professional development opportunities to attract and retain additional expertise (e.g., palliative care, lung transplantation, GI, endocrinology, ENT) and train them in the unique aspects of CF and CF care [10–12]. Thus, the current U.S. care model already encompasses a broader and more specialized workforce to meet the expanding needs of the patient population.

Routine care and clinical assessments have been time and labor intensive for both patients and health care providers. Routine surveillance typically consisted of quarterly in-person clinic visits in which the core care team members met with PwCF and their family, as appropriate. This approach has been conducive to long-term, mutually beneficial relationships between team members and patients/families, which provided a foundation for treatment decisions [13]. This center-based, in-person care model has been a resounding success as survival and other key clinical metrics have steadily improved over recent decades. Importantly, the growth of the adult CF population, now representing over 57% of the total population, has prompted an ongoing evolution of the care model primarily impacting adult programs. (Fig. 1)

Despite the successes, challenges remain. There are a finite number of CF centers, which means that some PwCF and families must travel great distances for clinic visits. While this may be manageable for scheduled monitoring visits, it can be challenging when acute health issues arise. Not all care centers have access to the expertise to meet all the needs of their current patient population, and for those that do, availability may be limited. Although providing an interdisciplinary team for a single visit offers some efficiencies, it may also lead to long clinic visits and the risk of information overload for some PwCF and families. Integration of telehealth visits may offer greater access to specialists outside of routine clinic times to improve access. Furthermore, despite widespread adoption of infection prevention and control practices, some PwCF are concerned about the risk of cross-infection in the clinic setting. These factors were already pressing further evolution in the CF care model.

3. The changing care needs of people with CF

CFTR modulators, drugs that increase CFTR quantity and/or function, are not a cure, but they directly address the underlying cause of the disease. As a result, many PwCF started on CFTR modulators have experienced remarkable improvement in clinical outcomes with increased pulmonary function, reduced numbers of pulmonary exacerbations, improved nutritional status, among other health benefits [14].

As these drugs are approved for younger and younger patients, we anticipate a more diverse range of clinical phenotypes will emerge. Adults with established lung disease will likely still have bronchiectasis and chronic airways infection. Children started on treatment early in life might expect a longer delay before the onset of significant lung disease, while infants might be able to avert most manifestations of the disease. PwCF will likely live longer and develop more co-morbidities (e.g., CF-related diabetes), which they would have to manage in addition to their CF. We have also observed an increase in the proportion and number of PwCF who are overweight or obese associated with the availability of CFTR modulators. Such patients may experience other health consequences associated with obesity (e.g., hypertension, cardiovascular disease, type 2 diabetes mellitus, obstructive sleep apnea) [15]. PwCF taking modulators have also experienced liver function abnormalities, increased anxiety and depression, and rashes. These effects need close monitoring and further long-term study [16].

Since PwCF taking CFTR modulators feel much better, many are eager to reduce their onerous treatment burden [17]. Some have reduced the number and frequency of their treatments, and yet there is no generalizable knowledge as to whether this can be done safely. Many PwCF on CFTR modulators have reduced the frequency of clinic visits and as a result, there will be less data to inform treatment decisions. The clinical trials that supported current clinical practice guidelines were conducted prior to the widespread availability of CFTR modulators. Whether the recommendations in these guidelines will benefit PwCF treated with CFTR modulators is not known. Clinical studies to understand the impact of stopping chronic therapies after initiation of CFTR modulators are ongoing through HERO-2 [NCT04798014], SIMPLIFY [18] and CF STORM [NIHR131889]. There is also a risk of patients skipping or discontinuing CFTR modulator therapy without a framework for monitoring such as in clinic or asynchronous care and presenting with untreated or more severe disease.

We must also acknowledge that CFTR modulators are not available to a sizable proportion of the population. Lack of access to CFTR modulators could be due to many reasons including unresponsive genotype, drug intolerance, access barriers (e.g., lack of insurance coverage, out-of-pocket costs) and missed or delayed diagnoses (e.g., missed diagnosis at newborn screening related to race/ethnicity). Those without access to CFTR modulators will continue to have a complex set of health issues and should continue with recommended therapies. Individual patients' access to and tolerability of CFTR modulators should be considered in equitable care needs and outcome metrics.

We have outlined many of the factors that have contributed to better outcomes and an evolving CF population. Although there

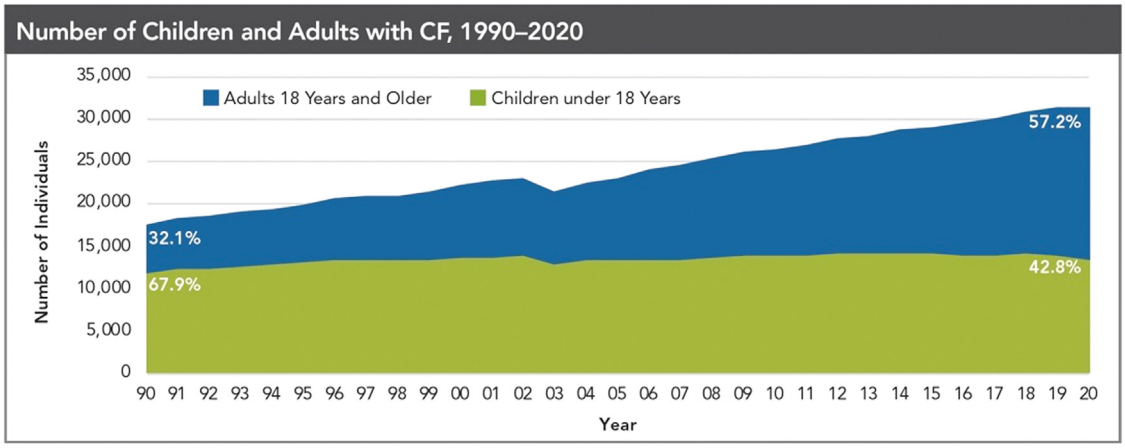

Fig. 1. Adults with CF comprised 57.2% of the total U.S. CF patient population reported in the CF Foundation Patient Registry 2020 Annual Report.

Table 1
Factors likely to increase the complexity of the CF care model.

Improved Long Term Survival	• More adults with CF needing care • Increased mobility of PwCF changing care programs more frequently • More adults with CF are working full-time and raising children with limited time for frequent appointments • Living longer with CF-related co-morbidities • Co-morbidities associated with aging (e.g., hypertension, cardiovascular disease) • Decreased or delayed need for solid organ transplantation
CFTR modulators	• Not available to all PwCF • Age at initiation results in wider diversity of clinical phenotypes • Therapies require monitoring for adverse effects • Risk of significant drug/drug interactions • Risk of PwCF choosing to skip doses or discontinue therapy • Assessment of optimal needs for other chronic therapies in setting of modulators

may be a reduced need for acute care (e.g., pulmonary exacerbations), there will likely be a greater need for chronic and preventive care. Specialized care managed by CF centers will be necessary because of these contributing factors. (Table 1) Further evolution of the CF care model is inevitable, and external forces rapidly accelerated this process.

4. The onset of COVID-19: an inflection point in CF care

The CF care model was severely tested with the onset of COVID-19 in 2020. Events surrounding the pandemic forced the rapid implementation of telehealth, previously used sparingly by a few CF centers [3]. In the early days of the pandemic, many care teams were impacted by redeployments for COVID-19 care and/or furloughs as hospitals lost revenue from halting or limiting revenue-generating procedures and operations [19]. Despite these challenges, many CF care teams successfully delivered interdisciplinary care through telehealth. Notably, the quality of telehealth care was reported to be equal or better to in-person care by over half of both care team members and patients/families [20–22].

While PwCF and families acknowledge the benefit of reduced travel and time burden associated with telehealth visits, limitations and barriers to its use were identified [22]. For example, telehealth was less appropriate for sensitive conversations, assessing family dynamics, and for younger children who may not engage as readily via a computer screen [20–22]. The use of telehealth was preferred to a greater extent by adult teams as compared to pediatric teams [21,22]. In summary, telehealth is not well-suited for every visit or interaction, but CF teams acknowledged the merit of its continued use as an option in CF care delivery moving forward.

The ability to nearly replicate pre-pandemic clinical care through telehealth does not mean that all PwCF will benefit from this mode as a primary means of accessing care. Determining the optimal use of telehealth will be an important area of study in years to come and likely highly linked to care centers and the individual needs of the populations they serve. We must be attentive to the needs of all PwCF and recognize that “one size does not fit all.” Innovations such as telehealth have the risk of exacerbating inequities for some. Not all PwCF will have access to telehealth and remote monitoring either because of technological disadvantages, cultural hurdles, or other factors [23,24]. How and when telehealth is used will be an important area of study and may be linked to centers and the needs of the populations they serve.

5. Advancing fundamental change

5.1. Organizing the CF community

In 2021, the U.S. CF Foundation convened a multi-stakeholder workshop to explore the lessons learned during the pandemic and

Table 2
Identifying opportunities to generate evidence to support new approaches to care.

Theme	Virtual Access to Care and Research	Models of Care	Standardization of Measures/Endpoints
Description	Understanding the impact of telehealth on access to care and ensuring equitable access to telehealth for both care and research	Defining a sustainable interdisciplinary model of care which includes telehealth and remote monitoring	Determining accuracy, standardization, and optimal frequency of home measures and virtual sample collection
Key questions	• What impact does telehealth have on access to care and research and resulting health outcomes? • How do we ensure equitable access to telehealth? • How do we best support the regulatory needs for remote work? • How do we ensure adequate funding for technology to enable telehealth?	• What is the optimal hybrid model of care which includes telehealth? • How are relationships and trust built and maintained in the virtual environment? • How do we ensure that a hybrid model of care is financially sustainable moving forward? • What policies will be important to address coverage/access challenges? • What is the optimal interval between visits to ensure timely detection of new symptoms, infections, and changes in health outcomes to inform timely interventions?	• What is the validity, reliability, feasibility, and optimal frequency of home measures (i.e., home spirometry, scales, height, self-trackers, wearables)? • How do we standardize and validate virtual sample collection (i.e., cultures/labs)?

identify opportunities to generate evidence to support new approaches to care. Assuming that telehealth and remote monitoring would be incorporated into the care model, key questions were identified. (Table 2) Taskforces were organized to validate remote clinical endpoints for use in clinical trials and to design pragmatic trials to assess the impact of care delivery innovations. Key stakeholders (e.g., care team members, PwCF and families, and researchers) have contributed with a goal of developing a pipeline of studies to assess models of high quality, co-produced, equitable care with valid clinical research endpoints. One request for proposals has been issued and another will soon follow.

5.2. Reflecting on technology and tailored care

Clinical care delivery systems evolve at the frontline. The CF community can learn from others who use virtual methods to manage chronic health conditions to advance our model [25]. Telehealth has many positive features (e.g., ability to reach and connect with PwCF/families for shorter/more flexible visits, reduce access barriers associated with travel, less time away from work/school, greater access to subspecialists and mental health care). However, there are also potential pitfalls such as missed physical exam findings, lack of access to technology and the internet, access to language translation/interpretation, burdening patients/families with more screening/care tasks at home. There is also the additional pre-visit planning burden on care teams to collect and organize data generated at home and remotely in other care or lab settings. Bringing these data into the visit planning requires extra time and coordination with PwCF/families and other professional/facilities.

It will be important to define what aspects of care are best suited for in-person visits, what can be performed virtually, and for which patients/families. For example, telehealth permits asynchronous care, in which members of the care team or other specialists could interact with the patient/family at separate encounters. While this approach may result in a greater number of visits, they may permit greater focus on specific aspects of care and monitoring that may otherwise get insufficient attention in a busy in-person visit. Telehealth may also allow teams to accommodate an increasing population of patients by eliminating physical space constraints. Telehealth also reduces the challenges of time, distance, and travel by offering opportunities to connect similar groups of PwCF/families on education topics and processes. Virtual group visits have been successfully used for prenatal monitoring and other chronic conditions and warrant exploration in CF care [26].

5.3. Coordinating CF care

Retaining the specialized knowledge and experience of CF care teams will be invaluable and should remain a primary focus within any adaptations to the care model. The current care model revolves around the CF team taking responsibility for organizing and coordinating most aspects of care. We must ensure that coordination of care remains paramount as the complexity of care grows to meet the needs of an aging and increasingly diverse patient population. Although sustaining this approach will be a challenge, effective and timely communication facilitated by virtual meetings and messaging through electronic medical record platforms will make it feasible.

Care will need to be customized based on the needs and preferences of the individual patient. With a more diverse set of needs and severity of symptoms, it is anticipated that some patients may require fewer in-person visits to maintain optimal health metrics while others will benefit from closer in-person monitoring by the CF care team. Pre-visit planning with input from the care team as well as the patient and/or family can facilitate more effective and efficient clinic visits whether in-person or virtual. Incorporating health metrics and patients reported needs into care delivery planning will better align resources to meet the needs of individuals while ensuring access for all.

We must also anticipate the primary care needs of a growing and aging adult CF population. Primary care expertise could be integrated into the CF care team (e.g., via an advanced practice provider) or via a shared care model with a general internist. Of note, pediatric CF care teams typically share the care of infants and children with CF with a general pediatrician [27]. Adult programs could consider a similar approach using lessons learned from the pediatric experience to ensure all care needs are met.

5.4. Recognizing the changing role of people with CF and families

Partnership between PwCF and their families and the CF team has been the cornerstone of CF care and should remain a key element moving forward. However, gone are the days of all health care data being collected and stored by care teams with patients having little access. Fortunately, patients now have greater access to their own health data and are becoming more dynamic partners in shaping their care. Since the onset of the pandemic PwCF/families have played a more active role in taking measurements at home (e.g. height, weight, blood glucose, home-spirometry) and coordinating collection of blood and respiratory samples, collected at home (and mailed to the care center for anal-

ysis) or collected and analyzed at other locations (with the results sent to the care center) [24]. The COVID-19 pandemic has empowered more patients to take a larger stake in tracking their health care metrics. In order to ensure proper collection and interpretation of these data, PwCF and families will need training and education [28]. This shift in care interactions will require a more active role for PWCF/families when working with their CF team.

Little is understood about the role of health literacy and shared-decision-making in CF. The U.S. CF Foundation has supported training in enhanced relationship-centered communication, inviting shared decision-making and activating PwCF and families in the process; however, more is needed to understand the willingness, preferences, and readiness of PwCF/families to take on more responsibilities in their own care [29]. This is perhaps especially true for parents of children with CF, e.g., can they help their child perform home spirometry successfully, are they willing to obtain respiratory cultures, take their child to clinics for labs that do not offer support with child life or specifically trained pediatric technicians.

5.5. Recommendations for evolving the CF care model

We, as authors with considerable experiences and varying perspectives on CF care, offer several recommendations (Table 3) that are relevant to the next evolutionary change in the CF care model. They are geared to improve the quality of CF care that is carefully coordinated across the interdisciplinary care team and an expanding field of subspecialists, while supporting the ability of the patient and family to take on greater accountability in disease management.

5.6. Retain the interdisciplinary team approach

We believe the interdisciplinary team approach to care is vital and should remain firmly entrenched, but how this team interacts with PwCF and families may need to evolve. The rapid adoption of technology, using telehealth and remote monitoring, should be integrated into the model, enabling the CF team and other specialists to provide care to a larger number of PwCF over greater distances. A hybrid model of in-person and telehealth encounters should be tailored to the individual, permitting a variety of care patterns that lead to the best clinical outcomes. However, we cannot assume that such models are appropriate for all PwCF and their families, and so additional research is required to understand best practices. Attention to healthcare disparities will be important to ensure that everyone has equal access to effective care, leaving no one behind.

It is vital that care teams continue to facilitate specialized CF testing and surveillance of PwCF. Coordinating newborn screening, sweat testing, and diagnosis of CF should be done by care teams to ensure appropriate oversight and follow-up with PwCF and families and to maintain national data collection and surveillance via patient registries. CF care teams should also oversee the frequency and quality of collection of respiratory cultures so that PwCF receive timely treatment and chronic management for infections and, if warranted, expedited access to specialized inpatient care for treatment.

5.7. Evolve the care model

Although we recommend retaining the interdisciplinary care team approach, adding new subspecialists and primary care providers is essential as care needs are evolving. As the number of adults with CF continues to climb with advancing ages, more specialists are required to meet their dynamic needs. Adults are likely to live longer with comorbidities such as cystic fibrosis related diabetes, arthritis, osteopenia/osteoporosis, and liver disease, which will require further coordination with endocrinologists, gastroenterologists, and rheumatologists. Reproductive health specialists, including high risk obstetrician-gynecologists, are also likely to become more involved in CF care as adults pursue having children. The care model will need to be modified to include collaboration and consultation among specialists in a manner that makes the best use of providers' and patients' time and resources.

Coordination of care will remain critically important but may evolve as primary care providers play a larger role. Primary care clinicians typically coordinate healthcare maintenance (e.g., immunizations, screening, and preventative measure) in the general population, but the unique needs of the CF population have historically been met by the CF team. Perhaps it is time to develop guidelines for a shared, integrated model of care across the life span, much like the care of infants [27]. Unlike pediatrics, however, CF is relatively new to primary care in adults and considerable education will be needed to build successful partnerships.

5.8. Leverage technology advances

Technology has permeated health and health care. Individuals use personal devices and apps (e.g., Apple Watch, Fitbit) to measure and track exercise, sleep, calorie intake, and heart rate. These devices and apps are often connected to mobile phones that store, aggregate, and graphically display data. Patients can selectively share these data with health coaches or clinical care providers. Electronic medical records (EMR) are now mainstream. Clinicians and patients plan, schedule, and document care in this shared environment, with most EMRs offering portability of health information between health care systems.

Technology should be fully embraced in CF care. The pandemic offered lessons for how we might pursue using telehealth to deliver CF care and insights into the use of remote monitoring tools like home spirometry. While there is room to improve the utility of devices during care delivery, we also need to consider options for wearables and mobile health solutions to inform clinical decision-making and to help PwCF self-monitor, sustain their daily care routines, and manage their health.

5.9. Activate people with CF and families

If we change the way healthcare professionals interact with PwCF and families in a new model of care, PwCF and families will need the skills, knowledge, and confidence to undertake a greater role in the care process and to manage their own health. Like all patients, PwCF and families vary in the degree to which they are active participants in their care and their activation may shift as they age, and their health status changes. Arming PwCF and families with key health information and engaging them in shared decision-making in ways that mitigates language and cultural barriers, promotes health and data literacy, and invites partnership to coproduce care is required if we are to capitalize on the resources and technology.

PwCF and families demonstrated their willingness and ability to rapidly pivot to telehealth in response to the pandemic. Research was undertaken to understand the facilitators, barriers, and experience from their perspective, however the level of activation in their own care and the health care delivery process was not assessed. Were they passive participants or pushing further as their own advocates? As new aspects of the CF care models are tested, measures of activation and collaboration will provide important data to understand their efficiency and impact. As patient activation increases, do health outcomes and quality of life improve?

Table 3
Recommendations for the evolution of the CF care model.

Retain the interdisciplinary team approach	• Ensure specialized, interdisciplinary expertise is available to all recognizing specialty needs may change over time • Increase access to subspecialty expertise • Maintain specialized testing (e.g., sweat testing, microbiology, etc.) • Conduct surveillance to understand novel aspects of CF health associated with longer survival
Evolve the care model	• Engage new subspecialties to meet evolving needs • Increase inclusion of primary care providers in care delivery • Integrate asynchronous care to improve information sharing and optimize efficiency
Leverage technology advances	• Support for and coordination of some aspects of care via telehealth considering health status, access, and preference • Establish remote monitoring to enhance care
Activate people with CF and families	• Support development of skills for disease management to capitalize on available resources and adoption of technologies • Address health and data literacy to raise the level of informed, shared decision-making • Educate and empower in the management of complications of CF and aging
Enhance data systems	• Assess value of current data included in registries and other databases • Increase use of patient reported outcomes • Improve transparency and access to health data for patients and health care teams
Accelerate Learning and Dissemination of "Best Practices"	• Design validation studies of important clinical tools for remote monitoring (e.g., validity and use of spirometry performed at home) • Develop pragmatic trials/quality improvement project to assess best practices using technology • Assess novel models of care delivery (e.g., asynchronous care, group visits) • Develop guidelines describing data-driven best practices more rapidly • Enable rapid dissemination and implementation of new knowledge across the care center network
Advance health equity	• Reduce barriers to equal access to telehealth and/or in person clinical encounters • Increase representation of all groups in research, surveys, focus groups, and assessment of clinical outcomes • Research healthcare disparities to identify gaps in health care knowledge, education, and access to care
Advocate for sustainability of the model	• Eliminate barriers for licensure and reimbursement (e.g., ability to perform telehealth across state borders) • Align with health care payers and policy makers to incentivize and reimburse for value and quality of care • Tighten business alignment of the CF care center with host medical institution

5.10. Enhance data systems

In the CF clinical care setting, interactions between PwCF and care teams have generally focused on clinic-collected and patient-reported data. The systems that house these data are not necessarily integrated or transparent to all stakeholders. CF data generated within health care systems are becoming more accessible to PwCF and families with open notes and electronic health portals. We must continue to consider PwCF/family health literacy and preferences for communication and data sharing, especially with a growing number of clinicians becoming involved in care.

Work is underway to develop the next generation of the U.S. CF Foundation Patient Registry guided by the principles of collecting *the right* data with *less* effort and making it available to *all* stakeholders. An important aspect of this system may be collecting and consolidating patient reported outcomes (PROs) to monitor changes in energy level, sleep quality, and exercise tolerance beyond the current. Such data could be used to monitor changes

after initiation of therapies (e.g., CFTR modulators) and to identify early indicators of disease progression that may benefit from further evaluation long before changes are detected in objective clinical measures. A data ecosystem that is interoperable, frictionless, transparent, and easy to access for PwCF/families and clinicians could enhance their partnership in health management.

5.11. Accelerate learning and dissemination of "Best practices"

As we evolve the care model for a growing and diverse patient population and care workforce, we need to consider accelerating a CF learning system that will enable us to quickly harvest, curate, and disseminate data-driven best practices [30]. We need to amplify a culture of continuous learning and improvement, inclusion of patients/families, analyzing registry care experience data to improve, and assess outcomes and refine processes.

We must be nimble to ensure equity of care with a constant focus centered on the individual needs of PwCF while rapidly turning data into information for dissemination and implementation. Standards of clinical care based on systematic reviews of published literature that currently inform our model of care may not keep pace with information gleaned from real-world, pragmatic trials or multi-site projects using quality improvement science. Adopting a learning health system framework as we evolve the care model will help us learn if what we are doing is better and recognize what is not working and change course.

5.12. Advance health equity

Advancing health equity in CF means effecting changes so that no one with CF is disadvantaged because of who they are or their socially determined circumstances. In 2020 the U.S. CF Foundation Patient Registry reported that 4.7% of PwCF identified as Black and 9.6% as Hispanic. Yet the general perception of CF only affecting Whites remains and this impacts diagnosis, access to specialized care, and delivery of treatments and medical care [31]. Research has shown that non-White PwCF are at higher risk of worse health outcomes and they are more likely to have rare mutations that make them ineligible for the current modulators. PwCF in the U.S. who identified as Black or Hispanic were also less likely to report having a telehealth visit and less likely to get their needs addressed [23].

Reducing barriers to equalize access to specialized care delivery virtually or in-person must be a priority. Clinicians providing care, technology and data systems, and patient activation must consider the needs and concerns of under-served and vulnerable PwCF. The U.S. CF Foundation is committed to addressing these health inequities. Work is currently underway to a.) listen to the experience of PwCF of color and increase these voices in national strategy and programming, b.) recruit, retain and advance professional support for researchers and healthcare providers of color, and c.) improve health outcomes for PwCF of color to live, long fulfilling lives.

5.13. Advocate for sustainability of the model

The traditional interdisciplinary CF care model is relatively expensive. With a growing patient population, a longer life span, and greater complexity of complications, we anticipate that CF may be even more costly with increasing lifetime expenditures. In a healthcare world with competing interests and limited resources, the traditional CF care model may be at risk for sustainability. As we look to reshape the care model, it is imperative to understand the necessary elements that will ensure its continued success. The medical centers that host CF care centers will need to be part of the dialog.

CFTR modulators have reduced the need for inpatient resources but will increase the need for outpatient care. CF medications, especially CFTR modulators, are expensive and may shift funding support from personnel to medications. Healthcare systems across the globe have varied and complex mechanisms to financially support CF centers. Some systems will reimburse less for telehealth visits than for in-person visits, creating disincentives to implement telehealth. There is a need for greater advocacy of resources at the state and national levels to ensure that support for the care model is based upon improved outcomes.

Until CF stands for "cure found," there will need to be ongoing support and advocacy for patients, families and those who are providing care. The CF community has experienced tremendous strides and improvement over the past few decades with a rapid acceleration in the recent years impacted by the accessibility of CFTR modulator therapy and a global pandemic on the delivery of care. Any additional evolution will require ongoing support to ensure equitable access and sustainability as we move forward. While we have presented many ideas that will shape the care of PwCF in the years to come, it will only continue to be successful if we continue this path together.

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None.

CRediT authorship contribution statement

Michelle H. Prickett: Conceptualization, Writing – original draft. **Patrick A. Flume:** Conceptualization, Writing – review & editing. **Kathryn A. Sabadosa:** Project administration, Conceptualization, Writing – review & editing. **Quynh T. Tran:** Writing – review & editing. **Bruce C. Marshall:** Conceptualization, Writing – review & editing.

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References

[1] Goetz D, Ren CL. Review of cystic fibrosis. Pediatr Ann 2019;48(4):e154–61. doi:10.3928/19382359-20190327-01.
[2] O'Sullivan BP, Freedman SD. Cystic fibrosis. Lancet Lond Engl 2009;373(9678):1891–904. doi:10.1016/S0140-6736(09)60327-5.
[3] Sabadosa KA, Faro A, Nelson EC, Marshall BC. Impact of the COVID-19 pandemic: how our response is shaping the future of cystic fibrosis care. J Cyst Fibros Off J Eur Cyst Fibros Soc 2021;20(Suppl 3):1–2. doi:10.1016/j.jcf.2021.09.002.
[4] Castellani C, Duff AJA, Bell SC, et al. ECFS best practice guidelines: the 2018 revision. J Cyst Fibros Off J Eur Cyst Fibros Soc 2018;17(2):153–78. doi:10.1016/j.jcf.2018.02.006.
[5] Mogayzel PJ, Dunitz J, Marrow LC, Hazle LA. Improving chronic care delivery and outcomes: the impact of the cystic fibrosis Care Center Network. BMJ Qual Saf 2014;23(Suppl 1):i3–8. doi:10.1136/bmjqs-2013-002363.
[6] Stevens DP, Marshall BC. A decade of healthcare improvement in cystic fibrosis: lessons for other chronic diseases. BMJ Qual Saf 2014;23(Suppl 1):i1–2. doi:10.1136/bmjqs-2014-002871.

[7] Homa K, Sabadosa KA, Marrow LC, Marshall BC. Experience of care from the perspective of individuals with cystic fibrosis and families: results from 70 CF Foundation accredited programs in the USA. J Cyst Fibros Off J Eur Cyst Fibros Soc 2015;14(4):515–22. doi:10.1016/j.jcf.2014.12.011.
[8] Quittner AL, Abbott J, Hussain S, et al. Integration of mental health screening and treatment into cystic fibrosis clinics: evaluation of initial implementation in 84 programs across the United States. Pediatr Pulmonol 2020;55(11):2995–3004. doi:10.1002/ppul.24949.
[9] Zobell JT, Moss J, Heuser S, Roe L, Young DC. Understanding the expanding role of pharmacy services in outpatient cystic fibrosis care. Pediatr Pulmonol 2021;56(6):1378–85. doi:10.1002/ppul.25283.
[10] Brennan AL, Blackman SM. EnVisioning the future: endocrinology in cystic fibrosis. J Cyst Fibros Off J Eur Cyst Fibros Soc 2019;18(6):743–5. doi:10.1016/j.jcf.2019.09.012.
[11] Shaikhkhalil AK, Freeman AJ, Sathe M. Variations in nutrition practices in cystic fibrosis: a survey of the DIGEST program. Nutr Clin Pract Off Publ Am Soc Parenter Enter Nutr 2021;36(6):1247–51. doi:10.1002/ncp.10605.
[12] Dellon EP, Basile M, Hobler MR, et al. Palliative care needs of individuals with cystic fibrosis: perspectives of multiple stakeholders. J Palliat Med 2020;23(7):957–63. doi:10.1089/jpm.2019.0464.
[13] Homa K, Stevens G, Forcino R, Scalia P, Mertz P, Elwyn G. Assessing shared decision-making in cystic fibrosis care using collaborate: a cross-sectional study of 159 programs. J Patient Exp 2021;8 23743735211034030. doi:10.1177/23743735211034032.
[14] Mall MA, Mayer-Hamblett N, Rowe SM. Cystic fibrosis: emergence of highly effective targeted therapeutics and potential clinical implications. Am J Respir Crit Care Med 2020;201(10):1193–208. doi:10.1164/rccm.201910-1943SO.
[15] Kutney KA, Sandouk Z, Desimone M, Moheet A. Obesity in cystic fibrosis. J Clin Transl Endocrinol 2021;26:100276. doi:10.1016/j.jcte.2021.100276.
[16] Dagenais RVE, Su VCH, Quon BS. Real-World Safety of CFTR modulators in the treatment of cystic fibrosis: a systematic review. J Clin Med 2020;10(1):E23. doi:10.3390/jcm10010023.
[17] Hente E, Weiland J, Mullen L, et al. Assessment of treatment burden and complexity in cystic fibrosis: a quality improvement project. Pediatr Pulmonol 2021;56(7):1992–9. doi:10.1002/ppul.25361.
[18] Mayer-Hamblett N, Nichols DP, Odem-Davis K, et al. Evaluating the impact of stopping chronic therapies after modulator drug therapy in cystic fibrosis: the simplify clinical trial study design. In: Ann Am Thorac Soc, 18; 2021. p. 1397–405. doi:10.1513/AnnalsATS.202010-1336SD.
[19] Sawicki GS, Van Citters AD, Dieni O, et al. Financial impacts of the COVID-19 pandemic on cystic fibrosis care: lessons for the future. J Cyst Fibros Off J Eur Cyst Fibros Soc 2021;20(Suppl 3):16–20. doi:10.1016/j.jcf.2021.09.008.
[20] Van Citters AD, Dieni O, Scalia P, et al. Barriers and facilitators to implementing telehealth services during the COVID-19 pandemic: a qualitative analysis of interviews with cystic fibrosis care team members. J Cyst Fibros Off J Eur Cyst Fibros Soc 2021;20(Suppl 3):23–8. doi:10.1016/j.jcf.2021.09.004.
[21] Gifford AH, Ong T, Dowd C, et al. Evaluating barriers to and promoters of telehealth during the COVID-19 pandemic at U.S. cystic fibrosis programs. J Cyst Fibros Off J Eur Cyst Fibros Soc 2021;20(Suppl 3):9–13. doi:10.1016/j.jcf.2021.08.034.
[22] Solomon GM, Bailey J, Lawlor J, et al. Patient and family experience of telehealth care delivery as part of the CF chronic care model early in the COVID-19 pandemic. J Cyst Fibros Off J Eur Cyst Fibros Soc 2021;20(Suppl 3):41–6. doi:10.1016/j.jcf.2021.09.005.
[23] Albon D, Van Citters AD, Ong T, et al. Telehealth use in cystic fibrosis during COVID-19: association with race, ethnicity, and socioeconomic factors. J Cyst Fibros Off J Eur Cyst Fibros Soc 2021;20(Suppl 3):49–54. doi:10.1016/j.jcf.2021.09.006.
[24] Ong T, Van Citters AD, Dowd C, et al. Remote monitoring in telehealth care delivery across the U.S. cystic fibrosis care network. J Cyst Fibros Off J Eur Cyst Fibros Soc 2021;20(Suppl 3):57–63. doi:10.1016/j.jcf.2021.08.035.
[25] Solomon DH, Rudin RS. Digital health technologies: opportunities and challenges in rheumatology. Nat Rev Rheumatol 2020;16(9):525–35. doi:10.1038/s41584-020-0461-x.
[26] Lewis JB, Cunningham SD, Shabanova V, et al. Group prenatal care and improved birth outcomes: results from a type 1 hybrid effectiveness-implementation study. Prev Med 2021;153:106853. doi:10.1016/j.ypmed.2021.106853.
[27] Foundation Cystic Fibrosis, D Borowitz, Robinson KA, et al. Cystic Fibrosis Foundation evidence-based guidelines for management of infants with cystic fibrosis. J Pediatr 2009;155(6 Suppl):S73–93. doi:10.1016/j.jpeds.2009.09.001.
[28] Fettes E, Riley M, Brotherston S, et al. You're on mute!" Does pediatric CF home spirometry require physiologist supervision? Pediatr Pulmonol 2022;57(1):278–84. doi:10.1002/ppul.25708.
[29] George C, Raymond KF, Collins L, Arefy Z, Kazmerski TM. Partnership enhancement program: piloting a communication training program for cystic fibrosis care teams. J Patient Exp 2021;8:23743735211014050. doi:10.1177/23743735211014049.
[30] Fiordalisi C, Borsky A, Chang S, Guise JM. AHRQ EPC Series on improving translation of evidence into practice for the learning health system: introduction. Jt Comm J Qual Patient Saf 2019;45(8):558–65. doi:10.1016/j.jcjq.2019.05.006.
[31] McGarry ME, Williams WA, McColley SA. The demographics of adverse outcomes in cystic fibrosis. Pediatr Pulmonol 2019;54(Suppl 3):S74–83. doi:10.1002/ppul.24434.