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ORIGINAL RESEARCH

Infectious Disease

The impact of a point-of-care visual clinical decision support tool on admissions for cellulitis in the University of Maryland medical system

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Abstract

Introduction: Cellulitis is commonly diagnosed in emergency departments (EDs), yet roughly one third of ED patients admitted for presumed cellulitis have another, usually benign, condition instead (eg, stasis dermatitis). This suggests there is an opportunity to reduce health care resource use through improved diagnosis at the point of care. This study seeks to test whether a clinical decision support (CDS) tool interoperable with the electronic medical record (EMR) can reduce inappropriate hospital admissions and drive more appropriate and accurate care.

Methods: This study was a trial of an EMR-interoperable, image-based CDS tool for evaluation of ED patients with suspected cellulitis. At the point of assigning a provisional diagnosis of cellulitis in the EMR, the clinician was randomly prompted to use the CDS. Based on the patient features entered into the CDS by the clinician, the CDS provided the clinician a list of likely diagnoses. The following were recorded: patient demographics, disposition and final diagnosis of patients, and whether antibiotics were prescribed. Logistic regression methods were used to determine the impact of CDS engagement on our primary outcome of admission for cellulitis, adjusted for patient factors. Antibiotic use was a secondary end point.

Results: From September 2019 to February 2020 (or 7 months), the CDS tool was deployed in the EMR at 4 major hospitals in the University of Maryland Medical System. There were 1269 encounters for cellulitis during the study period. The engagement with the CDS was low (24.1%, 95/394), but engagement was associated with an absolute reduction in admissions (7.1%, $p = 0.03$). After adjusting for age greater than 65 years, female sex, non-White race, and private insurance, CDS engagement was associated with a significant reduction of admissions (adjusted OR = 0.62, 95% confidence interval (CI): 0.40–0.97, $p = 0.04$) and antibiotic use (Adjusted OR = 0.63, 95% CI: 0.40–0.99, $p = 0.04$).

Conclusions: CDS engagement was associated with decreased admissions for cellulitis and decreased antibiotic use in this study, despite low levels of CDS engagement.

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Further research should examine the impact of CDS engagement in other practice environments and measure longer-term outcomes in patients discharged from the ED.

KEYWORDS
clinical decision support, dermatology, emergency medicine, health care use, infectious disease

1 | INTRODUCTION

1.1 | Background

Cellulitis is a common disease with a global impact, responsible for a decrease of 15.5 (11.8 to 20.2) age-adjusted, disability-adjusted life years per 100,000 persons.[1] In the United States, 2.9 million (2.1%) of the 134.9 million emergency department visits in 2013 were related to cellulitis, and admissions for cellulitis was responsible for $4.2 billion dollars of inpatient charges.[2] Yet cellulitis is also commonly misdiagnosed. Several studies have consistently found that among patients hospitalized for cellulitis between 28%–33.6% had some other benign diagnosis that did not require hospitalization.[3–5]

1.2 | Importance

Given the risks of iatrogenic disease and the move toward a global health care budget in Maryland,[6,7] there is significant interest in identifying benign disease and preventing unnecessary admissions. Unfortunately, there is a lack of diagnostic criteria for cellulitis and, therefore, very few tools developed to assist in identifying cases.[8] Early, in-person evaluation of patients with suspected cellulitis by dermatologists is effective at reducing admissions and antibiotic use, but this approach is not feasible for most hospital systems.[3,4,9] Clinical decision support (CDS) tools may be a way to reduce health care use associated with suspected cellulitis.

1.3 | Goals of this investigation

Our primary objective was to determine whether the implementation of an image-based CDS integrated into our systemwide electronic medical record (EMR) was associated with a decrease in admissions for cellulitis. A secondary objective was to measure the amount of antibiotic use and determine whether there was a significant association with CDS engagement and decreasing antibiotic use. Our hypothesis was that engagement with the CDS would be associated with a decrease in patient admissions for cellulitis compared with encounters without CDS support.

2 | METHODS

2.1 | Study design

This was an interventional study measuring the impact of the EMR-interoperable CDS on ED encounters for cellulitis. The intervention was engagement or use of the CDS software by the treating physician. The primary end point was encounter disposition (admit, observation, discharge, etc). Encounter dispositions such as observation and transfers were considered admissions for this study. Encounter dispositions like elopement, left without being seen, and leaving against medical advice were considered discharges. The secondary end point was antibiotic use, as determined by the prescriptions or orders written during the encounter. Human subjects approval for this project was obtained through the University of Maryland (UM), Baltimore, Institutional Review Board (IRB) and through each of the participating sites.

2.2 | Population and setting

The project was implemented in a stepwise fashion in 4 EDs across the medical system. Each individual institution had a process for giving permission to deploy the tool after IRB approval was gained. Records from patients with cellulitis who were treated at study sites before the tool could be deployed were included in the study sample.

The study sites included the University of Maryland Medical Center (UMMC), the UM Medical Center Midtown Campus (MTC), the UM Baltimore Washington Medical Center (BWMC), and the UM St. Joseph's Medical Center (SJMC). UMMC is an urban academic tertiary care center with an annual ED census of approximately 65,000 patients a year. MTC is an urban community hospital treating 27,000 patients annually. BWMC and SJMC are suburban centers treating 93,000 and 44,000 patients, respectively.

2.3 | Power calculation

In the year before the study, there were approximately 219,000 total ED visits across the study sites, of which 6350 were for cellulitis. The literature suggests that 25% of these patients are admitted.[3–5] We planned a study with 1:1 experimental and control subjects ($N = 3{,}175$ per arm). Given that the admission rate among controls is 25%, an admission rate as high as 22.0% (698/3175) in the interventional arm will be statistically significant from controls (a priori alpha = 0.05, beta = 0.8).

2.4 | CDS tool

VisualDx[10] is a CDS program that allows the physicians to enter patient characteristics and create a differential diagnosis, with the capability to

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provide a visual differential diagnosis of skin exam features. Potential diagnoses are displayed with a spectrum of images to help the physician match one of the potential diagnoses to the patient they are treating. A web-based version of the CDS system was made available and linked to the EMR of the University of Maryland Medical System (UMMS).

2.5 | Implementation of the CDS tool

Potential encounters for inclusion in the study were those where the patient had been given a clinical impression or diagnosis code for cellulitis by the treating clinician. The specific trigger was the *International Classification of Diseases, Tenth Revision* (ICD-10), codes for cellulitis: L03.0–L03.9. Each encounter in our EMR is assigned a contact serial number (CSN). It is literally a running count of all patient encounters over time across our medical system (more than a million per year). CSNs are used internally by the EMR to uniquely identify link a patient and encounter. Because patients arrived throughout the day at all system hospitals and clinics, not just the study sites, we used the last digit of the CSN as a random number generator to select cases and controls. If the CSN for a given encounter was even, then the patient was considered a control subject. If the CSN was odd, then the encounter was considered a case, and the link to the CDS was shown as a “Best Practice Advisory” (BPA) to the user (Figure. 1).

The user could click on the link and pull up the web-based version of the CDS program via the EMR. The user would first be asked to verify deidentified patient information pulled from the EMR: age (eg, coded as >90 for those over 90 years of age and older) and sex. They would then be presented with a series of image-based menus of patient (eg, presence of fever, immunosuppression, recent travel) and rash characteristics (eg, body distribution, raised or flat, petechial or blanchable, etc.) to develop the differential. At the end, the user would be presented with an image-based list of the most likely diagnoses and a list of the of most dangerous diagnoses. Images would be provided in a range of skin tones. The user would then make note of the most appropriate diagnosis and exit the application. Engagement with the CDS was defined as loading the VisualDx website within the EMR, working through the prompts of the photo-based differential, and coming to a diagnosis. These data were sent to the cloud-based CDS application when the link was clicked to facilitate the building of the differential.

The ED setting is inherently time limited, and patients are often acutely ill. As a condition of IRB approval and to gain acceptance within the study sites, the CDS could not interfere with patient care. This was achieved by providing the “Acknowledge Reason” hard stop in the lower left of the pop-up. Clinicians who, for patient care reasons, did not have time to engage with the CDS were able to bypass it by clicking “Cellulitis Confirmed.” In some study sites there are teams of residents and attendings who are taking care of patients; for this reason, the CDS was shown only to the first clinician to assign a cellulitis diagnosis. CDS engagement was independently tracked. The CDS was implemented in September 2019 and continues in operation through today.

The Bottom Line

Up to one third of patients admitted for cellulitis from the emergency department have benign conditions, such as venous stasis dermatitis. Using an image-based clinical decision support tool within the electronic medical record, there was almost a 40% relative decrease in admissions and antibiotic use in patients with an initial clinical impression of cellulitis.

2.6 | Data acquisition and analysis

Patient demographics, including age, sex, race, and insurance status, were retrieved from the EMR. The time, place, outcome (admission vs discharge), and whether antibiotics were given to the patient were also retrieved from the EMR. Whether a given encounter was considered

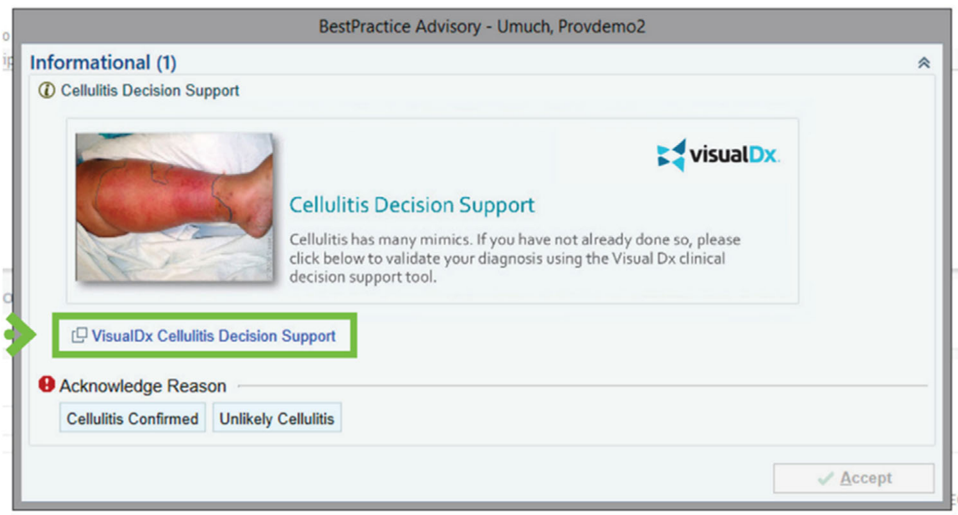

FIGURE 1 The Clinical Decision Support (CDS) prompt as implemented in EPIC. The link to the software is shown (green box and arrow).

a case or a control (ie, whether the link to the CDS was shown to the user or not, respectively) and whether the user engaged with the CDS (ie, used the CDS) were independently recorded and retrieved from the CDS database server. Subject characteristics were stratified by case status and reported by mean and 95 confidence interval (95% CI). Encounter location, disposition, and whether the user engaged with the CDS was shown as a series of counts and percentages. Chi-square and *t* tests were used as appropriate.

After a bivariate analysis, the unadjusted odds ratios (OR) for each of the patient characteristics were calculated using logistic regression with admission status as the outcome. Those factors that were independently associated with the outcome were included in the final adjusted model. These included age, sex, race, and insurance status. A sensitivity analysis was conducted to demonstrate how the observed trends might change as more subjects were enrolled.

3 | RESULTS

3.1 | CDS use

The CDS tool was implemented in September 2019. The data used in this study were collected from encounters occurring between September 2019 and February 2020. A total of 1269 patients were given a diagnosis or clinical impression of cellulitis across the 4 UMMS study hospitals. Of those, there were 875 controls where the CDS did not fire, and 394 cases where the link to the CDS was shown to the user. The proportion of encounters where the physician interacted with the CDS when it was shown was an average of 24.1% across the study period.

3.2 | Demographics

Most of the subjects were male (57.1%, 725/1269) and White (61.1%, 775/169), with a mean age of 49.1 years (95% CI: 48.0–50.1) (Table 1). There was a significant number of additional controls recruited from study sites that approved the protocol later than others (Figure 2). There were significant differences in the distribution of age, sex, race, and insurance status between cases and controls. The time required to discharge patients, or the length of stay for admitted patients, was not different between groups. Controls were admitted significantly more often than cases (46.4% vs 39.3%, $p = 0.03$). Most subjects were either admitted, observed, discharged, or transferred. There was a subject who left without discharge instructions, one who was sent to labor and delivery, one who died, and another who did not have their disposition recorded ($n = 4$ total, 0.3%).

3.3 | Logistic regression results

Given the differences in cases and controls, a logistic regression model was constructed using patient demographics (age, sex, race), insurance status, and then whether the physician used the CDS (ie, CDS "activity" was recorded). The results of the adjusted analyses are shown in Table 2. Note that model variables with ORs <1 reduce the likelihood of the dependent variable or outcome. Older patients were more likely to be admitted. There was a trend showing that engagement with the CDS reduced admissions by 38% (adjusted OR = 0.62, 95% CI: 0.40 to 0.97, $p = 0.04$), consistent with the a priori estimate of 28%–33% percent of patients admitted for cellulitis not actually having the condition.

4 | LIMITATIONS

Our study is limited in several important ways. Given the time-pressured environment of the ED, it is likely that the BPA and related CDS intervention were dismissed frequently with the "Acknowledge Reason" hard stop mentioned in the methods section. Thus the frequency of use of the intervention is limited by the time constraints of emergency practice and ambient conditions that might not be generalizable across emergency settings. The difficulty in gaining permission to deploy the tool and including records before the deployment of the tool resulted in an oversampling of controls. There are no follow-up data presented, so the proportion of patients who were assessed by the clinician using the CDS as having a mimic but truly had cellulitis (ie, the false negative rate) is unknown. One goal of the CDS intervention is to broaden the diagnostic decision maker's differential diagnosis to avoid premature closure on red skin as a single diagnosis of cellulitis, so the study is not a measure of final diagnosis provided by a second observer. Similarly, outcomes data would help determine the proportion of patients admitted with presumed cellulitis who actually have a mimic after the clinician uses the CDS (ie, false positive rate). Understanding the false positive and false negative rates would gauge the risks and benefits of deploying the CDS.

A potential limitation is this study was conducted before the COVID-19 pandemic. There is evidence that the public health measures deployed to combat COVID-19 (handwashing, masking, and closures) changed the case-mix of patients presenting to US hospitals,[11] reducing in the incidence of staphylococcal and streptococcal infections.[12] However, the United States has also seen a rapid increased ED boarding times due to a lack of appropriate beds and staff in the context of a seasonal peak in influenzae, respiratory syncytial virus, and COVID.[13] A tool that could safely reduce admissions would help to alleviate this problem.

The observed incidence of cellulitis (181 patients per month) is less than the expected incidence of 530 patients per month (6350 patients per year). It is unlikely to see such a change in incidence from 1 year to the next. However, cellulitis exhibits strong seasonal variation, with a nadir in the winter months and increasing 57.7%—71% in the summer months.[14,15] This study uses the clinical impression input by the ED physician; it does not account for additional diagnoses an admitted patient may have gained during their hospital stay. There may be a subpopulation of patients with cellulitis that were not captured by our study, which would have had an unknown effect on the outcome.

Clinicians were randomized to receive the CDS alert after they had assigned a diagnosis, which is usually after they have decided to admit or discharge the patient. This is late in the care of ED patients and so

TABLE 1 Descriptive characteristics of the study population, stratified by case status, September 2019–February 2020.

Disposition *N*, %		Controls (*N* = 875)		Cases (*N* = 394)	*p* value
Admit	238	27.2	82	20.8	<0.001
AMA	12	1.4	15	3.8	
Deceased	1	0.1	0	0.0	
Discharge	418	47.8	208	52.8	
Elopement	0	0.0	0	0.0	
Left before completing treatment	0	0.0	0	0.0	
Left without discharge instructions	1	0.1	0	0.0	
Observation	171	19.5	73	18.5	
Send to L&D after rooming	1	0.1	0	0.0	
Transfer	28	3.2	9	2.3	
Unknown	1	0.1	0	0.0	
Antibiotics given, *N*, %	686	78.4	267	67.8	<0.001
Length of stay (hours), mean, 95% CI					
Admitted patients	109.1	95.9 to 122.4	105.8	91.7 to 119.9	0.78
Discharged patients	5.5	5.1 to 5.9	6.6	5.6 to 7.6	0.01
Race *N*, %					
American Indian or Alaskan Native	1	0.1	1.0	0.3	<0.001
Asian	5	0.6	3	0.8	
Black or African American	265	30.3	174	44.2	
Declined to answer	0	0.0	0	0.0	
Other	34	3.9	9	2.3	
Unknown	1	0.1	1	0.3	
White	569	65.0	206	52.3	
Location *N*, %					
University of Maryland Medical Center	181	20.7	183	46.4	0.325
Midtown	156	17.8	112	28.4	
Baltimore Washington	398	45.5	68	17.3	
Saint Joseph's	140	16.0	31	7.9	
Insurance *N*, %					
Blue Shield	84	9.6	19	4.8	<0.001
Commercial	97	11.1	31	7.9	
MA MCO	330	37.7	209	53.0	
Medicaid	43	4.9	22	5.6	
Medicaid pending	3	0.3	1	0.3	
Medicare	228	26.1	73	18.5	
Medicare Replacement	32	3.7	9	2.3	
Military	10	1.1	6	1.5	
Other	1	0.1	1	0.3	
Out-of-state Medicaid	3	0.3	2	0.5	
Self-pay	43	4.9	21	5.3	
Worker's compensation	1	0.1	0	0.0	

Abbreviations: AMA, against medical advice; CI, confidence interval; L&D, labor and delivery; MA MCO, Maryland Managed Care Organization.

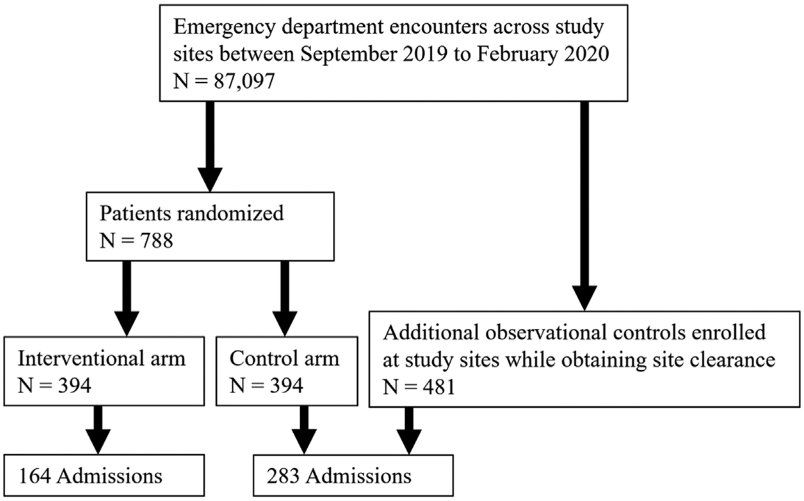

FIGURE 2 Consolidated Standards of Reporting Trials (CONSORT) diagram for study.

TABLE 2 Odds ratios for the effect of clinical decision support tool on patient admission for cellulitis and antibiotic use, September 2019–February 2020, *N* = 1269.

Variable	Unadjusted odds ratio	95% CI	Adjusted odds ratio	95% CI	*p* value*
Admission					
Engagement	0.57	0.37 to 0.88	0.62	0.40 to 0.97	0.04
No CDS Engagement	1.0 (Ref.)	1.0 (Ref.)	1.0 (Ref.)	1.0 (Ref.)	1.0 (Ref.)
Antibiotic Use					
Engagement	0.57	0.37 to 0.88	0.63	0.41 to 0.99	0.04
No CDS Engagement	1.0 (Ref.)	1.0 (Ref.)	1.0 (Ref.)	1.0 (Ref.)	–

Abbreviations: CDS, clinical decision support; CI, confidence interval.
**p* value refers to adjusted odds.

our intervention may have had limited impact. Future work can better define the best time in the patient evaluation to provide differential diagnostic support. Rather than alerting after a diagnosis has been reached, intervening at the time of diagnostic assessment might be more impactful in reducing diagnostic errors. Another investigational opportunity is to study the training effects of the intervention. Once a practitioner learns of the frequent mimics of cellulitis through an EMR intervention, does the individual need constant alerts? Assessing the frequency and volume of EM-provided alerts must be studied in the context of alert fatigue. Lastly, this study examines ED patients, whereas clinicians in other practice environments may see different effects. Hospitalists may see little impact, as consultants in infectious disease and dermatology may be more readily available. Outpatient clinicians in urgent care and other clinics may derive greater benefit given the lack of resources on hand and the increased incidence of cellulitis in the community.

5 | DISCUSSION

The objective of this observational study of ED patients was to determine whether EMR-interoperable diagnostic CDS software could prevent unnecessary hospital admissions by detecting mimics of cellulitis. We showed that use of the CDS was associated with a significant reduction of admissions (13.7% absolute decrease, adjusted OR of 0.62). Our models controlled for patient age, sex, race, and insurance status as a bivariate analysis suggested these were significantly different between subject groups and must be accounted for. these factors also commonly feature in models predicting admissions in ED patients.[16] Our models show that CDS use was associated with significant reductions in both admissions and antibiotic use. These reductions in admissions for cellulitis are consistent with the expected 30% of cases that are admitted for cellulitis unnecessarily, suggesting there is room for further improvement.

Although CDS tools have found a place in support of certain diseases (eg, pulmonary embolism[17] or deep venous thrombosis[18]) or practice environments (intensive care units[19]), there are few studies examining the utility of CDS for skin-presenting diagnoses and in particular cellulitis. There are several studies suggesting that consultation with dermatologists to determine whether or not a patient has cellulitis is cost-effective and reduces admissions and antibiotics use.[3,9,20] Each of these studies relied on dermatologists being immediately available to screen cases, which is not feasible for most health systems. There are a few clinical scoring tools that can help. One cross-sectional study of patients admitted for presumed cellulitis found that age, tachycardia, leukocytosis, and the presence of an asymmetric rash were significant predictors of a discharge diagnosis of cellulitis.[21] Another set of investigators retrospectively examined dermatology case files to derive a predictive rule. They found that the presence of 4 out of the following 7 features were 100% sensitive and 95% specific for cellulitis: New onset, erythema, warmth, history of associated trauma, ache, unilateral, and number of white blood cells (leukocytosis).[22] Unfortunately, these scoring tools have not been validated. Several studies focused on improving the in-hospital care of patients with cellulitis. Investigators at the University of Utah created an inpatient cellulitis care pathway that was integrated into their EMR and contained CDS for antibiotic use. They found that using the pathway decreased the administration of broad-spectrum antibiotics for patients with cellulitis 75%, which was associated with a 13% decrease in length of hospital stay and a 25% decrease in pharmacy costs.[23]

The study builds on and supports prior work showing there is a substantial number of patients presenting to ED with mimics of cellulitis. The study further shows there are ways to significantly reduce unwarranted expenditure of health care resources and prevent iatrogenic injury from unnecessary admissions and adverse drug reactions to avoidable antibiotics. This study does not provide follow-up data on these patients. Future studies should follow patients for longer-term outcomes to determine the accuracy of the diagnosis at the initial ED presentation. Future work should also examine the efficacy of this CDS in other practice environments.

Zach Dezman designed the study, conducted the analysis, and drafted the manuscript. Dan Lemkin created the EPIC-VisualDx interface and collected the data. Art Papier generated the original research objective and provided the VisualDx software. Brian Browne provided supervison. All authors reviewed, revised, and agree to the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The work was funded through a grant by the Coverys Corporation. VisualDx licenses the CDS software to the University of Maryland. Authors ZD, DL, BB do not have any personal financial interests related to the subject matters discussed in this manuscript. The funder had no influence over the results of this study. AP is CEO of VisualDx

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