

# Design and Implementation of a Novel Electronic Health Record Tool to Enhance the Care of Individuals with Cystic Fibrosis: The Cystic Fibrosis Note Template

David M. Leander<sup>1</sup> Alex H. Gifford<sup>2</sup> John N. Mecchella<sup>3</sup> Kathryn A. Sabadosa<sup>4</sup> Aricca Van Citters<sup>4</sup>  
Jennifer A. Snide<sup>5</sup> Eugene C. Nelson<sup>4</sup>

<sup>1</sup>Dartmouth Geisel School of Medicine, Hanover, New Hampshire, United States

<sup>2</sup>Department of Pulmonary and Critical Care Medicine, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire, United States

<sup>3</sup>Department of Rheumatology, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire, United States

<sup>4</sup>The Dartmouth Institute for Health Policy and Practice, Lebanon, New Hampshire, United States

<sup>5</sup>Analytics Institute, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire, United States

**Address for correspondence** David M. Leander, BA, MSIV, Dartmouth Geisel School of Medicine, One Rope Ferry Road, Hanover, NH 03755-1404, United States (e-mail: david.m.leander.med@dartmouth.edu).

ACI Open 2019;3:e26–e36.

## Abstract

Cystic fibrosis (CF) is a genetic disease in which dysfunction of a single protein channel leads to organ damage, resulting in chronic health problems and premature death. In the United States, medical care of individuals living with CF is delivered by care centers accredited and subsidized by the CF Foundation. CF outcomes have improved significantly through the use of collaborative networks, registry data, and research. CF clinicians are perpetually challenged to assimilate and act upon large quantities of data generated by the care of these individuals. CF Foundation accreditation also requires care centers to enter patient-level data from clinical encounters into the CF Foundation Patient Registry (CFFPR). Commercially available electronic health record systems often lack tools with sufficient context specificity and ease of use to facilitate productive interactions between clinicians and patients. We describe a CF-specific NoteWriter template built and implemented in Epic, which captures discrete data and simultaneously generates clinical documentation during ambulatory encounters. Unlike other examples of note templates in CF, this project involves SmartData Elements (SDEs) using the NoteWriter tool in Epic, which enables data to be entered in the exact way in which the CFFPR captures data. By conducting a pre-/poststudy of its use in our health system, we found that the template can expedite note completion when clinicians have adequate time to become familiar with the tool. We anticipate that the NoteWriter template will become a vehicle for delivering standardized, structured patient data to the CFFPR.

## Keywords

- ▶ electronic health record
- ▶ coproduction
- ▶ note template
- ▶ cystic fibrosis

received  
February 20, 2018  
accepted after revision  
April 3, 2019

DOI <https://doi.org/10.1055/s-0039-1688804>.  
ISSN 2566-9346.

© 2019 Georg Thieme Verlag KG  
Stuttgart · New York

License terms



## Background and Significance

Modern electronic health records (EHRs) are sophisticated platforms that assimilate a vast array of patient data and present information to clinicians through a graphical user interface. Shortly after passage of the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009, which authorized up to \$27 billion in Medicare and federal Medicaid payments over 10 years to qualified health care entities,<sup>1</sup> EHR adoption surged.<sup>2,3</sup> To capitalize on this incentive, health care entities must demonstrate meaningful use.<sup>4</sup> Consequently, clinicians experience significantly increased screen time to assiduously document their efforts in the EHR. Recent studies have revealed that clinicians spend at least as much time charting in the EHR environment as they do conversing with their patients.<sup>5-7</sup> Being unable to disengage from the EHR, particularly after hours, may contribute to physician burnout.<sup>8,9</sup> Therefore, improved documentation strategies are needed to mitigate the tension between fulfilling meaningful use mandates and preserving clinician job satisfaction.

Although most EHRs offer functionalities well-suited to the needs of primary care practices<sup>10</sup> and can improve the productivity of primary care physicians,<sup>11,12</sup> they tend to offer fewer and/or limited solutions for providers of specialty care. Some evidence suggests that EHRs neither slow nor hasten the workflow of specialists,<sup>13</sup> a conclusion that can be viewed positively or negatively. Uptake of EHRs has progressed unevenly in specialty care.<sup>14</sup> For chronic conditions, particularly those with relapsing and remitting courses and those in which treatment adherence strongly impacts their natural history, clinicians frequently struggle with data volume and diversity. Multiple authors have articulated that EHRs notoriously lack features capable of supporting the idiosyncratic workflows of specialists while also achieving meaningful use end points.<sup>15-18</sup>

Cystic fibrosis (CF) is a chronic disease affecting multiple organ systems for which “out of the box” EHR systems currently lack tools that help clinicians impute information about the individualized, nuanced manner by which patients with CF complete their self-care regimens. Peckham et al<sup>19</sup> first reported on this limitation of an EHR platform used by a regional CF unit in the United Kingdom. In the United States, most individuals with CF establish close, lifelong relationships with interdisciplinary teams at CF Foundation-accredited care centers and are seen at least quarterly. More than 180 care centers are incentivized by grant funding from the CF Foundation to provide encounter-level data on consenting patients to the CF Foundation Patient Registry (CFFPR), a valuable resource for both quality improvement and clinical research.<sup>20</sup> As of 2012, approximately 84% of individuals with CF living in the United States had contributed data to the CFFPR.<sup>21</sup> To the best of our knowledge, EHR systems used by CF care centers in the United States do not provide clinicians with documentation solutions that capture the specific types of data required by the CFFPR in real time and in a format that enables straightforward transmission to the CFFPR.

A far more important issue than the barriers CF clinicians must overcome to finish their documentation is the fact that

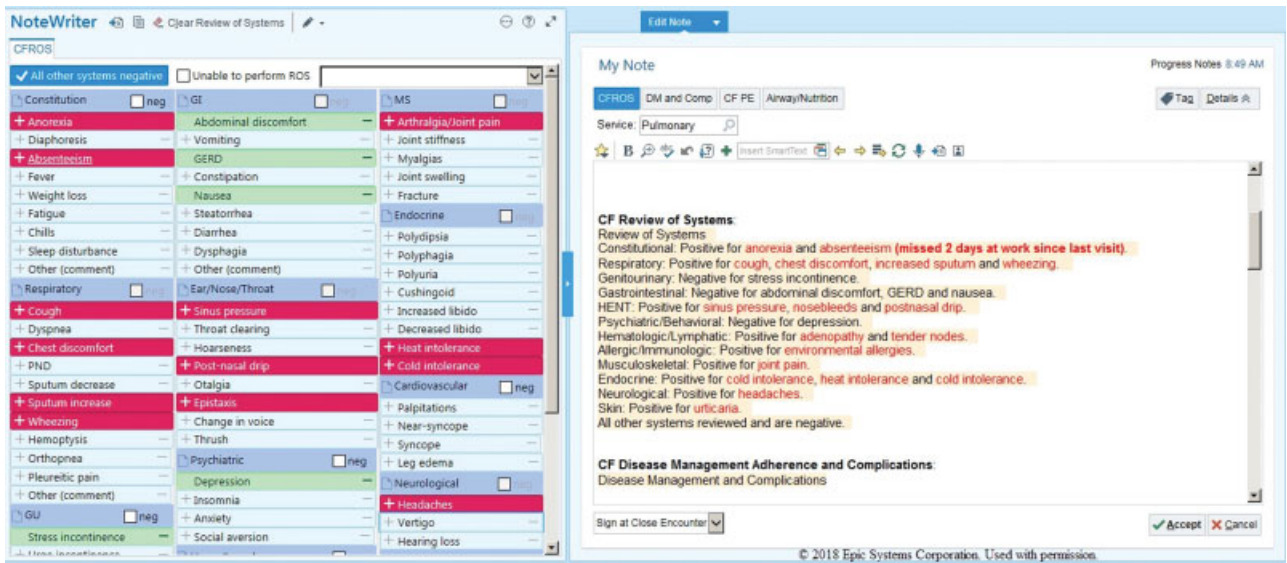
the voices of their patients and their patients' families have historically been excluded from EHRs. Most commercial EHRs now include some type of mechanism to acquire patient-reported outcome measures (PROs), but this information is clinician-facing<sup>22</sup> and is often insulated from other data streams such as medication lists and laboratory results for patients. Only certain components of a patient's visit are consistently available for view within a patient's EHR portal despite national campaigns, such as OpenNotes, and mounting evidence of the benefits in sharing views with patients to important medical data.<sup>23</sup> Moreover, most PROs capable of being evaluated by EHR tools such as patient portals are not disease-specific. Informatics innovators have devised strategies to marry common data streams from the EHR environment with disease-specific PROs to populate electronic dashboards.<sup>24-27</sup> These dashboards have served as catalysts for health care coproduction,<sup>28</sup> a paradigm in which patients and clinicians are not merely consumers and providers of health care, respectively, but are instead partners in assessing health status, planning and delivering treatments, and evaluating the impact of treatments on key clinical outcomes and health-related quality of life. In CF, a major initiative is underway to facilitate coproduction of care.<sup>29-32</sup>

Herein, we describe the design and implementation of a CF NoteWriter template in the 2015 iteration of the Epic EHR platform (Epic Systems Corporation, Verona, Wisconsin, United States). Our study had three goals: (1) reduce physician workload by creating a disease-specific EHR documentation tool, (2) capture data in a form amenable to direct transmission to the CFFPR, and (3) establish a framework for data acquisition that could be used in future coproduction efforts in CF. From the outset, we sought to capture the nuances of how individuals with CF not only take but also respond to their treatments, to prompt clinicians in real time through the process of data entry itself about best practices,<sup>33-35</sup> and to increase the efficiency of clinician documentation. The CF NoteWriter template differs from other Epic note-generation options in that each of its components is discretely captured and can then be exported for reporting purposes. Although the use of clinician-customized SmartForms has been described,<sup>36,37</sup> this project provides an application of SmartForms within the Epic NoteWriter tool, which has not been fully described in the literature. Our project demonstrates that the Epic EHR platform can be leveraged to collect and organize data elements that are harmonized with those contained in the CFFPR and serves as a proof of concept for other EHR vendors.

## Methods

### CF NoteWriter Template Design and Build

The project began with a series of discussions between a CF physician and two consultants with Epic programming expertise. During their ambulatory encounters with CF patients, physicians at Dartmouth Hitchcock Medical Center (DHMC) had previously used a single exhaustive SmartPhrase template, which generated nonreportable text. Physicians introduced this SmartPhrase into the standard “Create Note” window by

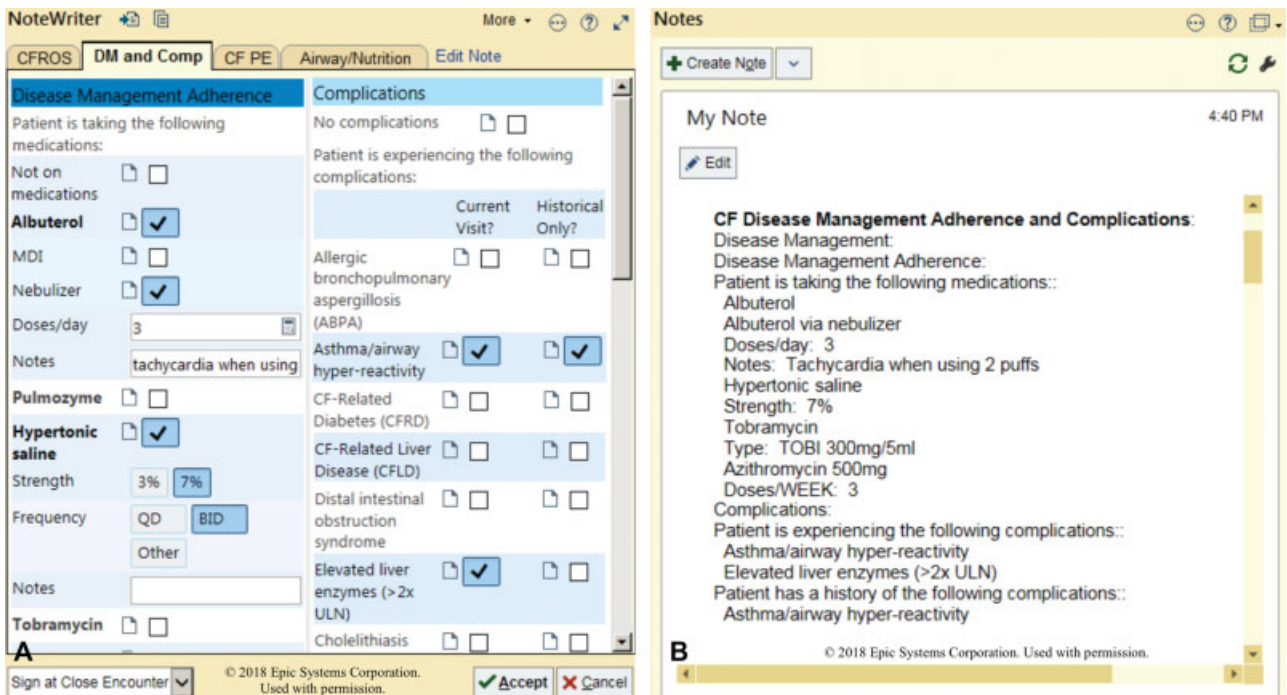


**Fig. 1** Screenshots of CF Review of Systems Tab in the CF NoteWriter template. After choosing to create his/her ambulatory visit documentation, the cystic fibrosis clinician is presented with a panoply of radio buttons and free-text fields (left panel) corresponding to medications, doses, and administration schedules. The provider can toggle to his/her note (right panel) which is being generated as selections are being made.

typing a “dot-phrase” (.cfclinicnote) (→Fig. 1). Through a codesign process, a new tool called the CF NoteWriter (→Fig. 2) was developed to create a more flexible and efficient documentation experience. The design of the CF NoteWriter template was informed by clinical workflow requirements as well as knowledge of the types of data necessary for the CFFPR. The instrument took shape through several iterations of design and testing over a period of 2 years.

We also devised a CF NoteWriter template with the goal of enabling CFFPR data extraction. In Epic, this requires the use

of SDEs. SDEs are records in Epic that are created to store data with a specific meaning in a particular context. These elements can be linked to various other tools within Epic that can be specified for the tool and context in which the element is used. Some potential contexts that SDEs can be stored in are at the patient, encounter, or note level. Thus, one can report on these discrete data points to determine whether a specific piece of information was documented for a patient in a specific context. Epic has already developed thousands of standardized SDEs that are primarily used for quality metrics



**Fig. 2** Screenshots of the Disease Management (DM) Adherence and Complications (Comp) (A) in the CF NoteWriter template (B).

reporting. However, custom SDEs can be configured to meet additional data collection needs. These SDEs are distinct from other aspects of the medical record such as documentation flowsheets, SmartText, or other clinical documentation sections such as the Problem List or Medical History. For our purposes, these custom SDEs were placed inside the physician note tool called the NoteWriter. The SDEs were organized through an interface called a SmartForm, which allows users to click on a template comprising specific SDEs, and enter data by either clicking on radio buttons or typing free text. Through this note-specific context, the SDEs can be reported individually for each note that the patient has, which is a unique way to capture these data which may otherwise be challenging to extract. Once a note is signed, the SDEs are stored by their context and can be pulled through the Epic reporting tool Clarity, which is an analytical software that can extract information such as SDEs from the entire system and generate structured reports that can be organized in a way that is actionable. Therefore, custom SDEs within a custom NoteWriter SmartForm for the purposes of a disease-specific registry (CFFPR) represent a novel approach to managing data, distinct from other methods of note templating (SmartTexts) or documentation flowsheet methodologies.

The template was built by creating the discrete data points required by the CFFPR such as airway clearance techniques (ACTs), pancreatic enzyme type, and CF-related comorbidities. These data points were defined with the same level of granularity as captured in the CFFPR, that is, specific treatment frequency, enzyme dosage, and binary “yes/no” values. With 263 data points created, the NoteWriter template was structured thematically by disease management and complications, airway, and nutrition (→ Fig. 2). The specific items were organized in a collapsible format so that only relevant options were viewable when prompted, allowing a multitude of information to be captured in less space. As data are entered, a scripting function drafts text in a narrative note form. Several iterations of this template were created, tested, and edited to ensure that all relevant aspects of documentation, such as a CF-specific review of systems and physical examination, were included to satisfy institutional requirements for a complete progress note. The development of this EHR tool for an external registry, such as the CFFPR, is distinct from other EHR registries, which focus on internal registry creation.<sup>38</sup>

Many of these data elements exist elsewhere in the EHR such as medication doses and medical complications. Although documenting these details again is duplicative, the benefit is that they can be viewed clearly alongside other CF registry data while writing the note and are able to be carried forward through the copy last note feature, as many of these items such as medical history or genotype do not change over time. In our experience, there is a small upfront cost involved with setting up a patient’s chart with this tool; however, it adds value by streamlining and structuring the data.

### Evaluation of CF NoteWriter Template and Physician Documentation Practices

While designing a system to exhaustively collect data in defined fields is not new, our approach is novel in that we

expected it to decrease documentation time for physicians. We conducted a pre-/poststudy to measure the effect of implementing the CF NoteWriter template on the timeliness of complete documentation at one CF care center seeing patients at two locations. One location was the main teaching hospital (DHMC) and the other was an affiliated free-standing multispecialty clinic in the state’s largest city (Manchester). The same instance of the EHR template was used at each location, although approximately twice as many CF patients are followed at Manchester. During the period of our study, all clinicians saw CF patients at both locations. All providers in this study remained consistent, and the patient populations were stable. As a measure of timeliness, the time from scheduled appointment to encounter closure (note completed) was assessed. The CF NoteWriter tool was first implemented in October 2015. Adoption was determined by initiation of usage and was voluntary. Clinicians were blinded to this study and were not aware that we were interested in uptake and use of this tool. As part of business standards, no consent was obtained for this study by the cohort of clinicians. We did not delve deeply into clinician attributes; each clinician was assigned a random number identifier because it might be sensitive for a clinician to compare their documentation times with others, and adoption timelines may vary. To ensure that we had enough data to compare encounters during which the tool was and was not used, we included data for a 22-month period prior to CF NoteWriter implementation. In total, data collected from October 2013 to June 2017 were included in the analysis. Before and after data were matched by clinician and patient to control for the effect of a given patient’s complexity on documentation time by a given clinician. Patient and clinician dyads were included in the dataset if they had at least one encounter where the note tool was used and one where it was not used. The final dataset included 1,826 ambulatory encounters for 136 patients and five clinicians. Clinicians were ranked 1 to 5 (adopter status) according to when they first used the CF NoteWriter, with 1 being the earliest adopter, to explore the possibility that a training effect influenced the outcome measure of time to encounter closure.

The primary end point of the implementation study was elapsed time between patient appointment and encounter closure by the provider. Documentation efficiency is related to this time interval. To test the hypothesis that the use of the CF NoteWriter by each clinician increased documentation efficiency, we compared rates of encounter closure when each clinician did and did not use the CF NoteWriter. We first identified encounters between specific patients and specific clinicians (i.e., patient-clinician dyads) at which the CF NoteWriter was and was not used. To be included in our analyses, each patient-clinician dyad was required to have at least one encounter when the CF NoteWriter was and was not used. For each clinician, we compared rates of encounter closure using a Cox proportional hazard (PH) model that included CF Notewriter use, unique patient identifier (patient ID), and adopter status as covariates. Patient ID was included in the models to adjust estimates for factors specific to the patient-clinician interaction that could influence the primary end



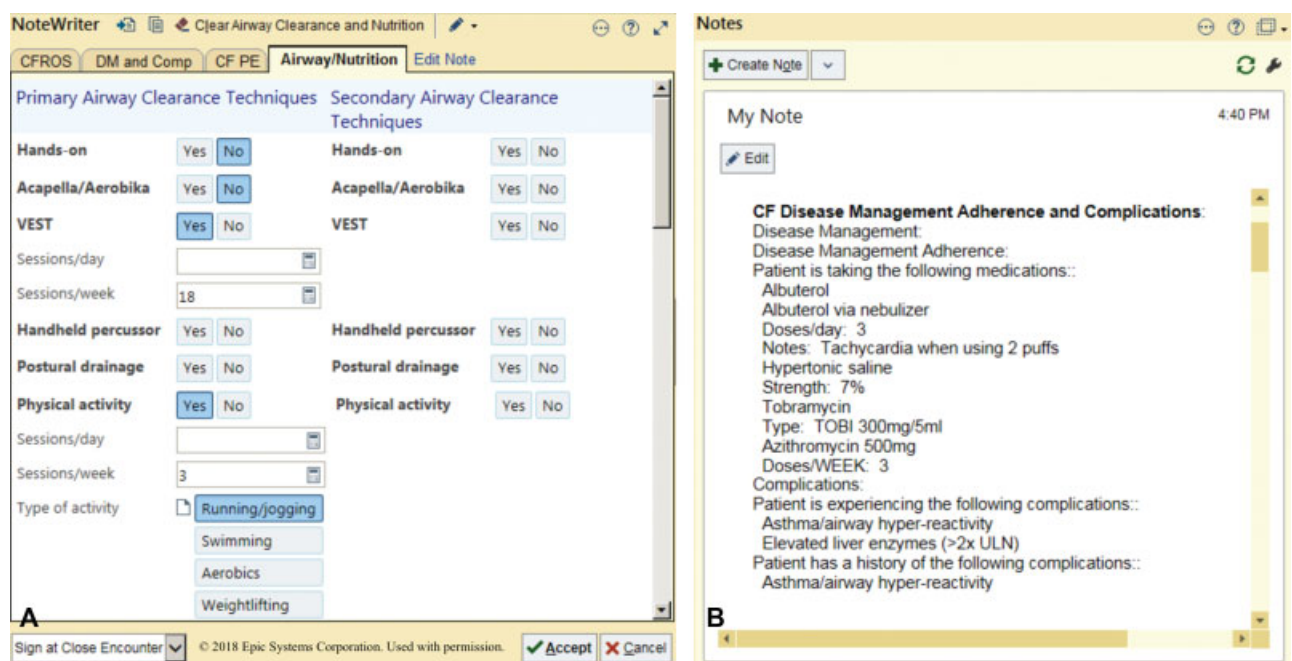
point. Adopter status was an ordinal variable indicating the sequence in which each clinician started to use the CF NoteWriter between October 2013 and June 2017. By including adopter status, we aimed to evaluate the possibility of any training effect on our primary end point. The proportion of notes completed (synonymous with the proportion of closed encounters) is presented as a function of time for each provider.

### Description of the CF NoteWriter Template

While this template functions to facilitate data review and capture, it also serves as a decision support tool to help clinicians align standardized care with best practices and evidence-based recommendations. Within the encounter workspace, the clinician is presented with four tabs corresponding to the sections of the office note. The first of these tabs, CF Review of Systems (CF ROS; [→Fig. 1](#)), allows the clinician to denote the presence or absence of various symptoms by selecting radio buttons with positive (+) or negative (-) signs. As these tasks are performed, the CF ROS section of the office note is populated with the corresponding data ([→Fig. 2](#)). The second tab, Disease Management Adherence and Complications (DM and Comp), contains a list of medications commonly prescribed to individuals with CF,<sup>33</sup> including inhaled bronchodilators, mucolytic agents, antibiotics, and corticosteroids, and those formulated for oral administration, such as macrolides, leukotriene antagonists, and antibiotics. Pivotal clinical trials<sup>39,40</sup> have reported the patterns of inhaled antibiotic use included in the note, which makes providing evidence-based care that much easier. The clinician can enter the frequency with which the patient is taking these medications and any free-text information by clicking on a nearby icon of a piece of paper with a folded corner. In the case of an inhaled antibiotic, the clinician can specify whether it is

being used every other month with intervening “off-cycle” months (alternate) or whether it is being used every other month with a different inhaled antibiotic being used during intervening months (continuous). This functionality of the CF NoteWriter template provides a level of detail not captured in the standard EHR medication list. The DM and Comp tab also contains a list of complications that are tabulated in the CFFPR (a full list of CFFPR data variables can be found at <https://www.cfsmartreports.com/pages/prelogin/PortCFCRFs>). The clinician can check the box next to any relevant complication. When more information pertaining to a specific complication is requested, a panel of stereo buttons drops down. For example, patients with CF-related diabetes can have gastroparesis<sup>41</sup> and those with CF-related liver disease can have hepatic steatosis<sup>42</sup> ([→Fig. 2](#)).

Clearing mucoid secretions from the lungs<sup>33</sup> and maintaining adequate nutrition<sup>34</sup> are critically important aspects of CF care. The Airway/Nutrition tab ([→Fig. 3](#)) contains groups of stereo buttons that the clinician can use to document a patient’s preference of ACTs and frequency. Types and frequencies of physical activity can also be noted. Physical activity is especially important as routine aerobic exercise has been associated with positive outcomes.<sup>43–45</sup> Most individuals with CF have exocrine pancreatic insufficiency necessitating prandial administration of an oral pancreatic enzyme preparation<sup>46</sup> and daily intake of a fat-soluble vitamin supplement.<sup>47</sup> The user of the CF NoteWriter template can choose which brand of pancreatic enzyme replacement therapy a patient is using and enter how many capsules a patient takes with meals and snacks and during the entire day. The brand and dose of fat-soluble vitamin can be recorded in a similar manner. The Airway/Nutrition tab was also designed to capture information about the use of antacids (e.g., proton-pump inhibitor



**Fig. 3** Screenshots of the Airway Clearance Techniques (Airway) and Nutrition (A) in the CF NoteWriter template (B).

**Office Spirometry - PFT Data**

© 2018 Epic Systems Corporation. Used with permission.

**Office Spirometry**

FEV1 (L)	1.36	FEV1 (%)	45
FVC (L)	2.96	FVC (%)	75
FEF 25-75 (L)	0.37	FEF 25-75 (%)	18
FEV1/FVC (absolute)	0.46	FEV1/FVC (%)	68
Peak Flow		FeNO (ppb)	5

**Additional PFT Data (if needed)**

Uncorrected DLCO (ml/min/mm Hg)	22.3	DLCO (%)	82
TLC (liters)	4.53	TLC (%)	95

**Notes**

My Note 4:40 PM

**Spirometry**

PFT Results Office Visit from 2/3/2019

FEV1 (L)	1.36 liters
FEV1 (%)	45
FVC (L)	2.96 liters
FVC (%)	75
FEF 25-75 (L)	0.37
FEF 25-75 (%)	18
FEV1/FVC (absolute)	0.46
FEV1/FVC (%)	68 %
FeNO (ppb)	5

**Additional PFT Data (if needed)**

Uncorrected DLCO (ml/min/mm Hg)	22.3
DLCO (%)	82 %
TLC (liters)	4.53 liters
TLC (%)	95 %
FRC (L)	3.23 L
FRC (%)	85 %

© 2018 Epic Systems Corporation. Used with permission.

**Fig. 4** Office Spirometry Function for cystic fibrosis (CF) ambulatory encounters. A SmartForm (A) was built to enter PFT data which could then be pulled into the CF NoteWriter template (B).

and/or H<sub>2</sub>-antagonist), vitamin D supplements, and nutrition supplements. With respect to nutritional supplements, the clinician can document other details: brand, calorie density, route of administration (e.g., by mouth or by feeding tube), and units taken per day. We also devised a link within the encounter documentation through which data from pulmonary function testing (PFT) can be entered at the encounter level (→Fig. 4).

At the time of publication, connectivity between PFT vendors and Epic to enable automatic data collection of spirometry and plethysmography equipment as discrete data elements was not universally available. When the “Office Spirometry” link is selected (→Fig. 2), fields corresponding to various PFT parameters appear. The clinician can manually impute data found in a source document, such as that generated by the PFT software and printed out by a technician, and offer a brief interpretation by clicking on radio buttons labeled with typical observations. Once the

data are entered in this format, the results can be pulled into the encounter documentation in a tabular format.

## Results

### Effects of the CF NoteWriter Template on the Efficiency of Clinician Documentation

Data were extracted for review from five clinicians (four physicians, one nurse practitioner), providing outpatient CF care before and after the CF NoteWriter template became available (→Table 1). Two clinicians completed their notes faster using the CF NoteWriter template. One clinician was less efficient. Two clinicians had no significant difference in time to completion between the two documentation strategies. A Cox PH regression model incorporating data from all five providers (→Table 2) revealed that using the CF NoteWriter template decreased time to note completion by 15% (95% confidence interval: 4–26%;  $p = 0.005$ ). The model also

**Table 1** Effect of CF NoteWriter template utilization on time to office note completion

Adopter status	CF NoteWriter template used	Patients seen by the provider (n)	Time to note completion (days) <sup>a</sup>	Median difference (days), yes/no	p-Value <sup>b</sup>
First	No	199	0.78 (0.04–6.38)	–0.39 (faster)	0.0001
	Yes	176	0.39 (0.04–1.84)		
Second	No	394	0.49 (0.07–14.96)	–0.11 (faster)	<0.0001
	Yes	265	0.38 (0.02–14.78)		
Third	No	230	0.32 (0.01–5.29)	0.06 (slower)	0.01
	Yes	118	0.38 (0.01–4.38)		
Fourth	No	156	0.19 (0.04–9.86)	0.04 (no difference)	0.77
	Yes	65	0.23 (0.01–14.91)		
Fifth	No	123	1.47 (0.05–5.08)	0.39 (no difference)	0.63
	Yes	100	1.86 (0.07–8.18)		

<sup>a</sup>Median (range).

<sup>b</sup>Wilcoxon rank-sum test.

**Table 2** Cox proportional hazard model for time to office note completion

Covariate	Hazard ratio	95% CI	SE	z	p-Value
CF NoteWriter template use	1.15	1.04–1.26	0.06	2.83	0.005
Patient ID	1.00	0.9997–1.0020	0.0006	1.43	0.15
Adopter status	0.85	0.82–0.88	0.02	–8.85	<0.0001

Abbreviations: CI, confidence interval; SE, standard error.

identified a significant negative effect of later adoption of the CF NoteWriter template by clinicians on the likelihood of note completion. The identity of each patient within each patient–clinician dyad had no effect on the estimated likelihood of note completion.

## Discussion

Clinicians need to parse, interpret, and act on multiple data streams during patient care encounters. These data streams can be cumbersome to navigate even when they are contained within a single EHR system. We set out to design the CF NoteWriter template in the EHR environment with three goals in mind: to reduce clinician documentation time by enhancing data capture for clinical use, to facilitate electronic transfer to the CFFPR, and to assimilate clinical findings for use during an encounter to more effectively coproduce documentation and care plans with patients.

First, we recognized that the CF population generates a considerable amount of data. This relates to the multisystem nature of the disease, the frequency with which diagnostic tests are performed in this population, the fact that the natural history of CF consists of relapsing and remitting symptoms, polypharmacy, and the longitudinal nature of relationships among patients and clinicians. To streamline physician workflow, we developed a tool that could be used to quickly import data into ambulatory documentation using a rational system of radio buttons, text fields, and macros, thereby increasing their efficiency. To test this hypothesis, we evaluated CF patient–clinician dyads at our institution with respect to time to note completion before and after implementation of the CF NoteWriter template. We found that “early adopters” of the template (clinicians 1 and 2) completed their notes more rapidly than “late adopters” of the template (clinicians 4 and 5). Clinician 3, who did not fit into either category, was less efficient using the CF NoteWriter template. This is not surprising because many factors, including age, sex, presence or absence of specific certifications, and practice environment, can influence how well clinicians perform with respect to record keeping.<sup>48,49</sup>

With regard to our original design goals (to reduce clinician documentation time by enhancing data capture for clinical use, to facilitate electronic transfer to the CFFPR, and to assimilate clinical findings for use during an encounter to more effectively coproduce documentation and care plans with patients), we believe we have begun to approach the first goal with the results of this study. Ultimately, we were able to transfer data from Epic SDEs entered in the NoteWriter SmartForm to the CFFPR, meeting our second

goal. Work on the third goal is still in progress; we believe that by reducing documentation time, more time could become available for coproduction. This will require further research.

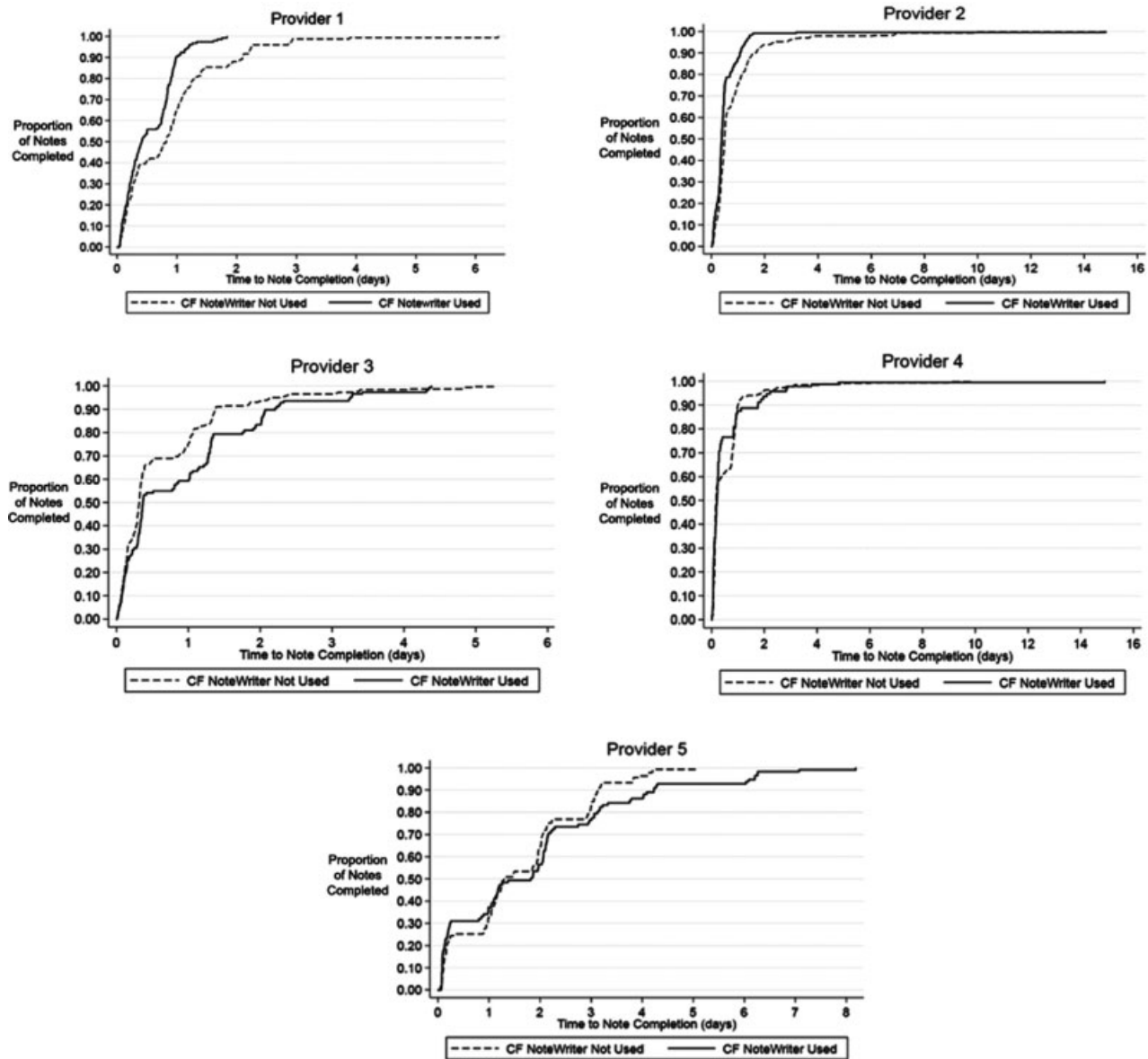
## Future Work

Our goal for the CF NoteWriter template is to facilitate coproduction of health care in the CF population. In future work, we hope to leverage macrofunctions built into the EHR environment to push PRO data entered by patients through the patient check-in kiosk interface on tablet computers at check-in or through institution-specific iterations of the personal health record. In partnership with the CF Foundation, we are testing a patient-facing dashboard that couples PRO and CFFPR data at the point of care (<https://www.cff.org/Care/Clinician-Resources/Network-News/March-2018/CF-Health-Check-Building-Partnerships-Through-Shared-Information/>). Unlike EHR data, this would allow individuals with CF to view their longitudinal CF data regardless of the facility in which their CF center is located. The CFFPR is structured such that a patient’s data can be viewed at any CF Foundation accredited care center in the United States (<https://www.cfsmartreports.com>). Data from the NoteWriter template will feed forward data into CFFPR and CFSmartReports, thus adding a new connection that merges data together in an effective and useful way for CF care. Another issue we intend to work on is the evaluation of data completeness and timely data entry.

We plan to share this work with other health systems that use Epic and have made this SmartForm template available within the Community Library. We are working with several other Epic organizations to develop an efficient process to share this time-intensive build. The overall goal of sharing this work is to standardize how an extract from Epic can be established and delivered to the CFFPR. This work would be an excellent subject for future research.

## Limitations

We acknowledge several limitations of this study. In designing the CF NoteWriter template, we tried to mitigate the critical tension between completeness and efficiency of provider documentation. Although dictation into the EHR is faster than typing for many clinicians, data entered in this manner cannot easily be migrated to disease-specific registries, perhaps with the exception of using natural language processing (NLP) algorithms for data extraction.<sup>50–52</sup> To the best of our knowledge, NLP has not yet been successfully used to accomplish this for the CFFPR but has shown promise in



**Fig. 5** Time to office note completion by providers adjusted for patient ID. For provider 1, the chi-square statistic for the log-rank test for equality of survivor functions is 34.7 ( $p < 0.00001$ ). For provider 2, the chi-square statistic for the log-rank test for equality of survivor functions is 38.4 ( $p < 0.00001$ ). For provider 3, the chi-square statistic for the log-rank test for equality of survivor functions is 5.5 ( $p = 0.02$ ). For provider 4, the chi-square statistic for the log-rank test for equality of survivor functions is 0.02 ( $p = 0.89$ ). For provider 5, the chi-square statistic for the log-rank test for equality of survivor functions is 4.3 ( $p = 0.04$ ).

other areas such as rheumatology.<sup>50</sup> The checkboxes, macros, and form fields in the CF NoteWriter template capture discrete data elements while concurrently generating the office note; however, some clinicians might desire greater flexibility in their approach to note writing than the tool currently provides. Like the majority of published studies recently reviewed by Ellsworth et al,<sup>53</sup> we did not elicit such preferences through formal usability evaluation. This process will be undertaken with dissemination of our tool. In terms of efficiency of registry data entry, we did not formally evaluate the current delay between a patient encounter and the time at which these data were entered into the CFFPR. The CF Learning Network reports on CFFPR timely data entry (<https://cflearningnetwork.org/where-weve-been-1/>). Per these reports, the highest performing sites

have an encounter completed in 14 days, reflecting the lag due to culture results.

Because we did not pursue user acceptance testing of the CF NoteWriter template by the clinicians at DHMC, we can only speculate as to why the template heterogeneously impacted their productivity (→Table 1, →Fig. 5). In a qualitative study of primary health care providers, Terry et al<sup>54</sup> found that the onus of having to learn how to use an EHR system jeopardized utilization and that perceptions of enhanced efficiency and confidence with technology promoted utilization. In our study, early adopters of the template completed their notes faster than late adopters; this suggests the presence of a “learning curve” inherent to any new EHR initiative. It is quite possible that the perspectives identified by Terry et al<sup>54</sup> were shared by our CF providers



and influenced their behavior. Computer literacy among clinicians has been linked to satisfaction with the EHR,<sup>55</sup> and this might have varied across our CF clinicians.

This study had a narrow focus and did not include clinician satisfaction or billing implications of the implementation of this tool. In this pilot study, we did not ask clinicians about what constitutes a meaningful reduction in documentation time that could be attributed to the NoteWriter. More study is needed to elucidate these issues and would be an excellent focus for a multicenter study. Given that the CF NoteWriter allows one to quickly impute information referable to multiple organ systems and medication regimens, it could be very useful to other members of a multidisciplinary team. Presently at our institution, only physicians and nurse practitioners have been granted access to the CF NoteWriter content because they ultimately submit their professional charges for each ambulatory encounter. They also have the ultimate responsibility for documenting and closing each encounter.

Considerable effort and grant support were required to design and implement the tool at our institution. Some health care systems could face formidable implementation challenges even if they already use the same EHR software. Having categorized the many barriers to EHR adoption, Boonstra and Broekhuis<sup>56</sup> concluded that change management is critical to success. In the case of the CF NoteWriter template, stakeholders have included the software vendor (Epic), the health care institution (DHMC), a health care improvement think tank (The Dartmouth Institute), and a well-funded and highly organized foundation dedicated to promoting the health of a specific patient population (CF Foundation). Next steps regarding the CF NoteWriter template should include the development of a thoughtful strategy for change management. Solutions need to be devised for problems of adding and removing content to ensure congruency with the CFFPR, adapting the content to be compatible with other EHR platforms, manually entering PFT data, and responding to concerns from clinicians and CF Foundation accredited care centers. This will require effective partnerships among the aforementioned stakeholders.

One might also question whether the CF NoteWriter template really mitigates the pervasive practice of “cutting and pasting” information into notes.<sup>57</sup> Many therapies for CF are continued from visit-to-visit with unchanged doses and frequencies of administration. Although the EHR note interface allows a user to carry forward these selections from his/her last note, the user can easily modify them during the patient interview by clicking radio buttons. We hope that this functionality will improve the accuracy of data regarding treatment adherence, a key determinant of health outcomes in the CF population,<sup>58,59</sup> and complement the process of reconciling medication lists, which are often inaccurate.<sup>60–62</sup> We think that the CF NoteWriter template should serve as a framework for contemporaneous data entry.

## Conclusion

This paper describes our initiative to develop a CF-specific NoteWriter template, which houses discrete data elements

specific to the CFFPR dataset. Once validated and tested, the tool was implemented with clinicians at DHMC, and its use was tracked within Epic. The primary findings of this implementation demonstrated that “early adopters” of the tool were more agile than “late adopters” with respect to note completion times. This gain in productivity shows the potential to improve the way that clinicians document these complex visits. Combined with future work of integrating these data in a streamlined way with the CFFPR, this method of integrating data entry with extraction could lead to efficiency improvements at multiple levels including clinician data entry, note completion, and avoiding duplication of effort of data extraction from the medical record to the registry database. This approach to documentation of registry-related data in the flow of care presents a working model for other complex disease registries.

## Clinical Relevance Statement

The implementation of a registry-based and encoded NoteWriter template has significant implications to both reduce the physician documentation time of current registry maintenance and enhance clinical documentation for these visits. By demonstrating the viability of this tool in a significant disease-based registry such as CF, this project serves as an example for applications in other registries as well. The future work to be able to deliver this registry data directly to the CF Foundation has significant implications in terms of health information exchange. Enabling a shorter time to note completion could also offer other benefits beyond more timely population of registries, such as sooner availability of the note for patient viewing through portals and more rapid generation of charges to insurance.

### Protection of Human and Animal Subjects

The patient identities of the participants in this study were deidentified in accordance with DHMC policy. No animal subjects were used in this study.

### Funding

This work was supported by a grant (#72313) from the Robert Wood Johnson Foundation (Nelson, P.I.) and a grant (#OCONNO04Q10) from the Cystic Fibrosis Foundation (Gifford, P.I.).

### Conflict of Interest

None declared.

## References

- 1 Gold M, McLAUGHLIN C. Assessing HITECH implementation and lessons: 5 years later. *Milbank Q* 2016;94(03):654–687
- 2 Adler-Milstein J, Jha AK. HITECH act drove large gains in hospital electronic health record adoption. *Health Aff (Millwood)* 2017;36(08):1416–1422
- 3 Rittenhouse DR, Ramsay PP, Casalino LP, McClellan S, Kandel ZK, Shortell SM. Increased health information technology adoption and use among small primary care physician

- practices over time: a national cohort study. *Ann Fam Med* 2017;15(01):56–62
- 4 Blumenthal D, Tavenner M. The “meaningful use” regulation for electronic health records. *N Engl J Med* 2010;363(06):501–504
  - 5 Tai-Seale M, Olson CW, Li J, et al. Electronic health record logs indicate that physicians split time evenly between seeing patients and desktop medicine. *Health Aff (Millwood)* 2017;36(04):655–662
  - 6 Sinsky C, Colligan L, Li L, et al. Allocation of physician time in ambulatory practice: a time and motion study in 4 specialties. *Ann Intern Med* 2016;165(11):753–760
  - 7 Young RA, Burge SK, Kumar KA, Wilson JM, Ortiz DF. A time-motion study of primary care physicians’ work in the electronic health record era. *Fam Med* 2018;50(02):91–99
  - 8 Shanafelt TD, Dyrbye LN, Sinsky C, et al. Relationship between clerical burden and characteristics of the electronic environment with physician burnout and professional satisfaction. *Mayo Clin Proc* 2016;91(07):836–848
  - 9 Arndt BG, Beasley JW, Watkinson MD, et al. Tethered to the EHR: primary care physician workload assessment using EHR event log data and time-motion observations. *Ann Fam Med* 2017;15(05):419–426
  - 10 O’Malley AS, Draper K, Gourevitch R, Cross DA, Scholle SH. Electronic health records and support for primary care teamwork. *J Am Med Inform Assoc* 2015;22(02):426–434
  - 11 Hassey A, Gerrett D, Wilson A. A survey of validity and utility of electronic patient records in a general practice. *BMJ* 2001;322(7299):1401–1405
  - 12 Bae J, Encinosa WE. National estimates of the impact of electronic health records on the workload of primary care physicians. *BMC Health Serv Res* 2016;16:172
  - 13 Lo HG, Newmark LP, Yoon C, et al. Electronic health records in specialty care: a time-motion study. *J Am Med Inform Assoc* 2007;14(05):609–615
  - 14 Grinspan ZM, Banerjee S, Kaushal R, Kern LM. Physician specialty and variations in adoption of electronic health records. *Appl Clin Inform* 2013;4(02):225–240
  - 15 Slotwiner DJ. Electronic health records and cardiac implantable electronic devices: new paradigms and efficiencies. *J Interv Card Electrophysiol* 2016;47(01):29–35
  - 16 Boland MV, Chiang MF, Lim MC, et al; American Academy of Ophthalmology Medical Information Technology Committee. Adoption of electronic health records and preparations for demonstrating meaningful use: an American Academy of Ophthalmology survey. *Ophthalmology* 2013;120(08):1702–1710
  - 17 Redd TK, Doberne JW, Lattin D, et al. Variability in electronic health record usage and perceptions among specialty vs. primary care physicians. *AMIA Annu Symp Proc* 2015;2015:2053–2062
  - 18 Resneck JS Jr, VanBeek M. What dermatology still needs to create meaningful patient outcome measurements. *JAMA Dermatol* 2015;151(04):371–372
  - 19 Peckham D, Etherington C, White H, et al. The development and deployment of integrated electronic care records in a regional adult and paediatric cystic fibrosis unit. *J Cyst Fibros* 2014;13(06):681–686
  - 20 Schechter MS, Fink AK, Homa K, Goss CH. The Cystic Fibrosis Foundation Patient Registry as a tool for use in quality improvement. *BMJ Qual Saf* 2014;23(Suppl 1):i9–i14
  - 21 Knapp EA, Fink AK, Goss CH, et al. The Cystic Fibrosis Foundation Patient Registry. Design and methods of a national observational disease registry. *Ann Am Thorac Soc* 2016;13(07):1173–1179
  - 22 Wu AW, Kharrazi H, Boulware LE, Snyder CF. Measure once, cut twice—adding patient-reported outcome measures to the electronic health record for comparative effectiveness research. *J Clin Epidemiol* 2013;66(8, Suppl):S12–S20
  - 23 Delbanco T, Walker J, Bell SK, et al. Inviting patients to read their doctors’ notes: a quasi-experimental study and a look ahead. *Ann Intern Med* 2012;157(07):461–470
  - 24 Newman ED, Lerch V, Billet J, Berger A, Kirchner HL. Improving the quality of care of patients with rheumatic disease using patient-centric electronic redesign software. *Arthritis Care Res (Hoboken)* 2015;67(04):546–553
  - 25 Aakre C, Franco PM, Ferreyra M, Kitson J, Li M, Herasevich V. Prospective validation of a near real-time EHR-integrated automated SOFA score calculator. *Int J Med Inform* 2017;103:1–6
  - 26 Banerjee D, Thompson C, Kell C, et al. An informatics-based approach to reducing heart failure all-cause readmissions: the Stanford heart failure dashboard. *J Am Med Inform Assoc* 2017;24(03):550–555
  - 27 Azad TD, Kalani M, Wolf T, et al. Building an electronic health record integrated quality of life outcomes registry for spine surgery. *J Neurosurg Spine* 2016;24(01):176–185
  - 28 Batalden M, Batalden P, Margolis P, et al. Coproduction of health-care service. *BMJ Qual Saf* 2016;25(07):509–517
  - 29 Sabadosa KA, Batalden PB. The interdependent roles of patients, families and professionals in cystic fibrosis: a system for the coproduction of healthcare and its improvement. *BMJ Qual Saf* 2014;23(Suppl 1):i90–i94
  - 30 Kaplan HC, Thakkar SN, Burns L, et al. Protocol of a pilot study of technology-enabled coproduction in pediatric chronic illness care. *JMIR Res Protoc* 2017;6(04):e71
  - 31 CF Health Check: Building Partnerships Through Shared Information. Available at: <https://www.cff.org/Care/Clinician-Resources/Network-News/March-2018/CF-Health-Check-Building-Partnerships-Through-Shared-Information/>. Accessed June 28, 2018
  - 32 *Success With Therapies Research Consortium*. Available at: <https://www.cff.org/Research/Researcher-Resources/Success-With-Therapies-Research-Consortium/>. Accessed June 28, 2018
  - 33 Flume PA, O’Sullivan BP, Robinson KA, et al; Cystic Fibrosis Foundation, Pulmonary Therapies Committee. Cystic fibrosis pulmonary guidelines: chronic medications for maintenance of lung health. *Am J Respir Crit Care Med* 2007;176(10):957–969
  - 34 Stallings VA, Stark LJ, Robinson KA, Feranchak AP, Quinton H; Clinical Practice Guidelines on Growth and Nutrition Subcommittee; Ad Hoc Working Group. Evidence-based practice recommendations for nutrition-related management of children and adults with cystic fibrosis and pancreatic insufficiency: results of a systematic review. *J Am Diet Assoc* 2008;108(05):832–839
  - 35 Schwarzenberg SJ, Hempstead SE, McDonald CM, et al. Enteral tube feeding for individuals with cystic fibrosis: Cystic Fibrosis Foundation evidence-informed guidelines. *J Cyst Fibros* 2016;15(06):724–735
  - 36 Schnipper JL, Linder JA, Palchuk MB, et al. “Smart Forms” in an Electronic Medical Record: documentation-based clinical decision support to improve disease management. *J Am Med Inform Assoc* 2008;15(04):513–523
  - 37 Marsolo K, Margolis PA, Forrest CB, Colletti RB, Hutton JJ. A digital architecture for a network-based learning health system: integrating chronic care management, quality improvement, and research. *EGEMS (Wash DC)* 2015;3(01):1168
  - 38 Kannan V, Fish JS, Mutz JM, et al. Rapid development of specialty population registries and quality measures from electronic health record data\*. *An Agile framework. Methods Inf Med* 2017;56(99):e74–e83
  - 39 Retsch-Bogart GZ, Quittner AL, Gibson RL, et al. Efficacy and safety of inhaled aztreonam lysine for airway pseudomonas in cystic fibrosis. *Chest* 2009;135(05):1223–1232
  - 40 Ramsey BW, Pepe MS, Quan JM, et al; Cystic Fibrosis Inhaled Tobramycin Study Group. Intermittent administration of inhaled tobramycin in patients with cystic fibrosis. *N Engl J Med* 1999;340(01):23–30
  - 41 Moran A, Brunzell C, Cohen RC, et al; CFRD Guidelines Committee. Clinical care guidelines for cystic fibrosis-related diabetes: a position statement of the American Diabetes Association and a clinical practice guideline of the Cystic Fibrosis Foundation,

- endorsed by the Pediatric Endocrine Society. *Diabetes Care* 2010; 33(12):2697–2708
- 42 Debray D, Kelly D, Houwen R, Strandvik B, Colombo C. Best practice guidance for the diagnosis and management of cystic fibrosis-associated liver disease. *J Cyst Fibros* 2011;10(Suppl 2):S29–S36
  - 43 Schneiderman-Walker J, Pollock SL, Corey M, et al. A randomized controlled trial of a 3-year home exercise program in cystic fibrosis. *J Pediatr* 2000;136(03):304–310
  - 44 Orenstein DM, Franklin BA, Doershuk CF, et al. Exercise conditioning and cardiopulmonary fitness in cystic fibrosis. The effects of a three-month supervised running program. *Chest* 1981;80(04):392–398
  - 45 Selvadurai HC, Blimkie CJ, Meyers N, Mellis CM, Cooper PJ, Van Asperen PP. Randomized controlled study of in-hospital exercise training programs in children with cystic fibrosis. *Pediatr Pulmonol* 2002;33(03):194–200
  - 46 Wilschanski M, Novak I. The cystic fibrosis of exocrine pancreas. *Cold Spring Harb Perspect Med* 2013;3(05):a009746
  - 47 Rayner RJ. Fat-soluble vitamins in cystic fibrosis. *Proc Nutr Soc* 1992;51(02):245–250
  - 48 Wenghofer EF, Williams AP, Klass DJ. Factors affecting physician performance: implications for performance improvement and governance. *Healthc Policy* 2009;5(02):e141–e160
  - 49 Miller RH, Sim I. Physicians' use of electronic medical records: barriers and solutions. *Health Aff (Millwood)* 2004;23(02):116–126
  - 50 Kaufman DR, Sheehan B, Stetson P, et al. Natural language processing-enabled and conventional data capture methods for input to electronic health records: a comparative usability study. *JMIR Med Inform* 2016;4(04):e35
  - 51 Barnado A, Casey C, Carroll RJ, Wheless L, Denny JC, Crofford LJ. Developing electronic health record algorithms that accurately identify patients with systemic lupus erythematosus. *Arthritis Care Res (Hoboken)* 2017;69(05):687–693
  - 52 Jensen K, Soguero-Ruiz C, Oyvind Mikalsen K, et al. Analysis of free text in electronic health records for identification of cancer patient trajectories. *Sci Rep* 2017;7:46226
  - 53 Ellsworth MA, Dziadzko M, O'Horo JC, Farrell AM, Zhang J, Herasevich V. An appraisal of published usability evaluations of electronic health records via systematic review. *J Am Med Inform Assoc* 2017;24(01):218–226
  - 54 Terry AL, Brown JB, Bestard Denomme L, Thind A, Stewart M. Perspectives on electronic medical record implementation after two years of use in primary health care practice. *J Am Board Fam Med* 2012;25(04):522–527
  - 55 Al Alawi S, Al Dhaheri A, Al Baloushi D, Al Dhaheri M, Prinsloo EA. Physician user satisfaction with an electronic medical records system in primary healthcare centres in Al Ain: a qualitative study. *BMJ Open* 2014;4(11):e005569
  - 56 Boonstra A, Broekhuis M. Barriers to the acceptance of electronic medical records by physicians from systematic review to taxonomy and interventions. *BMC Health Serv Res* 2010; 10:231
  - 57 Wang MD, Khanna R, Najafi N. Characterizing the source of text in electronic health record progress notes. *JAMA Intern Med* 2017; 177(08):1212–1213
  - 58 Eakin MN, Bilderback A, Boyle MP, Mogayzel PJ, Riekert KA. Longitudinal association between medication adherence and lung health in people with cystic fibrosis. *J Cyst Fibros* 2011;10(04):258–264
  - 59 Eakin MN, Riekert KA. The impact of medication adherence on lung health outcomes in cystic fibrosis. *Curr Opin Pulm Med* 2013;19(06):687–691
  - 60 Monte AA, Anderson P, Hoppe JA, Weinshilboum RM, Vasiliou V, Heard KJ. Accuracy of electronic medical record medication reconciliation in emergency department patients. *J Emerg Med* 2015;49(01):78–84
  - 61 Wagner MM, Hogan WR. The accuracy of medication data in an outpatient electronic medical record. *J Am Med Inform Assoc* 1996;3(03):234–244
  - 62 Hogan WR, Wagner MM. Accuracy of data in computer-based patient records. *J Am Med Inform Assoc* 1997;4(05):342–355