

Use of Systems Engineering Tools and Concepts to Improve Chronic Disease Management

Gulshan Sharma, Carlos Clark and Lindsay Sonstein
Department of Internal Medicine
The University of Texas Medical Branch
Galveston, TX 77055, USA

Rick Trevino
Department of Clinical Data Management
The University of Texas Medical Branch
Galveston, TX 77055, USA

Laura Grady
Department of Information Services – Clinical Documentation
The University of Texas Medical Branch
Galveston, TX 77055, USA

Susan Seidensticker
Department of Quality and Healthcare Safety
The University of Texas Medical Branch
Galveston, TX 77055, USA

Abstract

UTMB has a growing population of Chronic Obstructive Pulmonary Disease patients, and efforts are ongoing to evaluate the processes of care associated with caring for these individuals. Literature reviews indicated a lack of precedence in the utilization of systems engineering tools when addressing the management of chronic disease. The team has utilized some of these tools to identify opportunities regarding patient access to clinical services, evidence based medicine practice, improving health information technology and identifying factors that can increase the likelihood of readmission. The implementation of process changes have already increased the standardization of processes for scheduling, testing, medication usage and clinical documentation; all of these elements promote a better method of delivering long-term care, though more work still needs to be done.

Keywords

Chronic Obstructive Pulmonary Disease (COPD), Evidence Based Medicine, Processes of Care, Systems Engineering, Healthcare

1. Introduction

Systems engineering tools have been used in health care with great success to reduce line infections (Pronovost et al. 2006) and surgical complication rates (Haynes et al. 2009). The logical next step was to investigate how these tools can impact the processes of care for patients with chronic disease. The Internal Medicine Department of the University of Texas Medical Branch (UTMB) Health system is utilizing the tools of systems engineering to improve the processes of care for Chronic Obstructive Pulmonary Disease (COPD).

COPD is the third leading cause of death in the United States (US) and the only leading cause for which morbidity and mortality are rising (Global Initiative on Obstructive Lung Disease 2011). COPD currently affects approximately 6.2% of the adult population in the US, and is characterized by chronic inflammation of the lungs and a slowly progressive persistent airflow obstruction (Decramer et al. 2012). The natural course of the disease is

marked by acute exacerbations of COPD (AECOPD), which are defined as a worsening of symptoms or respiratory failure requiring a provider encounter (telephone, emergency room visit, office visit, or hospitalization) that resulted in a prescription of a steroid, antibiotic or both. These events require frequent interactions with the whole spectrum of the health care system — from outpatient to emergency room to inpatient care. As COPD is an ambulatory care sensitive condition, the adherence of the primary care provider (PCP), specialists and the patient with recommended guidelines and treatment plans are critical to the success in managing this chronic disease. The current care model for these patients is fragmented and delivered in silos by different health care providers, even within a single healthcare system.

Tien and Goldschmidt-Clermont (2009) describe healthcare as an integrated service system with four dimensions. As seen in the Venn diagram of Figure 1, those four dimensions (physical, temporal, organizational and functional) are required to understand the care continuum required to manage any chronic disease. The techniques of systems engineering apply across these dimensions, and it is understood that a combination of efforts will be required to truly affect change in how the COPD patient population is managed.

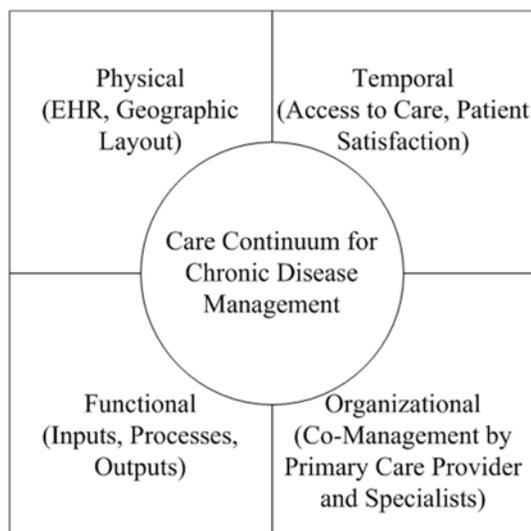


Figure 1: Venn Diagram of the Four Domains of Care Continuum for Critical Disease Management (Smith, 1977)

The Healthcare system is a complex integration of human-centered activities which are increasingly dependent on information technology (IT). The three essential “Ps” (people, process and products) have to be both integrated and adaptive in order to enhance effectiveness and efficiency of care delivery. It is known that an understanding of the three essential Ps is vital for impacting any of these four dimensions. People are unpredictable in their values, behaviors, attitudes, expectations and knowledge, which adds complexity to any service-based system. Processes are dependent on adherence to standards, procedures, protocols and/or algorithms. Products (such as hardware, software and infrastructure) have to be appropriate and available to support the service system.

The fragmentation of knowledge and communication between the activities has led to a data-rich but information-poor environment that does not allow for the highest quality of care to be provided to all patients. Variations in practice between providers are common, so there are numerous opportunities to embed evidence based medicine practices into the care delivery via systemic change. With this in mind, the systems engineering project team is evaluating the overall care of patients with COPD within all elements of their experience at UTMB Health.

2. Outpatient

The first goal was to identify the total population that carries the diagnosis of COPD at UTMB Health. Using the electronic health record (EHR), the data was pulled to identify those patients with an outpatient encounter diagnosis of COPD (patients greater than 40 years of age and not part of the Texas Department of Justice population) by year: there were 1150 in calendar year 2009, 1254 in 2010, 1371 in 2011 and 1516 in 2012. A random review of the accuracy of the encounter diagnosis was performed, and it was noted that there were numerous patient carrying the COPD diagnosis without the presence of a documented confirmatory spirometry test. One element of the standard of

care for COPD patients, regardless of disease severity, is the prescription of short acting bronchodilators, commonly referred to as “rescue inhalers”; these are typically Albuterol, Ipratropium, or a combination of the two. The data in the EHR indicated some consistency in the percentage of patients who were listed as having COPD with the presence of at least one of these medications within the prior 12 months. The systems engineering group then looked to validate the denominators of the COPD population for the four years by identifying the number of patients who had both a recorded spirometry test and the prescribed short acting bronchodilator(s); as seen in Table 1, the validated population was reduced to 363 in 2009, 484 in 2010, 567 in 2011 and 625 in 2012.

Year	Unique Patient Encounters	Documentation of Current Prescription for Short Acting Bronchodilator(s)	Documentation of Spirometry Order and Current Bronchodilator(s)	Documentation of Spirometry without Bronchodilator(s)	No Documentation of Spirometry or Bronchodilator(s)
2009	1150	901 (78.35%)	363 (31.57%)	44 (3.83%)	133 (11.57%)
2010	1254	1028 (82.00%)	484 (38.60%)	47 (3.75%)	116 (9.25%)
2011	1371	1106 (80.67%)	567 (41.36%)	66 (4.81%)	135 (9.85%)
2012	1516	1168 (77.04%)	625 (41.22%)	112 (7.3%)	179 (11.81%)

Table 1: COPD Encounter Diagnosis Validity Review

Concurrent to the systems engineering efforts, a clinical review of COPD guideline concordance was performed. Spirometry is “gold standard” to diagnose COPD. The overall spirometry use during the study period ranged from 35.39% (2009) to 48.61% (2012). Management of COPD is based on spirometry data. Utilizing 2010 data, it was determined that of COPD patients at UTMB with confirmed diagnosis of COPD by spirometry, 43.55% were not receiving treatment that based on 2007 Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines (40.22% were under-treated, 3.33% were over-treated) (Sharif et al. 2013). To improve adherence with management and accuracy of diagnosis, UTMB Health built and deployed a best practice advisory (BPA) into the EHR. The BPA was designed to deploy on a patient with a listed diagnosis of COPD without documented spirometry. It alerts the primary care provider during an office that spirometry is recommended and facilitates ordering of the spirometry. Figure 2 shows the alert that is seen by the provider, as well as the opportunity to open the order to perform a spirometry test.

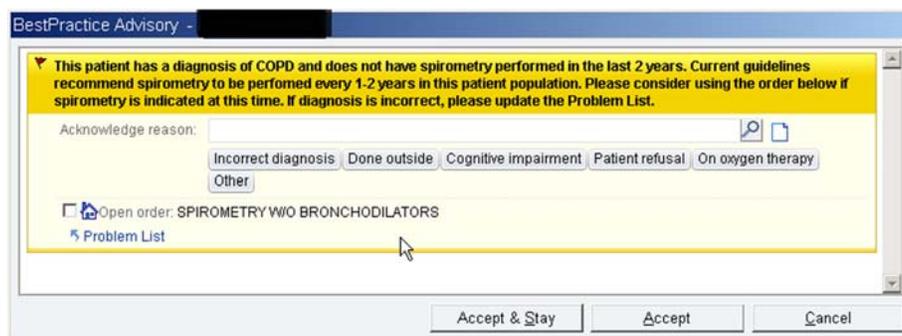


Figure 2: BPA for COPD Outpatient Clinic Visit Where No Spirometry On File

Typically, two thirds of patients with COPD are exclusively managed by their PCP.. To improve access to current recommendations, all PFT reports from Pulmonology provide recommendations for management (Figure 3). This snapshot of a sample PFT report should assist in the long term planning and management of COPD patients; the hypothesis is that a better care planning partnership between the PCPs and Pulmonary providers will lead to a reduction in preventable AECOPD occurrences.

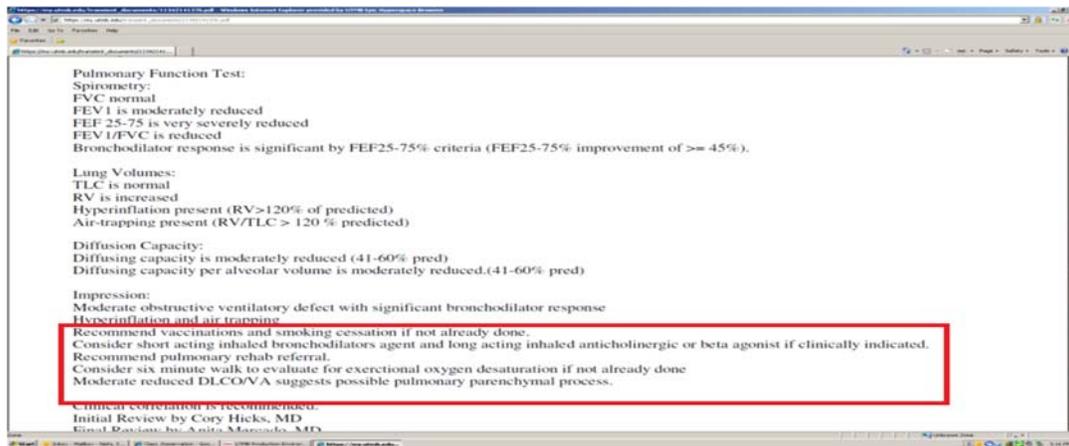


Figure 3: Snapshot of Typical PFT Report

UTMB Health has modified its processes of care by adding testing capability. Spirometry testing is now available at a location within the same building as Internal Medicine and Family Medicine clinics, with the intention that PCPs would be able to send their patients for spirometry testing immediately upon completion of their clinic visit. The utilization data on this additional functionality is currently under review.

3. Emergency Department

Access to care for UTMB's COPD population was identified as another area of investigation. During a 29-month timeframe (discharges from January 1, 2010 – May 31, 2012), there were 376 admissions with a primary diagnosis related to COPD; over 79% of those (298/376) came into the hospital via the Emergency Department (ED). Of the 298 ED admissions, over 36% (91/298) arrived during normal clinic hours. As noted previously, COPD is an ambulatory care sensitive condition, and thus improved access to outpatient care has been shown to reduce acute care hospitalization and ED visits. The systems engineering project team chose to investigate why such a large percentage of the patient population had bypassed the outpatient clinic.

3.1 FMEA

The failure mode effect analysis (FMEA) of the arrivals during clinic hours noted that most of the COPD patients had some form of sponsorship. The financial element behind the decision to go directly to the ED appeared irrelevant, though there is some research to suggest that the presence of any form of insurance may correlate to a patient being less willing to curb their vices in order to reduce the risks to their health (Stanicole 2008). The data indicated that the ages and genders of the patients were in concordance with previous internal analyses of the COPD population, so there were no obvious indications as to the patient's decision making when it came to access. The telling element from the FMEA was that over 72% of these COPD patients had not had any contact with a provider (PCP or otherwise) in the two weeks prior to arriving in the ED. That discovery prompted the decision to conduct a modified root cause analysis (RCA) on a sampling of these patients to identify specific clinical and socio-economic factors that may have influenced the patient to omit their PCP from their care needs during an acute exacerbation of COPD.

3.2 RCA

For this RCA, 20 admissions were chosen at random for review. Figure 4 shows the questions utilized to conduct this RCA. The Internal Medicine providers on the team reviewed the ED and Inpatient notes, as well as relevant lab and testing values, to assess the clinical state of the patient at the time they arrived in the ED. It was noted that all 20 patients met the criteria for a full admission due to AECOPD. The review found that 60% (12/20) of the sampled patients should have contacted their PCP rather than report to the ED. The costs to UTMB and the patient would have been greatly reduced if the management of the exacerbation had begun in an ambulatory setting, and this would not have delayed them receiving an inpatient bed assignment; only 5% (1/20) of the sampled population had reported to the ED at the direction of their PCP. The remaining 35% (7/20) were found to have been in severe enough distress to contraindicate management of their symptoms in an ambulatory setting, but the involvement of

the PCPs regarding the decision to report to the ED were found to be lacking. It was also noted that many of the patients who could have begun their treatment in a lower acuity (less resource intensive) setting presented at times when the inpatient census for their targeted unit(s) was an issue: when no beds are available, patients remain in the ED, thus compounding the length of stay issues there.

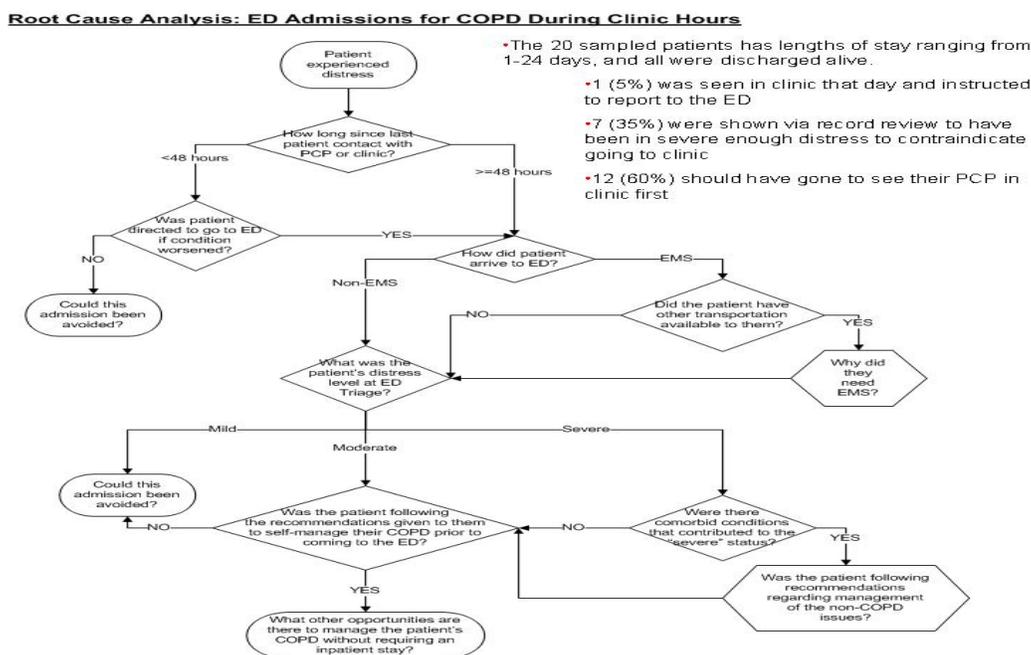


Figure 4: Root Cause Analysis Structure and Findings for Patients Arriving in the ED during Clinic Hours

Based on the findings of the Internal Medicine providers during this RCA, the cause and effect diagram in Figure 5 was developed. The issues were grouped into four major categories: Patient controllable factors, Clinical Status, Providers and UTMB Operations (Clinics, Hospital, etc.). Themes emerged in each of these categories.

- Patient: non-compliance with home care instructions was a prevailing theme. Patients were noted to be actively smoking, not taking the medications prescribed and/or making the conscious decision to utilize the ED as their primary care source. These behaviors are opportunities for providers and the UTMB system to better educate and support the patients on the expectations put upon them for managing their own chronic conditions.
- Clinical Status: the presence of multiple comorbid conditions (such as Congestive Heart Failure, Hypertension, Diabetes, etc.) was identified as a primary influence on the patient's decision making regarding access to care.
- Providers: variation in compliance with existing standard order sets was noted. UTMB had already invested considerable efforts into the development of a COPD clinical protocol, which went live in the middle of the timeframe these patients were sampled from; the utilization of the COPD clinical protocol once it was available indicated that there was room for improvement. The providers also have room for improvement on the ordering of PFTs, which are recommended every 1-2 years by the Physician Quality and Reporting System (PQRS 2011) for patients with COPD. Incomplete documentation of other conditions was also noted.
- UTMB Operations: the (in) ability access same-day or next-day clinic appointments may drive patients to choose to go directly to the ED. During the timeframe assessed, the ED was frequently a holding area for patients waiting for inpatient beds to become available, so the additional strain of COPD patients that could have been managed in an ambulatory setting was even more critical.

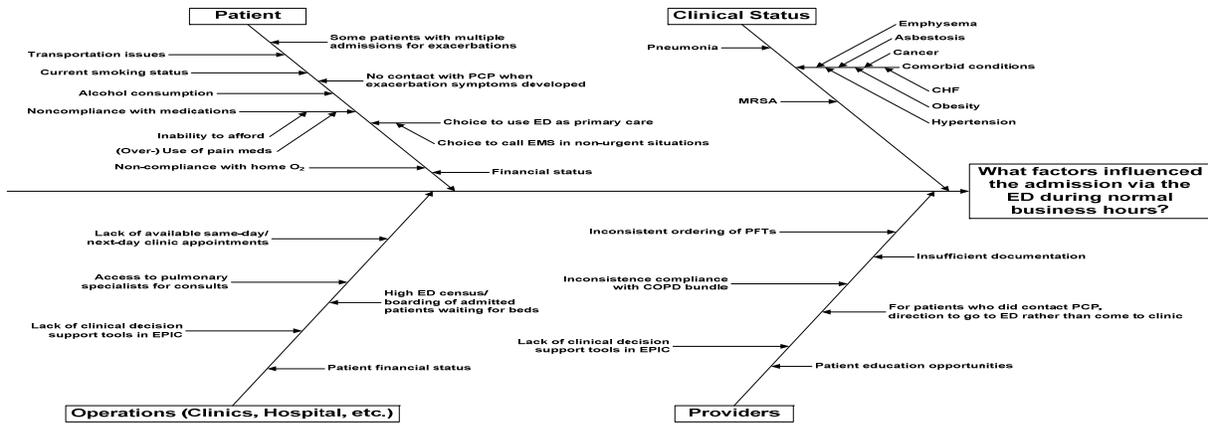


Figure 5: Cause and Effect Diagram for Patients Arriving in the ED during Clinic Hours

The access to care RCA helped support efforts related to order sets, as well as emphasizing the need to increase the availability for PFTs. A review of documentation showed that large portions of the COPD cohort did not have a PFT result available, thus making it difficult to determine if the patient truly had COPD. Additional testing equipment has been purchased and deployed in the ambulatory setting to make it easier for PCPs to order these tests for patients who have (or who are thought to have) COPD.

4. Inpatient

4.1 Guideline Compliance Review

Another avenue of study utilizing systems engineering tools was to assess the impact of implementing a COPD order set on the amount of steroids given to a patient during hospitalization. The GOLD guidelines recommend that a 40mg dosage of prednisone equivalent is adequate in management of AECOPD, and there was a perception that providers were consistently exceeding this dosage. Patients with a primary discharge diagnosis of COPD in a 45 month period (January 1, 2009 – September 30, 2012) were studied, with their total steroid usage calculated by adding all prednisolone together with 125% of the methylprednisolone given to the patient. The intervention point (order set implementation) occurred in February 2011, and the pre and post intervention population sizes are nearly equal. Table 2 shows that while the average dosages of steroids have decreased, they are still above the target of 40mg.

Variable	Pre-intervention (N=203)	Post-intervention (N=217)	p-value
Corticosteroid use (calculated as prednisone equivalent) in the first 48 hrs. of hospitalization in mg [mean (SD)]	423.37 (353.5)	206.73 (175.9)	<0.0001
Corticosteroid use during entire hospitalization in mg [mean (SD)]	537.64 (522.7)	273.58 (343.59)	<0.0001
Antibiotics received	180 (88%)	195 (90%)	0.8128
Inhaled corticosteroid	31 (15%)	32 (15%)	0.9891
Long acting beta agonist	7 (3%)	13 (6%)	0.3205
Long acting Muscuranic antagonist	26 (13%)	54 (25%)	0.0025
Pneumococcal vaccination	91 (45%)	123 (57%)	0.0197
Influenza vaccination	112 (55%)	138 (64%)	0.0973

Table 2: Process of Care of Patients Hospitalized with AECOPD

Statistical process control clearly showed the variation in practice in the pre-intervention timeframe. The implementation of the standardized order set influenced a reduction in the amount of steroids given to the patient

both during the first 48 hours (Figure 6) and the total hospitalization (Figure 7), as well as a significant drop in the variation in practice.

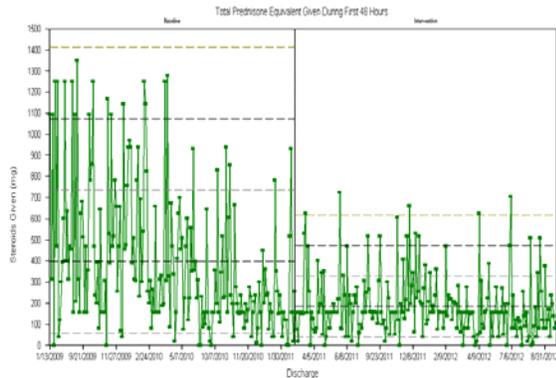


Figure 6: Total Steroid Usage during First 48 Hours of Hospitalization (Pre and Post COPD Order Set Implementation). Excludes all points >+3 standard deviations from the initial dataset (to remove true outlier patients with compounding comorbidities).

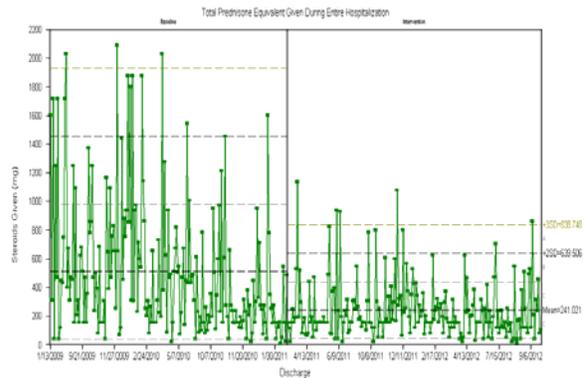


Figure 7: Total Steroid Usage during Entire Hospitalization (Pre and Post COPD Order Set Implementation). Excludes all points >+3 standard deviations from the initial dataset (to remove true outlier patients with compounding comorbidities).

To further support the physicians caring for COPD patients, UTMB Health’s EHR team has developed a COPD flow sheet, thus adding structure and standardization to the documentation process. Figure 8 shows a snapshot of what is available to the physicians; this was designed to comply with the GOLD practice guidelines.

COPD Assessment	
Year first diagnosed with COPD	1999
Oxygen therapy?	
Low dose CT candidate?	
Current medication technique demonstrated to patient?	
Patient understands medication teaching?	
Pulmonary rehab?	
Alpha 1 Antitrypsin risk assessed?	
Risk for Osteo assessed?	
DEXA Scan ordered?	
No. of PCP visits for AECOPD in last 1 year	1400
No. of ER visits for AECOPD in last 1 year	
No. of Hospitalizations for AECOPD in last 1 year	
BODE Index for COPD (Composite marker of disease taking into consideration the systemic nature of COPD)	
FEV1% predicted	
6MWD (six minute walking distance)	
Modified MRC Dyspnea Scale	
BMI	
BODE Index - Approximate 4 Year Survival Interpretation: 0.2 Points = 80%, 3.4 Points = 67%, 5.6 Points = 57%, 7.10 Points = 18%	
Total BODE Index score (0 to 10 units)	
GOLD Score (Global Initiative for Chronic Obstructive Lung Disease)	
GOLD Assessment (A-D)	
Consider lung transplant evaluation if age < 65 with BODE Index > 6, receiving supplemental oxygen, BMI < 30, no evidence of CAD, and serum creatinine < 1.6	
Is patient candidate for lung transplant evaluation?	

Figure 8: COPD Documentation Flow Sheet

4.2 Outcomes Review

Utilizing the same patient dataset as used for the guideline compliance review, the patient outcomes were then studied. Two-sample tests were applied to compare length of stay, attendance at 15- and 30-day follow-up appointments in clinic and 30-day readmissions in the pre- and post- intervention period. Specifically, unpaired t test was used for length of stay, and Chi-squared test was used for other outcomes. The *p*-values in these tests are given in Table 3; the implementation of the order set did not have any statistically significant impact to length of stay, attendance at 15-and 30-day follow-up appointments in clinic, or 30-day readmissions.

Outcomes	Pre-intervention (N=203)	Post-intervention (N=217)	p-value
Length of Stay in days mean (SD)	3.48 (2.78)	3.49 (3.20)	0.9909
15-day outpatient follow up post discharge	95 (47%)	105 (48%)	0.8196
30-day outpatient follow up post discharge	129 (64%)	123 (57%)	0.1817
30-day Readmission (All cause)	45 (22%)	44 (20%)	0.7230
30-day Readmission (COPD)	19 (9%)	22 (10%)	0.9170

Table 3: Outcomes of Patients Hospitalized with AECOPD

The COPD systems engineering team has also evaluated readmissions, which may be an indicator that the quality of care received on the initial admission was less than ideal or that the care plan for the patient post-discharge was inadequate (Lindenauer et al. 2010). Readmissions utilize hospital resources in the same manner of the initial stay. The same room and staffing requirements exist, as well as the ancillary services such as laboratory, diagnostic imaging and dietary support. The team elected to use the Institute for Healthcare Improvement's State Action on Avoidable Rehospitalizations (IHI 2013) template to assess a sample of readmitted COPD patients. Figure 9 shows the questions utilized to conduct this RCA.

All readmissions within the COPD cohort for a nine month period (January 1 – September 30, 2012) were reviewed, for a total of 21 cases (16 unique patients). The readmission occurred on average 13.5 days after they had gone home. It was determined that approximately 52% of these readmissions were related to COPD, thus highlighting the need for improved care coordination for all conditions that patients deal with. Only one third of the patients had attended their scheduled follow-up in clinic after the initial discharge, though all had an appointment for the visit. Concerns related to patient compliance with medications were noted, and opportunities to both engage Care Management and improve patient education have been identified.

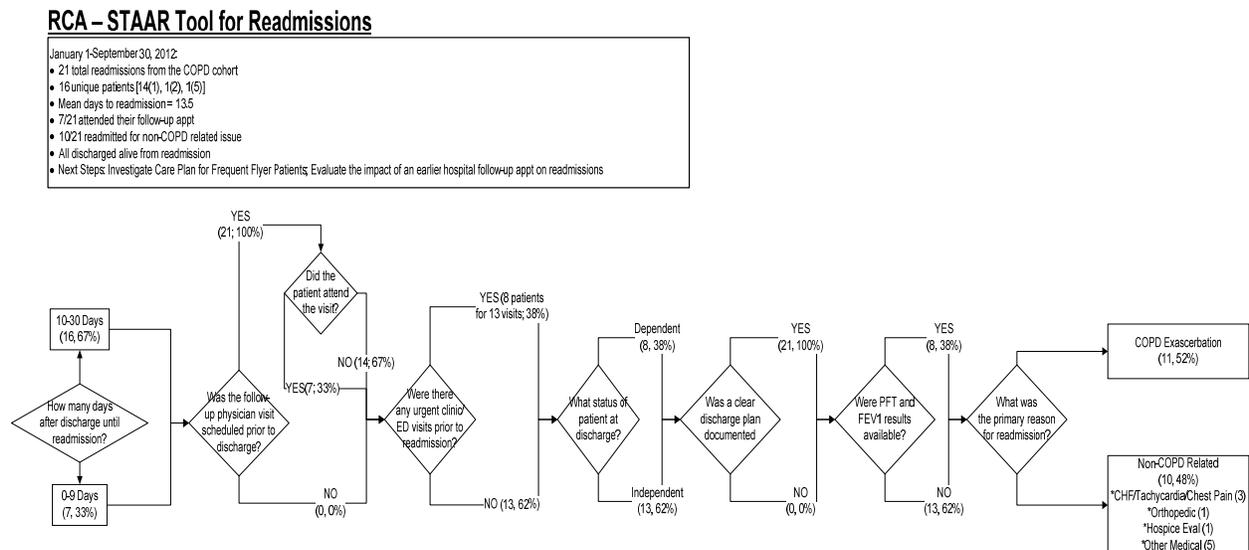


Figure 9: Root Cause Analysis Structure and Findings for Readmitted Patients

Concurrent to the systems engineering work on COPD, UTMB Health is tracking its 30-day all-cause readmission indexes for specific diagnoses. Figure 10 shows that for a 12 month period (November 2011-October 2012), the trend line for COPD readmissions is at a negative slope, but there is room for further improvement. It is notable that the trend lines for the Pneumonia, Acute Myocardial Infarction (AMI) and Heart Failure (HF) are all increasing during this same time period. T-tests were performed on the regression lines of each diagnosis; as seen in Table 4, none of the p-values were significant.

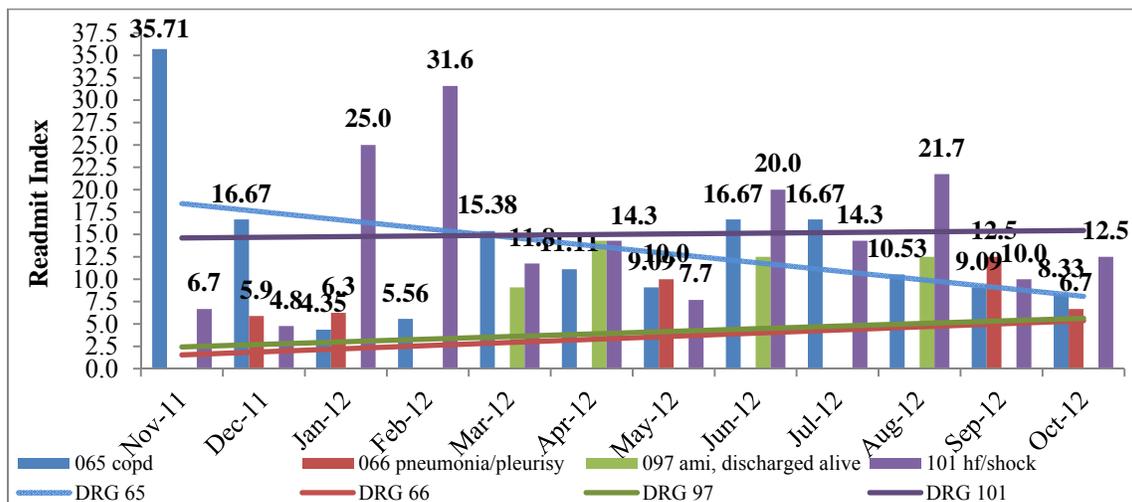


Figure 10: UTMB 30-Day Readmission Index Data November 2011-October 2012 for COPD, Pneumonia, Acute Myocardial Infarction and Heart Failure.

Table 4: 30-Day Readmission Index T-Tests

Diagnosis Related Group (DRG)	Fitted model	p-value of coefficient
COPD (DRG 65)	$y=19.3711 - 0.9397x$	0.1863
Pneumonia (DRG 66)	$y=1.2 - 0.3462x$	0.394
AMI (DRG 97)	$y= 2.1379 - 0.2916x$	0.590
HF (DRG 101)	$y= 14.6015 - 0.0664x$	0.9269

5. Discussion and Conclusions

UTMB Health is utilizing COPD as a pilot for improving the way that all chronic disease patients are managed. The efforts to enhance Health IT (via the EHR) have resulted in practice variation reduction, with more work in progress. The systems engineering team have identified other opportunities to make better use of lower-cost resources, as well as increasing the involvement of the patient in the management of their own care.

The planned next steps for this team are to work on: improving outpatient access to care (scheduling); increasing pulmonary co-management; providing PCP education on available resources; increasing pulmonary rehab usage; and supporting UTMB Health’s certification as a Center of Excellence in the care of COPD patients.

Acknowledgement

The authors gratefully acknowledge financial support from the University of Texas System Chancellor’s Health Fellow for Systems Engineering Grant.

References

- Decramer, M., Janssens, W. and Miravittles, M. Chronic obstructive pulmonary disease. *Lancet*, vol. 379, no. 9823, pp. 1341-1351, 2012.
- Global initiative on obstructive lung disease. Diagnosis and management Guidelines 2011. Available: <http://www.goldcopd.org/international-news.html>, February 18th, 2012.

Haynes, A.B., Weiser, T.G., Berry, W.R., Lipsitz, S.R., Breizat, A.H., Dellinger, E.P., ... and Gawande, A.A. A surgical safety checklist to reduce morbidity and mortality in a global population. *New England Journal of Medicine*, vol. 360, no. 5, pp. 491-499, 2009.

Institute for Healthcare Improvement (IHI). STate Action on Avoidable Rehospitalizations (STAAR) Initiative 2013. Available: <http://www.ihf.org/offerings/Initiatives/STAAR/Pages/default.aspx>, April 4, 2013.

Lindenauer, P.K., Bernheim, S.M., Grady, J.N., Lin, Z., Wang, Y., Wang, Y., ... and Krumholz, H.M. The performance of US hospitals as reflected in risk-standardized 30-day mortality and readmission rates for Medicare beneficiaries with pneumonia. *Journal of Hospital Medicine*, vol. 5, no. 6, pp. E12-E18, 2010.

PQRS. 2011 Physician quality reporting system measures list. Available: https://www.cms.gov/PQRS/Downloads/2011_PhysQualRptg_MeasuresList_033111.pdf, April 4, 2013.

Pronovost, P., Needham, D., Berenholtz, S., Sinopoli, D., Chu, H., Cosgrove, S., ... and Goeschel, C. An intervention to decrease catheter related blood stream infections in the ICU. *New England Journal of Medicine*, vol. 355, no. 26, pp. 2725-32, 2006.

Sharif, R., Cuevas, C.R., Wang, Y., Arora, M. and Sharma, G. Guideline adherence in management of stable chronic obstructive pulmonary disease. *Respiratory Medicine*, 2013 (in press).

Stanciole A. Health insurance and lifestyle choices: Identifying ex ante moral hazard in the US market. *Geneva Papers on Risk & Insurance - Issues & Practice*, vol. 33, no. 4, pp. 627-644, 2008.

Tien, J.M., Goldschmidt-Clermont, P.J. Engineering Healthcare as a service system. *Information Knowledge Systems Management*, Chapter 16, pp. 277-297, 2009.

Biography

Gulshan Sharma, MD is a Director and Associate Professor in the Department of Internal Medicine. Dr. Sharma's clinic expertise in Pulmonology and Critical Care has led him to champion the development of clinical protocols and pathways, order sets and the increased use of Health IT in the delivery of care.

Carlos Clark, DO is the Chief Medical Information Officer for UTMB and Assistant Professor in the Department of Internal Medicine. He has successfully developed and implemented clinical decision support via disease specific best practice alerts and smartsets; he currently leads the Epic workflow committee to improve the clinical application functionality.

Lindsay Sonstein, MD, is an Assistant Professor and Director of Quality Improvement in the Department of Internal Medicine. She has completed Clinical Safety and Effectiveness training at The University of Texas MD Anderson Cancer Center. She oversees and develops QI projects that align with Institutional priorities throughout the Department of Medicine. She has extensive experience in developing and implementing Epic smart-sets into clinical workflow.

Rick Trevino is a Programming and Network Services Manager in the Department of Clinical Data Management. His expertise at extracting data from the EHR is vital to evaluating the effectiveness of any improvement effort.

Laura Grady, RN is a Lead Applications Systems Analyst in the Department of Information Service – Clinical Documentation. She is responsible for ensuring that the process changes that are to be built into the EHR are put in place and meet all clinical documentation requirements.

Susan Seidensticker is the Director of Waiver Quality Operations at the University of Texas Medical Branch (UTMB). She has a BS in Industrial Engineering from Purdue and a MS in Health Administration Informatics from the University of Maryland University College; she is also a Certified Healthcare Quality Professional (CPHQ), Six Sigma Black Belt (SSBB) and Project Management Professional (PMP). Susan has 17+ years of experience in performance and quality improvement in healthcare settings (hospitals, ambulatory clinics and non-clinical operations), and has presented previously at the Society for Health Systems. She is an active senior member of the Institute of Industrial Engineers, an active senior member of the American Society for Quality (ASQ) and a member of the Project Management Institute (PMI).