Artificial intelligence and e-health for inflammatory bowel diseases: the quest to enhance patient experiences, outcomes and costs

Zand, A.

CHAPTER 9

Summary of Chapters, General Discussion, Future Perspectives

Summary of Chapters

Inflammatory Bowel Diseases (IBD) such as Crohn's disease (CD) and ulcerative colitis (UC) are chronic immunological digestive diseases with a progressive character and associated with significant healthcare costs[1,2]. The symptoms of IBD are generally frequent abdominal pain and diarrhea and the disease state alternates between remission and exacerbation. In the United States, IBD affects nearly 3 million people who regularly require medical therapy, surgeries, and hospitalizations[3]. The impact is not limited to the hospital but also affects patients and their caregivers in their daily life and at the workplace. Due to the unpredictable course of the disease, developing innovative methods using technology that can identify patients at risk for adverse outcomes such as relapses outside of the traditional hospital setting would help to better manage this chronic condition, prevent negative outcomes and reduce the associated healthcare costs.

PART I: The Need for Innovation to Address the Economic and Psychosocial Impact of IBD

There is still a tremendous psychosocial and economic impact of IBD that has not been sufficiently addressed. The impact of chronic conditions remains a big force threatening the U.S. workforce productivity[4], not just deteriorating the patient experience and quality of life but also causing significant economic impact due to the associated indirect costs. **Chapter 2** looked at the impact of IBD on the productivity of patients and revealed that employed IBD patients experience significantly more presenteeism (decreased productivity at work) than healthy controls without IBD (54.7% vs. 27.3%, respectively; P=0.02), even when these patients are in complete clinical remission. We showed that indirect costs encountered for IBD patients in remission were still significantly higher when compared to healthy controls without IBD (p=0.02). Additionally, we demonstrated that patients continue to deal with decreased productivity at the workplace, where 66% of patients had not taken any necessary measures (like workplace adjustments) to tackle these issues, most likely due to the social stigma but also because of a lack of the appropriate tools and shortage of meaningful interventions.

Furthermore, in **Chapter 3** we discovered that the impact of IBD is not limited to only patients but extends to their caregivers as well. Caregiver burden is described as the emotional, physical, practical, and/or financial burden associated with taking care of a

patient with a chronic condition[5]. We found that caregivers with burden have significantly more absenteeism
(taking sick day; 58%) and presenteeism (84%) than caregivers without burden (24% absenteeism and 37% presenteeism). More importantly, caregivers expressed that they felt they should be doing more and better for their care recipients. This indicates that the development of strategies to address caregiver's distress and perceived burden when caring for IBD patients is warranted. Innovative solutions are required to battle these problems for patients with IBD and their caregivers, to improve outcomes and decrease costs.

PART II: Identifying IBD Patients' Needs using eHealth and Artificial Intelligence

The rising costs of healthcare with its associated negative experiences and adverse outcomes for patients has accelerated the quest for potential solutions. The Triple Aim is a framework of health care delivery improvement that consists of three objectives, 1) to improve outcomes, 2) to improve patient experience and 3) to decrease costs[6]. This framework has been proposed by the Institute for Health care Improvement (IHI) in order to assist health care organizations to optimize their performance by using these three metrics. This framework provides guidance on how to structurally implement change to improve the quality of the care delivered. It is applicable to chronic conditions like IBD, where rising healthcare expenditures are a major problem, patient experiences need improvement and outcomes are not fully optimized. Electronic health (eHealth) interventions are a potential solution for more effective care management beyond the clinical setting, both in terms of patient outcomes and cost reduction. Smartphones with mobile applications are extensively available and short message reminders have been already been used effectively by patients with IBD[7]. Furthermore, eHealth could be further enhanced with artificial intelligence (AI) to optimize care processes, identify patients in need of intervention, and improve the quality of care.

In **Chapter 4** we discovered that medication non-adherence was present in 33% of IBD patients, consistent with prior findings in the literature[8]. We then assessed what questions can most accurately assess medication adherence based on previously reported patient-reported outcome measurements, based on which we developed a single-item screening tool for medication non-adherence that can be used to monitor adherence remotely through eHealth applications. Our 1-item screening tool detects non-adherence with a sensitivity of 87% and a specificity of 64% and is accompanied by a 9-item survey to assess the leading

extrinsic and intrinsic factors that contribute to nonadherence. The 1-item screening tool together with the 9-item survey can be used for detecting and managing adherence in IBD patients. While several tools are available to assess non-adherence, few specify the reasons for non-adherence in IBD, which is critical for appropriate management. The unsurmountable surge of AI in healthcare has offered a tremendous amount of opportunities to develop new strategies and technologies that can assist healthcare providers and patients in their care management in order to achieve the Triple Aim objectives.

In **Chapter 5** the feasibility of categorizing large datasets of electronic communications between patients and care providers using NLP for potential use in chatbots for IBD care management was demonstrated. We successfully categorized large amounts of electronic messaging data (>8000 lines) using a bag-of-words model into less than 10 categories. Furthermore, 90% of all dialogue fell into only seven categories: symptoms, medications, appointments, labs, finance or insurance, communications and miscellaneous. When comparing our algorithm to the assessment of three independent physicians, there were minor to no differences in 95% of cases. This demonstrates the potential to develop a chatbot with an NLP algorithm that can successfully categorize most questions and concerns of IBD patients.

With the increased use of Electronic Medical Records (EMRs), which has doubled in size since 2005, analyzing patient data is easier now than ever[9,10]. Furthermore, due to increased computational resources and availability of large data sets, a tremendous surge in development of healthcare technology driven by Artificial Intelligence has manifested. In **Chapter 6** we exhibited that it was feasible to successfully run complex AI models on large (Big Data), longitudinal claims data sets of IBD patients. We looked at four adverse outcomes for IBD (hospitalizations, surgeries, long-term steroid and biologics use) and assessed if 108 features regarding IBD-related care could be predictive of these adverse outcomes. We analyzed traditional regression models like LASSO and Ridge, machine learning methods such as Support Vector Machines and Random Forests but also involved more innovative methods like Neural Networks. We assessed the feasibility and performance of these models in early prediction of the aforementioned negative outcomes.

The Random Forest performed the best with the highest accuracy (AUCs between 0.71-0.92), this might indicate that the relationships between the claim's features are best captured by a Random Forest model and that this model framework might work best for claims predictions in general. We observed that different models identified different predictors

for the each of the outcomes. The regression models and the neural network had comparable findings, in which the most predictive features were related to medication use. The random forest used more heterogenous types of predictors, not only identifying medication use as predictive features but also procedures such as lab tests and imaging. Therefore, we believe that that these findings can be applied to the daily clinical practice to identify at-risk patients. The complex models pick up on detailed interactions between the features and can be used to make precise risk assessments based on an individual patient's data. We have identified several strategies that could enhance the use of eHealth and AI in IBD clinical practice and assist in the transition to data-driven IBD care.

PART III: eHealth to Facilitate the Delivery of High-value Care in IBD

There is significant variation in how care is delivered to IBD patients, a factor known to be inversely associated with quality of care[11]. As engagement with patients outside the hospital setting is becoming more relevant, standardization of outpatient care using eHealth could be a potential solution to reduce variation, and improve the patient experience, health outcomes and decrease costs. This process can be facilitated through the concept of care pathways, which pre-define the clinical activities and costs associated with a specific diagnosis for a defined amount of time, thereby standardizing the care delivered. eHealth solutions could facilitate the implementation and monitoring of care pathways in order to improve the quality of care delivered for IBD patients.

Despite significant advancement in novel medical therapeutics for IBD, a large percentage of IBD patients and in particular Crohn's disease patients will undergo surgery[12]. These surgical interventions are associated with costly readmissions and complications . In **Chapter 7** we assessed the feasibility and efficacy of a surgical eHealth intervention on readmission rates, emergency department (ED) visits and outpatient gastroenterology follow-up visits. We demonstrated the feasibility of implementing a surgical care pathway using eHealth for post-surgery IBD management. After being discharged from the hospital after surgery, patients filled out frequent surveys in order to monitor patient reported measures and correct potential complications. For example, patients who reported an increase in abdominal pain were triaged by a surgical nurse who then consulted the IBD surgeon. If necessary, the patient would be called into clinic or there would be an adjustment of medical management. In our pilot, 81% of participating patients rated their experience as "excellent" and 94% described the amount of questions in the surveys as reasonable. Additionally, 54% of patients felt their recovery would have had a different result without

participation in the program. We did not find a statistically significant difference on readmission rates, ED visits and outpatient clinic follow up, but demonstrated high acceptability and feasibility of this eHealth application for remote post-operative IBD management.

In **Chapter 8** we assessed the patient experience with the UCLA eIBD app after one year of use. UCLA eIBD is a mobile application that incorporates various components of care delivery such as appointment reminders and medication trackers for patients, a healthcare provider portal for the treating provider, and patient-provider chat functionality. UCLA eIBD seeks to empower patients to self-manage their IBD by increasing their access to healthcare providers through the app and providing self-help educational modules. The application also monitors disease activity, quality of life, and work productivity using validated questionnaires. As mobile applications are becoming more relevant in care management, our results provide guidance for further app improvement and provide critical feedback for other eHealth solutions.

In this study, we demonstrated 78% satisfaction with patient-provider communication through the app, a critical component of the patient experience. Furthermore, 54% of app users reported a perceived improvement in disease control and 56% reported a perceived improvement in quality of life (QoL), indicating that a majority of patients felt the platform positively impacted their health. When asked if they would recommend this app to friends, family or other patients, users rated this app with a median score of 8 on a ten-point scale (0 being the least likely to recommend and 10 being the most likely to recommend). Recommendations from patients on improving the app centered on specific content interests and the demand for additional educational subjects (i.e. female health topics) rather than technical problems or lack of need for an app. The result translates back to the overall satisfaction rate of 74% of participants finding the app easy to navigate. Educational fitness and nutrition modules were the two most-used optional wellness modules, with was each completed by 34% of users. Our findings suggest that a platform with interactive modules promoting healthy lifestyle habits along with increased access to communication with healthcare providers is well-received by IBD patients with self-reported improvement in disease outcomes and quality of life and may potentially result in enhanced satisfaction with outpatient care delivery.

General Conclusion and Future Perspectives.

Despite advances in medical therapy, IBD still has a significant economic and psychosocial impact. To improve quality of care, empowerment and self-management of patients outside the traditional clinical setting is imperative to improve the experience, decrease costs and improve outcomes.

In **Chapter 2** we demonstrated that employed IBD patients in clinical remission still have a substantial decrease in work productivity that mostly goes undetected. The associated high indirect costs constitute a significant economic burden on health expenditures. A method to lower indirect costs includes both care provider and employer interventions, ideally converging into an integrated approach[13]. The development and testing of productivity measuring enhancement tools could have a meaningful and immediate impact. Care providers (e.g. physicians, nurses, social workers, dieticians) should pro-actively discuss and propose employment-related adjustments tailored to the individual. Using eHealth applications, care providers can incorporate mental support, nutritional support, and wellness (e.g. fitness, yoga, meditation) in their care plan, thereby potentially improving patients' health and productivity at work. In addition, eHealth can facilitate the elimination of unnecessary tests, procedures and medical appointments through care pathways, which could reduce absenteeism. Surveys have demonstrated that employees with chronic conditions are more likely to be highly satisfied with their jobs if they had high self-efficacy in managing their disease, perceive workplace support, and had less work limitations[14]. This would also allow employers to make successful adjustments leading to a reductions in presenteeism and absenteeism and the associated indirect costs.

In **Chapter 3** we presented that caregiving for IBD patients causes significant work productivity decreases in caregivers. In addition, despite the burden, caregivers felt they should be doing more for their care recipient and felt they could do a better job at caregiving, warranting the need for more caregiver solutions. Behavioral interventions using web-based and mobile apps, have the ability to provide the power to patients for better management of their IBD, as well as motivation to engage in positive behavior[15], there is potential for caregivers in these solutions as well. Caregivers can be provided with necessary education on the disease of the care recipient and social support(contact with other caregivers) through eHealth applications in order to reduce caregiver burden and increase caregiver empowerment[16]. The development and implementation of such solutions for caregivers of IBD patients can be of tremendous value to a frequently overseen and challenging issue.

Electronic health (eHealth) technologies have the potential for promoting self-management and reducing the impact of the growing burden of IBD on health care resource utilization. Therefore in **Chapter 4** we developed an innovative screening tool for management of medication non-adherence in IBD. This allows care providers to screen for non-adherence in IBD and further identify the exact reasons for non-adherence so they may offer more personalized solutions. The use of this tool could allow for continuous and remote monitoring of medication adherence. Future studies should validate the effect of remote monitoring of adherence on medication adherence levels, patient satisfaction, and health care costs.

Furthermore, usage of smartphones and eHealth applications are on the rise, just like in daily life, electronic communication between patients and their providers is becoming the standard. In **Chapter 5** we demonstrated the feasibility of categorizing large sets of electronic messaging data in one of the most complex chronic conditions into a low (<10) number of categories. Our results showed that 25% of messages were related to appointments. This provides an opportunity for AI to play a role in care optimization. A chatbot could efficiently automate requests regarding appointments or even play an active role in triage, following the same guidelines of questioning as nurses, saving the provider team valuable time that could be reallocated to better patient care. The value of a chatbot is clear and has been demonstrated in other industries[17]; a chatbot is available at all times, can handle large amounts of communications simultaneously, and has no wait times. Now that feasibility has been showcased, further studies are necessary to assess the technical build and implementation as well as the effect on patients, providers, and costs.

Due to increased use of EMRs[9,10], availability of large patient data repositories and advancement of computational processing power, AI has now been presented as the next best thing for healthcare. The practical reality of AI is an enigma to many clinicians. However it is clear that big data cannot be optimally studied with the standard methods of statistical analysis[10]. In **Chapter 6** we exhibited that it was feasible to successfully run complex AI models on large data sets (Big Data) of IBD patients. Additionally, we demonstrated that these findings can have potential use in daily clinical practice by risk profiling patients. Transferability of these models to different institutions has been successful, alleviating a major concern[18]. The next step would be to integrate these models in a prospective setting to study their performance on reliability, patient outcomes and costs.

In an era where the use of mobile technology has become irreplaceable in daily life, disruptive innovation in healthcare is predicted to redefine personalized medicine. There is undoubted benefit of incorporating AI and eHealth applications in the management of chronic conditions. Studies have shown the effectiveness of mobile applications but also that patients still desire improvements to existing solutions[19,20]. In **Chapter 7** we demonstrated the feasibility of implementing a surgical care pathway using eHealth for post-surgery IBD management. It was well-received by patients, supporting the use and acceptability of a eHealth intervention for patient care. In Chapter 8 we showed that UCLA eIBD and its holistic approach has led to better patient experience and satisfaction, which can provide valuable recommendations for healthcare providers and app developers. However, bigger and controlled studies are recommended to assess its efficacy at a larger scale and its impact on costs.

References

1. Pariente B, Cosnes J, Danese S, et al. Development of the Crohn's disease digestive damage score, the Lémann score. *Inflammatory Bowel Diseases*. 2011;17(6):1415-1422. doi:10.1002/ibd.21506

2. Kappelman MD, Rifas-Shiman SL, Porter CQ, et al. Direct Health Care Costs of Crohn's Disease and Ulcerative Colitis in US Children and Adults. *Gastroenterology*. 2008;135(6):1907-1913. doi:10.1053/j.gastro.2008.09.012

3. Dahlhamer JM, Zammitti EP, Ward BW, Wheaton AG, Croft JB. Prevalence of inflammatory bowel disease among adults aged ≥18 years — United States, 2015. *Morbidity and Mortality Weekly Report*. 2016;65(42):1166-1169. doi:10.15585/mmwr.mm6542a3

4. Disease PtFC, Alliance USWW. The Burden of Chronic Disease on Business and U.S. Competitiveness: Excerpt from the 2009 Almanac of Chronic Disease: Partnership to Fight Chronic Disease; 2009. Accessed July 28, 2020. http://www.fightchronicdisease.org/sites/default/files/docs/2009AlmanacofChronicDisease_updated81009.pdf

5. Zand A, Kim BJ, van Deen WK, et al. The effects of inflammatory bowel disease on caregivers: significant burden and loss of productivity. *BMC health services research*. Published online 2020. doi:10.1186/s12913-020-05425-w

6. Berwick DM, Nolan TW, Whittington J. The triple aim: Care, health, and cost. *Health Affairs*. 2008;27(3):759-769. doi:10.1377/hlthaff.27.3.759

7. Con D, de Cruz P. Mobile Phone Apps for Inflammatory Bowel Disease Self-Management: A Systematic Assessment of Content and Tools. *JMIR mHealth and uHealth*. 2016;4(1):e13. doi:10.2196/mhealth.4874

8. Selinger CP, Robinson A, Leong RW. Clinical impact and drivers of non-adherence to maintenance medication for inflammatory bowel disease. *Expert Opinion on Drug Safety*. 2011;10(6):863-870. doi:10.1517/14740338.2011.583915

9. E YNJE and H. Office-based Physician Electronic Health Record Adoption. *December*. Published online 2016. Accessed July 20, 2020. https://dashboard.healthit.gov/quickstats/pages/physician-ehr-adoption-trends.php

10.. Derrington D. *Artificial Intelligence for Health and Health Care.*; 2017. Accessed June 23, 2020. https://pdfs.semanticscholar.org/4f32/7be94508a5c1f2a6f09917d7dcf57698af24.pdf

11.. Weaver KN, Kappelman MD, Sandler RS, et al. Variation in Care of Inflammatory Bowel Diseases Patients in Crohn's and Colitis Foundation of America Partners: Role of Gastroenterologist Practice Setting in Disease Outcomes and Quality Process Measures. *Inflammatory Bowel Diseases*. 2016;22(11):2672-2677. doi:10.1097/MIB.0000000000000933

12.. Kozuch PL, Hanauer SB. Treatment of inflammatory bowel disease: A review of medical therapy. *World Journal of Gastroenterology*. 2008;14(3):354-377. doi:10.3748/wjg.14.354

13.. Zand A, van Deen WK, Inserra EK, et al. Presenteeism in inflammatory bowel diseases: A hidden problem with significant economic impact. *Inflammatory Bowel Diseases*. 2015;21(7):1623-1630. doi:10.1097/MIB.0000000000000399

14.. Siu AMH, Hung A, Lam AYL, Cheng A. Work limitations, workplace concerns, and job satisfaction of persons with chronic disease. *Work*. 2013;45(1):107-115. doi:10.3233/WOR-121550

15.. Stiles-Shields C, Keefer L. Web-based interventions for ulcerative colitis and Crohn's disease: Systematic review and future directions. *Clinical and Experimental Gastroenterology*. 2015;8:149-157. doi:10.2147/CEG.S56069

16.. Adelman RD, Tmanova LL, Delgado D, Dion S, Lachs MS. Caregiver burden: A clinical review. *JAMA - Journal of the American Medical Association*. Published online 2014. doi:10.1001/jama.2014.304

17.. Zhou L, Gao J, Li D, Shum H-Y. The Design and Implementation of XiaoIce, an Empathetic Social Chatbot. *Computational Linguistics*. 2018;46(1):53-93. Accessed August 20, 2020. http://arxiv.org/abs/1812.08989

18.. Kim E, Caraballo PJ, Castro MR, Pieczkiewicz DS, Simon GJ. Towards more Accessible Precision Medicine: Building a more Transferable Machine Learning Model to Support Prognostic Decisions for Micro- and Macrovascular Complications of Type 2 Diabetes Mellitus. *Journal of Medical Systems*. 2019;43(7). doi:10.1007/s10916-019-1321-6

19.. Stunkel L, Karia K, Okoji O, et al. Impact on Quality of Life of a Smart Device Mobile Application in Patients with Inflammatory Bowel Disease. *American Journal of Gastroenterology*. 2012;107:S635-S636. doi:10.14309/00000434-201210001-01575

20.. Ashish A, Sameer K, Eva S, et al. Improved Quality of Care for IBD Patients Using HealthPROMISE App: A Randomized, Control Trial. *American Journal of Gastroenterology*. Published online 2018. doi:10.14309/00000434-201802001-00003