Identification of Clinical Characteristics Associated With High-Level Care Among Patients With Skin and Soft Tissue Infections

William R. Mower, MD, PhD*; Samantha P. Kadera, MD, MPH; Armando D. Rodriguez, MD, MS; Vera Vanderkraan, DO; Pravin K. Krishna, MPH; Emily Chiu, BS; McKenzie J. Wilson, BS; Malkeet Gupta, MD, MS; Anusha Krishnadasan, PhD; Gregory J. Moran, MD; David A. Talan, MD

*Corresponding Author. E-mail: wmower@ucla.edu.

Study objective: Serious adverse outcomes associated with skin and soft tissue infections are uncommon, and current hospitalization rates appear excessive. It would be advantageous to be able to differentiate between patients who require high-level inpatient services and those who receive little benefit from hospitalization. We sought to identify characteristics associated with the need for high-level inpatient care among emergency department patients presenting with skin and soft tissue infections.

Methods: We conducted a nonconcurrent review of existing records to identify emergency department (ED) patients treated for skin and soft tissue infections. For each case, we recorded the presence or absence of select criteria and whether the patient needed high-level care, defined as ICU admission, operating room surgical intervention, or death as the primary outcome. We applied recursive partitioning to identify the principal criteria associated with high-level care.

Results: We identified 2,923 patients, including 84 experiencing high-level events. Recursive partitioning identified 6 variables associated with high-level outcomes: abnormal computed tomography, magnetic resonance imaging, or ultrasonographic imaging result; systemic inflammatory response syndrome; history of diabetes; previous infection at the same location; older than 65 years; and an infection involving the hand. One or more of these variables were present in all 84 patients requiring high-level care.

Conclusion: A limited number of simple clinical characteristics appear to be able to identify skin and soft tissue infection patients who require high-level inpatient services. Further research is needed to determine whether patients who do not exhibit these criteria can be safely discharged from the ED. [Ann Emerg Med. 2019;73:366-374.]

Please see page 367 for the Editor's Capsule Summary of this article.

Readers: click on the link to go directly to a survey in which you can provide **feedback** to *Annals* on this particular article.
A **podcast** for this article is available at www.annemergmed.com.
Continuing Medical Education exam for this article is available at http://www.acep.org/ACEPeCME/.

0196-0644/$-see front matter

https://doi.org/10.1016/j.annemergmed.2018.09.020

INTRODUCTION

Background

Emergency department (ED) visits for skin and soft tissue infections increased 200% between 1993 and 2005.[1,2] It has been estimated that 870,000 patients are hospitalized annually for treatment of skin and soft tissue infection in the United States, at a cost of $4.84 billion.[3,4] Serious adverse outcomes are rare, and mortality is extremely low, less than 5% among hospitalized patients.[5,6] Although the increase in admission rates for skin and soft tissue infections may be related to the emergence of presumably more virulent and transmissible community-associated methicillin-resistant *Staphylococcus aureus*, the low overall associated mortality suggests that the current hospitalization rates are excessive.[5] Furthermore, the observed variability in rates of hospital admission from the ED indicates admission practices are somewhat arbitrary and that hospitalization may be overused at many centers.[7]

With an average length of stay for skin and soft tissue infection admissions of 4 to 5 days costing $8,000 per stay, even a 10% reduction in the more than 870,000 skin and soft tissue infection patients admitted each year could result in annual savings exceeding $696 million.[6,8,9]

Importance

Low mortality and high costs provide strong incentives for developing reliable risk-stratification systems that reduce skin and soft tissue infection hospitalizations. Although guidelines have been developed for this indication, they are based on literature review and expert

Editor's Capsule Summary

What is already known on this topic

Patients with skin and soft tissue infection do not frequently require advanced care.

What question this study addressed

What are the features of emergency department patients with these infections that are associated with death, surgical intervention, or ICU care?

What this study adds to our knowledge

In analysis of 2,923 patient records from 3 California hospitals, patients with abnormal imaging results, evidence of a systemic inflammatory response, a history of diabetes, or previous infection at the same site; those who were older than 65 years; and those who had hand involvement were at higher risk for the composite outcome.

How this is relevant to clinical practice

These data reinforce common-sense views and may aid development of risk-stratifying tools for these patients.

opinion and have not been shown to reduce unnecessary admissions.[5,10-15] Substantial benefit could be realized by a rigorous assessment of criteria that could be used to distinguish between patients who are likely to benefit from hospitalization and those who would be best served by outpatient care.

Hospital admission is critical for patients who require high-level inpatient services such as ICU or surgical care. Patients who require these services can only receive adequate care through inpatient admission. The value of other inpatient care is less clear. For example, administration of intravenous antibiotics is frequently used to justify admission,[16] but intravenous antibiotics have yet to be shown to lead to better outcomes among otherwise stable and medication-adherent patients being treated for skin and soft tissue infection. Additionally, there are more convenient and less costly means for administering intravenous drugs in the outpatient setting compared with hospitalization.[17-19]

Work by Talan et al[16] on US ED admission practices among 619 ED patients presenting to 11 EDs with skin and soft tissue infection revealed that only 3 of 94 hospitalized patients (3.2%) received ICU care and no patients died. Clinicians were able to reliably identify the need for surgical intervention, which occurred for 20 of the 94 admitted patients (21.3%). The need for intravenous antibiotics was the most frequent reason clinicians cited for admission (for 80 of 94 patients [85.1%]) and was the only reason for admission for approximately 40% of patients. Failure of oral antibiotics and inability to tolerate oral antibiotics were rarely indicated as a reason for hospitalization.

A rigorous assessment of patient characteristics could provide valuable information to discriminate need for admission and ensure that patients who are likely to require high-level services are identified for admission while sparing admission for many patients who do not require such care.

Goals of This Investigation

The purpose of this study was to examine the ED presentations of patients with skin and soft tissue infections and identify characteristics that most clearly distinguish between patients who experienced death or required high-level care and those who did not require high-level services. We hypothesized that patients who require hospitalization, as reflected by need for ICU or surgical care, can be reliably distinguished by a limited number of clinical criteria that are evident in the ED. Identification of these criteria may enable clinicians to better assess need for admission and identify patients who do not require high-level inpatient care, and who might be best served by outpatient therapy, thus offering the potential to substantially reduce the overall number of inpatient admissions. Confirmation of our hypothesis would support further efforts to develop decision tools to guide admissions for patients with skin and soft tissue infections.

MATERIALS AND METHODS

Study Design and Setting

We conducted a nonconcurrent electronic medical record review at 3 centers: Ronald Reagan UCLA Medical Center in Los Angeles, CA; Olive View–UCLA Medical Center in Sylmar, CA; and Antelope Valley Hospital in Lancaster, CA. These centers include urban, suburban, and rural population centers, as well as public and private institutions, and teaching and nonteaching environments. The study was reviewed and approved with a waiver of consent by the institutional review boards at each center.

Selection of Participants

At each site, we identified a minimum of 1,000 consecutive eligible cases, using ED disposition *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes for cellulitis, abscess, and wound infections (list *ICD-9* codes) between March 2013 and July 2014. Cases identified through our electronic medical record search were then reviewed to assess eligibility. Cases were

excluded if patients were younger than 18 years or had known or suspected necrotizing fasciitis, diabetic foot infection, perirectal infection, genitourinary tract infection, septic arthritis, osteomyelitis, infection of a prosthetic device, decubitus or ischemic ulcers, infection from an animal bite, or burns. We applied formal methods to our abstraction process and identification of our high-risk clinical criteria.[20] Trained abstractors, who were blinded to the study objective, recorded demographic characteristics, presence or absence of candidate predictor criteria, and ultimate outcomes, using a standardized abstraction form developed and tested by study investigators (Appendixes E1 and E2, available online at http://www.annemergmed.com). Performance of abstractors was monitored throughout the data abstraction process by random chart review and quantified by κ statistics for the assessments of each of the dichotomous criteria and outcome measures, and by assessments of bias, variability, and Pearson's correlation coefficient for each of the continuous criteria (Appendix E3, available online at http://www.annemergmed.com).

On patient enrollment, we assigned each case a unique study number and recorded the corresponding medical record number in a password-protected linkage file. At review, abstractors accessed the linkage file to obtain the case medical record and study numbers. Characteristics obtained from each record review were recorded in the main study database. We assessed and recorded patient outcomes with a separate review, with raters blinded to the criteria evaluations, to eliminate the potential for review bias.

Methods of Measurement

For each case, we recorded the following demographic information: age in years, sex (male or female), race (white, black, American Indian or Alaska Native, Asian, and Native Hawaiian or other Pacific Islander), and ethnicity (Hispanic/Latino or not Hispanic/Latino). We also recorded the presence or absence of the following specific comorbidities from the case history: diabetes, HIV or AIDS, chronic kidney disease, coronary artery disease or myocardial infarction, peripheral vascular disease, immunocompromised state (ie, any transplant, chemotherapy, or immunosuppressant, including corticosteroids, within the last 3 months), and other comorbidity. We recorded whether the patient had documented use of antibiotics within 4 weeks of the index visit, and the antibiotic, if listed.

We abstracted ED vital signs from the nursing flow sheet and recorded the highest temperature (degrees Celsius), highest pulse rate (beats/minute), lowest systolic blood pressure (mm Hg), highest respiratory rate (breaths/minute) and lowest pulse oximetry percentage during the ED stay. We also recorded the following laboratory values if ordered by the physicians during the first 24 hours after ED arrival: WBC count ($\times 10^3$/microliter), hemoglobin (grams/deciliter), sodium (millimoles/liter), bicarbonate/carbon dioxide (millimoles/liter), glucose (milligrams/deciliter), creatinine (milligrams/deciliter), lactate (millimoles/liter), and c-reactive protein (milligrams/liter). In instances of repeated testing, we recorded results from initial testing. We also recorded whether each patient exhibited evidence of systemic inflammatory response syndrome (SIRS).[21]

We classified skin and soft tissue infection locations into the following categories: head or neck; torso; groin, perineum, or buttocks; upper extremity (excluding hand); hand; and lower extremity. If an infection crossed body areas, we recorded the primary site of infection.

We considered cases to be positive for injection drug use or incarceration if either was documented in the electronic medical record at any time (current or former). If we were unable to find documentation on these criteria in the electronic medical record, we recorded the criterion to be "no/not documented." Suspected or known homelessness was recorded as positive based on current visit physician charting and verified with the registration address. If housing was not documented in the record, we entered "no/not documented" into our database. Skin and soft tissue infection size was recorded according to documentation in the ED provider chart verbatim as numbers, text, or reference to a diagram. If no mention of the size of the skin and soft tissue infection was made, "no size description" was recorded. We used *ICD-9* codes in the ED clinical impression to categorize skin and soft tissue infection as cellulitis, abscess, or wound infection. We recorded all documented skin and soft tissue infection diagnoses. We assigned positive status to "previous skin and soft tissue infection" at the same or different locations if such events were recorded and "no/not documented" if documented as negative or not recorded. Because medical records rarely provide specific documentation of the absence of our individual candidate criterion, we considered "not documented" to be equivalent to "no" (absence) for these criteria and did not quantify the number of actual negative responses.

We reviewed the interpretations of all imaging tests, including radiographs, computed tomography (CT) scans, magnetic resonance imaging (MRI) scans, formal ultrasonography, and bedside ultrasonography performed on the location of the skin and soft tissue infection during

the visit. The radiology departments performed and read formal ultrasonography. We recorded imaging test results as abnormal if the impression of the radiology or ED provider (bedside ultrasonography only) mentioned the presence of any of the following: air or gas, abscess or fluid collection, osteomyelitis, or suspicion of osteomyelitis. We designated imaging results as normal if none of these terms were used in the impression. All abnormal radiology test results received secondary review by the abstractors to confirm findings and proper categorization.

Outcome Measures

In the second part of our abstraction process, a different abstractor collected outcome information. We recorded disposition as admitted to the hospital, discharged from the ED, transferred to another hospital, left against medical advice, eloped and left without being seen. We categorized patients who were transferred to another hospital or left against medical advice as admissions, whereas we treated patients who eloped or left without being seen as neither admitted nor discharged and excluded these cases from our final database. We designated patients as receiving ICU level of care if they had a documented note from an ICU team at any point in the hospital stay. We designated patients as requiring a surgical procedure if their records contained a documented operative note by a surgeon at any point during the hospital stay. We recorded procedures performed at the bedside as distinct from those performed in the operating room. We classified deaths according to documentation of pronouncement during the hospitalization for the incident skin and soft tissue infection. We made note of any ambiguous or missing information, which was referred to the study investigators to resolve on a case-by-case basis. We designated the need for high-level care as our primary clinical outcome, defined as ICU admission, surgery in the operating room, or death, and, based on our review, assigned an outcome status for each patient.

Primary Data Analysis

We reviewed our assembled cases and deleted those meeting our predefined exclusion criteria. We then applied χ^2 binary recursive partitioning to the remaining cases to identify patient characteristics that best predicted our primary outcome. We designated a priori that the recursive partitioning would terminate under the following conditions: one or more of the characteristics identified at any stage were present in all patients requiring high-level care, the partitioning process exhausted all criteria while failing to identify all patients requiring high-level care, or the partitioning process assigned high-risk status to all patients and failed to identify a low-risk cohort. Our ultimate results consist of the variables identified by the recursive partitioning. Our secondary outcomes include the univariate associations observed in the first step of the partitioning process, along with the corresponding positive and negative likelihood ratios. In conducting our recursive partitioning, we treated missing variables as being absent to ensure that our results would be based on observed characteristics as much as possible and not on missing data.

We used our entire cohort of skin and soft tissue infection patients in conducting recursive partitioning, including those discharged from the ED. This reflected our desire to better examine the differences between patients who require high-level care and those who do not.

Our study adheres to the Strengthening the Reporting of Observational Studies in Epidemiology checklist for observational studies (http://www.strobe-statement.org).

RESULTS

Characteristics of Study Subjects

We reviewed 3,226 cases presenting to one of 3 centers. After removing 303 ineligible cases, we were left with 2,923 skin and soft tissue infection cases for analysis. Overall, 652 patients were admitted to the hospital from the ED, with 84 of these patients (2.9% of all skin and soft tissue infection patients and 12.9% of admitted patients) requiring high-level care, including 6 who died (overall mortality 0.2%), 16 who required ICU-level care (0.5%), and 68 who required surgery in the operating room (2.3%). Table 1 presents demographic and clinical characteristics of patients who required high-level care in comparison with those who did not, as well as among the admitted and discharged patients.

Main Results

Table 2 presents univariate associations between individual clinical variables and need for high-level inpatient care. An abnormal imaging result was present for 38 of 84 patients (45.2%) receiving high-level care and 46 of 2,632 patients (1.7%) not needing high-level care, making it the strongest discriminator (positive likelihood ratio 6.20 [95% confidence interval 4.74 to 8.12]; negative likelihood ratio 0.59 [95% confidence interval 0.49 to 0.72]). SIRS, documented in 46 patients requiring high-level care (54.8%), was the most prevalent variable associated with high-level care.

Recursive partitioning identified 6 variables associated with need for high-level care: abnormal CT, MRI, or

Table 1. Demographic and clinical characteristics of patients hospitalized for skin and soft tissue infections (SSTIs).

Characteristic	Patients With High-Level Outcomes* (n=84) (%)	Patients Without High-Level Outcomes* (n=2,839) (%)	Patients Admitted (n=652) (%)	Patients Discharged (n=2,271) (%)
Median age (IQR, range), y	51 (43–62, 21–85)	45 (32–57, 18–89)	53 (42–64, 19–89)	42 (30–51, 18–88)
Male sex, No. (%)	48 (57.1)	1,560 (54.9)	371 (56.9)	1,237 (54.5)
Race, No. (%)				
White	53 (63.1)	2,018 (71.1)	479 (73.5)	1,592 (70.1)
Black	13 (15.5)	390 (13.7)	69 (10.6)	334 (14.7)
Asian	3 (3.6)	68 (2.4)	20 (3.1)	51 (2.2)
Hawaiian/Pacific Islander	1 (1.2)	9 (0.3)	1 (0.2)	9 (0.4)
American Indian/Alaskan Native	0	9 (0.3)	2 (0.3)	7 (0.3)
Other	14 (16.7)	345 (12.2)	81 (12.4)	278 (12.2)
Hispanic ethnicity, No. (%)	21 (25.0)	650 (22.9)	136 (20.9)	535 (23.6)
>65 y	17 (20.2)	336 (11.8)	148 (22.7)	205 (9.0)
Diabetes	34 (40.5)	528 (18.6)	185 (28.4)	377 (16.6)
HIV/AIDS	1 (1.2)	31 (1.1)	8 (1.2)	24 (1.1)
Chronic kidney disease	10 (11.9)	92 (3.2)	50 (7.7)	52 (2.3)
Congestive heart disease	6 (7.1)	118 (4.2)	53 (8.1)	71 (3.1)
Peripheral vascular disease	5 (6.0)	55 (1.9)	30 (4.6)	30 (1.3)
Injection drug use	5 (6.0)	132 (4.6)	36 (5.5)	101 (4.4)
Prison	0	66 (2.3)	7 (1.1)	59 (2.6)
Homeless	3 (3.6)	84 (3.0)	25 (3.8)	62 (2.7)
Previous SSTI, same site	32 (37.6)	811 (28.6)	220 (33.7)	623 (27.4)
Previous SSTI, different site	13 (15.3)	322 (11.3)	72 (11.0)	263 (11.6)
Previous antibiotics	32 (38.1)	740 (26.1)	236 (36.2)	536 (23.6)
Immunocompromised†	7 (8.3)	150 (5.3)	75 (11.5)	82 (3.6)
Cellulitis	45 (53.6)	1,899 (66.9)	521 (79.9)	1,423 (62.7)
Abscess	35 (41.7)	1,126 (39.7)	204 (31.3)	957 (42.1)
Abnormal imaging result‡	38 (45.2)	207 (7.3)	135 (20.7)	110 (4.8)
SIRS§	46 (54.8)	347 (12.2)	243 (37.3)	150 (6.6)
Location				
Hand	5 (6.0)	228 (8.0)	51 (7.8)	182 (8.0)
Upper extremity	5 (6.0)	317 (11.2)	69 (10.6)	253 (11.1)
Torso	25 (29.8)	423 (14.9)	93 (14.3)	355 (15.6)
Lower extremity	35 (41.7)	1,186 (41.8)	333 (51.1)	888 (39.1)
Head/neck	8 (9.5)	365 (12.9)	63 (9.7)	310 (13.7)
Groin	6 (7.1)	320 (11.3)	43 (6.6)	283 (12.5)

IQR, Interquartile range.

*High-level outcome was defined as ICU admission, surgical intervention, or death.

†Immunocompromised was defined as any transplant, chemotherapy, or immunosuppressant, including corticosteroids, within the last 3 months.

‡Abnormal imaging results, including for radiographs, CT scans, MRI scans, and formal and bedside ultrasonography.

§SIRS was defined as the presence of at least 2 of the following criteria: temperature greater than 38°C (100.4°F) or less than 36°C (96.8°F), pulse rate greater than 90 beats/min, respiratory rate greater than 20 breaths/min or $PaCO_2$ less than 32 mm Hg, and WBC count greater than 12,000/mm^3 or less than 4,000/mm^3, or greater than 10% bands.

ultrasonographic imaging result; SIRS; history of diabetes; previous skin and soft tissue infection at the same location; older than 65 years; and an infection involving the hand. Abnormal imaging result exhibited the strongest association with high-level care (χ^2=153.0; P<.001). After exclusion of the 245 patients with abnormal imaging results, our partitioning process identified SIRS as the strongest discriminator among the remaining 2,365 patients (χ^2=66.6; P<.001]), making it the second strongest discriminator overall (Figure).

Our partitioning process terminated after finding 1 or more of these 6 variables in all patients requiring high-level care.

Table 2. Univariate associations of individual clinical criteria and need for high-level inpatient care.

Characteristic	Criterion Positive and High-Level Outcome*	Criterion Positive and Without High-Level Outcome*	Criterion Negative and High-Level Outcome*	Criterion Negative and Without High-Level Outcome*	Positive Likelihood Ratio (95% Confidence Interval)	Negative Likelihood Ratio (95% Confidence Interval)	χ^2 (*P* Value)
>65 y	16	314	68	2,525	1.72 (1.09–2.71)	0.91 (0.82–1.01)	5.20 (.02)
Diabetes	34	528	50	2,311	2.18 (1.66–2.85)	0.73 (0.61–0.87)	25.1 (<.001)
HIV/AIDS	1	31	83	2,808	1.09 (0.15–7.89)	1.00 (0.98–1.02)	0.007 (.93)
Chronic kidney disease	10	92	74	2,747	3.67 (1.99–6.80)	0.91 (0.84–0.99)	18.2 (<.001)
Congestive heart disease	6	118	78	2,721	1.72 (0.78–3.79)	0.97 (0.91–1.03)	1.79 (.18)
Peripheral vascular disease	5	55	79	2,784	3.07 (1.26–7.48)	0.96 (0.91–1.01)	6.54 (.01)
Injection drug use	5	132	79	2,707	1.28 (0.54–3.04)	0.99 (0.93–1.04)	0.31 (.58)
Prison	0	66	84	2,773	0.0	1.02 (1.02–1.03)	1.99 (.16)
Homeless	3	84	81	2,755	1.21 (0.39–3.74)	0.99 (0.95–1.04)	0.11 (.74)
Previous SSTI, same site	32	811	52	2,028	1.33 (1.01–1.76)	0.87 (0.73–1.03)	3.61 (.06)
Previous SSTI, different site	13	322	71	2,517	1.36 (0.82–2.27)	0.95 (0.87–1.05)	1.37 (.24)
Previous antibiotics	32	740	52	2,099	1.46 (1.11–1.93)	0.84 (0.71–0.99)	6.07 (.01)
Immunocompromised†	7	150	77	2,689	1.58 (0.76–3.26)	0.97 (0.91–1.03)	1.49 (.22)
Cellulitis	45	1,899	39	940	0.80 (0.66–0.98)	1.40 (1.11–1.77)	6.50 (.01)
Abscess	35	1,126	49	1,713	1.05 (0.81–1.36)	0.97 (0.80–1.16)	0.14 (.71)
Abnormal imaging‡	38	207	46	2,632	6.20 (4.74–8.12)	0.59 (0.49–0.72)	153.0 (<.001)
SIRS§	46	347	38	2,492	4.48 (3.60–5.57)	0.52 (0.41–0.65)	126.9 (<.001)
Hand	5	228	79	2,611	0.74 (0.31–1.75)	1.02 (0.97–1.08)	0.48 (.49)
Upper extremity	5	317	79	2,522	0.53 (0.23–1.26)	1.06 (1.00–1.12)	2.26 (.13)
Torso	25	423	59	2,416	2.00 (1.42–2.81)	0.83 (0.72–0.95)	13.9 (<.001)
Lower extremity	36	1,187	48	1,652	1.03 (0.80–1.32)	0.98 (0.81–1.18)	0.04 (.84)
Head/neck	8	365	76	2,474	0.74 (0.38–1.44)	1.04 (0.97–1.11)	0.81 (.37)
Groin	6	320	78	2,519	0.63 (0.29–1.38)	1.05 (0.98–1.11)	1.40 (.24)

*High-level outcome was defined as ICU admission, surgical intervention, or death.
†Immunocompromised was defined as any transplant, chemotherapy, or immunosuppressant, including corticosteroids, within the last 3 months.
‡Abnormal imaging result included for radiographs, CT scans, MRI scans, and formal and bedside ultrasonography.
§SIRS was defined as presence of at least 2 of the following criteria: temperature greater than 38°C (100.4°F) or less than 36°C (96.8°F), pulse rate greater than 90 beats/min, respiratory rate greater than 20 breaths/min or $PaCO_2$ less than 32 mm Hg, WBC count greater than 12,000/mm^3 or less than 4,000/mm^3, or greater than 10% bands.

LIMITATIONS

There are a few noteworthy limitations to our research. As with all nonconcurrent medical record reviews, our data collection relied on existing documentation that was not specifically collected or recorded for this study or its variables. It is impossible to determine whether missing data were absent because the associated findings were truly absent or whether the findings were present and either not assessed or not recorded.

Because we based our partitioning on actual observed and recorded events, our study likely underestimates the true prevalence of the individual variables. It is impossible to determine the direction of bias associated with this limitation because underestimation could occur among patients requiring high-level care, as well as those not requiring it.

We may have missed skin and soft tissue infection cases because of *ICD-9* coding errors. Missed cases may differ fundamentally from those we identified, making it impossible to estimate the potential bias that would arise from this problem.

We conducted the study at 3 separate centers, and it is possible that the patients and practice patterns at these centers differ from those at other centers. This could have an effect on the severity of illness among our identified patients and on their need for high-level services, as well as the prevalence of individual criteria, decisions on use of high-level services, and ultimate outcomes. We could have also used more objective measures in defining the need for ICU, such as the use of vasopressors or mechanical ventilation, but this approach ignores the fact that patients who are merely observed in an ICU setting are likely to be

Figure. Flow diagram for recursive partitioning results.

poor candidates for discharge to home, where they would receive no additional care or observation.

Because of the extraordinary difficulty of obtaining detailed follow-up on each of the 2,271 discharged patients, it is possible that some discharged patients eventually required high-level care that was not identified in our review. Although this is a theoretical concern, its actual implications to our study are relatively minor. This stems from the fact that only 3% of all skin and soft tissue infection patients require high-level care, so the baseline potential for missed events is already very low and is likely to be substantially lower among discharged patients. Existing evidence indicates that the sensitivity of clinical judgment approaches 99% in identifying patients who require high-level care,[16] which, when combined with the low prevalence of patients needing high-level care, makes it exceedingly unlikely that a significant number of missed cases existed, particularly a number sufficient to significantly alter the strong associations observed on our recursive partitioning.

DISCUSSION

One of the key impediments in developing a rational skin and soft tissue infection admission strategy is our limited understanding of when hospitalization is beneficial. For example, the recent increase in brief hospital admissions solely for intravenous antibiotic therapy likely reflects a heightened awareness of drug-resistant skin and soft tissue infections, along with the absence of clear admission guidelines.[1,2] However, there is little evidence that the increased admission rates improve outcomes, particularly with the availability of various means to administer parenteral antibiotics to outpatients, including outpatient parenteral antibiotic treatment, and extended-duration antibiotics such as dalbavancin and oritavancin, which have been associated with cure rates similar to those of intravenous vancomycin.[17-19] Furthermore, the mortality rate associated with skin and soft tissue infection is very low, even among hospitalized populations. Very few patients require high-level hospital services such as ICU

care or inpatient surgical procedures.[16] Our findings are consistent with these observations. We found a 2.9% rate of overall high-level care, including very low rates of mortality (0.2%) and ICU care (0.5%). We found that operative intervention was the most prevalent high-level service provided, which occurred in only 2.3% of all cases.

Hospitalization is likely to be beneficial for patients requiring high-level services or those needing specific treatment of concurrent medical problems. Conversely, hospitalization is likely to be of little benefit for patients having mild systemic responses or those who merely receive parenteral antibiotic therapy. What is less clear, and what our research does not address, is the unquantifiable benefit from observation and other supportive care that is inherent with hospitalization. For example, inpatients are likely to have superior medication adherence, hydration, supportive care, limb elevation, and fever control than those discharged home. However, hospitalization may not be the most cost-effective way to provide this supportive care.

With these caveats in mind, it appears that a limited number of clinical criteria can reliably identify patients who require high-level inpatient services, specifically, abnormal CT, MRI, or ultrasound imaging results; SIRS; diabetes; previous infection at the same location; older than 65 years; and an infection involving the hand. However, the practical implication of this finding is likely to be counterintuitive. In particular, these criteria are not well suited for determining which patients need inpatient admission or high-level inpatient care. This stems from the fact that although high-risk variables were found in all 84 patients receiving high-level care, close inspection of Figure reveals that these variables were also found in 1,671 patients who did not require high-level care. A policy of admitting patients who exhibit one or more of these high-risk variables would be counterproductive and lead to a substantial increase in hospital admission rates among patients with skin and soft tissue infections. Also, our findings should not be interpreted to support advanced imaging for all skin and soft tissue infection patients. Physicians should continue using their current approaches in making imaging decisions and realize the important role that imaging results may play in guiding treatment options, including hospitalization, among a select minority of patients.

The true value of these variables lies in their potential to identify patients who are unlikely to require high-level services and, all other things being equal, receive substantially less benefit from inpatient admission. From this perspective, our high-risk variables provide insight into which patients might be suitable for discharge, rather than identifying those who need admission.

Finally, in regard to the differences between the univariate associations that appear in Table 2 and our final discriminating variables, several variables, such as chronic kidney disease, peripheral vascular disease, and previous antibiotic use, demonstrate discriminating capabilities on univariate analysis but do not appear as important discriminators under the recursive partitioning. This is a reflection of the efficiency of the recursive process in dealing with correlated variables. In essence, our recursive process yields an embedded principle component analysis that reduces the predictor variables to those that are most unique and discriminating.

In conclusion, our study demonstrates that it is possible, with a limited number of clinical criteria, to identify skin and soft tissue infection patients who require high-level inpatient services. Further research is needed to determine whether patients who do not exhibit these criteria can be safely discharged from the ED.

Supervising editor: Donald M. Yealy, MD. Specific detailed information about possible conflict of interest for individual editors is available at https://www.annemergmed.com/editors.

Author affiliations: From the UCLA Department of Emergency Medicine, Ronald Reagan UCLA Medical Center, Los Angeles, CA (Mower, Kadera, Rodriguez, Vanderkraan, Krishna, Chiu, Wilson, Gupta); the Department of Emergency Medicine and Department of Medicine, Division of Infectious Diseases, Olive View–UCLA Medical Center, Sylmar, CA (Talan, Krishnadasan, Moran); Antelope Valley Hospital Emergency Department, Lancaster, CA (Krishna, Gupta); and the Desert Regional Medical Center Emergency Department, Palm Springs, CA (Vanderkraan).

Author contributions: WRM and SPK conceived the study. WRM, SPK, DAT, MG, AK, and GJM supervised the study design and definition of study measures. WRM, SPK, ADR, PKK, EC, MJW, and AK performed the processing and analysis of data. All authors contributed to the interpretation of the findings and writing of the article. SPK had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. WRM takes responsibility for the paper as a whole.

All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Publication dates: Received for publication November 27, 2017. Revisions received December 9, 2017; March 15, 2018; June 18, 2018, and August 31, 2018. Accepted for publication September 18, 2018.

REFERENCES

1. Pallin DJ, Egan DJ, Pelletier AJ, et al. Increased US emergency department visits for skin and soft tissue infections, and changes in antibiotic choices, during the emergence of community-associated methicillin-resistant *Staphylococcus aureus*. *Ann Emerg Med*. 2008;51:291-298.
2. Qualls ML, Mooney MM, Camargo CA Jr, et al. Emergency department visit rates for abscess versus other skin infections during the emergence of community-associated methicillin-resistant *Staphylococcus aureus*, 1997-2007. *Clin Infect Dis*. 2012;55:103-105.
3. Revankar N, Ward AJ, Pelligra CG, et al. Modeling economic implications of alternative treatment strategies for acute bacterial skin and skin structure infections. *J Med Econ*. 2014;17:730-740.
4. Suaya JA, Mera RM, Cassidy A, et al. Incidence and cost of hospitalizations associated with *Staphylococcus aureus* skin and soft tissue infections in the United States from 2001 through 2009. *BMC Infect Dis*. 2014;14:296.
5. Marwick C, Broomhall J, McCowan C, et al. Severity assessment of skin and soft tissue infections: cohort study of management and outcomes for hospitalized patients. *J Antimicrob Chemother*. 2011;66:387-397.
6. Edelsberg J, Taneja C, Zervos M, et al. Trends in US hospital admissions for skin and soft tissue infections. *Emerg Infect Dis*. 2009;15:1516-1518.
7. Sabbatini AK, Nallamothu BK, Kocher KE. Reducing variation in hospital admissions from the emergency department for low-mortality conditions may produce savings. *Health Aff (Millwood)*. 2014;33:1655-1663.
8. King MD, Humphrey BJ, Wang YF, et al. Emergence of community-acquired methicillin resistant *Staphylococcus aureus* USA 300 clone as the predominant cause of skin and soft-tissue infections. *Ann Intern Med*. 2006;144:309-317.
9. Zervos MJ, Freeman K, Vo L, et al. Epidemiology and outcomes of complicated skin and soft tissue infections in hospitalized patients. *J Clin Microbiol*. 2012;50:238-245.
10. CREST (Clinical Resource Efficiency Support Team). CREST (Clinical Resource Efficiency Support Team) guidelines on the management of cellulitis in adults. 2005. Available at: http://www.acutemed.co.uk/docs/Cellulitis%20guidelines,%20CREST,%2005.pdfs. Accessed November 2, 2018.
11. Eron LJ, Lipsky BA, Low DE, et al. Expert Panel on Managing Skin and Soft Tissue Infections. Managing skin and soft tissue infections: expert panel recommendations on key decision points. *J Antimicrob Chemother*. 2003;52(Suppl S1):i3-i17.
12. Ki V, Rotstein C. Bacterial skin and soft tissue infections in adults: a review of their epidemiology, pathogenesis, diagnosis, treatment and site of care. *Can J Infect Dis Med Microbiol*. 2008;19:173-184.
13. Marwick C, Rae N, Irvine N, et al. Prospective study of severity assessment and management of acute medical admissions with skin and soft tissue infection. *J Antimicrob Chemother*. 2012;67:1016-1019.
14. Stevens DL, Bisno AL, Chambers HF, et al. Practice guidelines for the diagnosis and management of skin and soft tissue infections: 2014 update by the Infectious Diseases Society of America. *Clin Infect Dis*. 2014;59:e10.
15. Wilson SE, Solomkin JS, Le V, et al. A severity score for complicated skin and soft tissue infections derived from phase III studies of linezolid. *Am J Surg*. 2003;185:369-375.
16. Talan DA, Salhi BA, Moran GJ, et al. Factors associated with decision to hospitalize emergency department patients with a skin and soft tissue infection. *West J Emerg Med*. 2015;16:89-97.
17. Nguyen HH. Hospitalist to home: outpatient parenteral antimicrobial therapy at an academic center. *Clin Infect Dis*. 2010;51(Suppl 2):S220-S223.
18. Boucher HW, Wilcox MD, Talbot GH, et al. Once-weekly dalbavancin versus daily conventional therapy for skin infection. *N Engl J Med*. 2014;370:2169-2179.
19. Corey GR, Kabler H, Mehra P, et al; SOLO I Investigators. Single-dose oritavancin in the treatment of acute bacterial skin infections. *N Engl J Med*. 2014;370:2180-2190.
20. Kaji AH, Schriger D, Green S. Looking through the retrospectoscope: reducing bias in emergency medicine chart review studies. *Ann Emerg Med*. 2014;64:292-298.
21. Bone RC, Balk RA, Cerra FB, et al. Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. The ACCP/SCCM Consensus Conference Committee. American College of Chest Physicians/Society of Critical Care Medicine. *Chest*. 1992;101:1644-1655.