Examining the Concordance in the Documented Pressure Injury Site, Stage, and Count in Medical Information Mart for Intensive Care-III

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Appl Clin Inform 2021;12:897–909.

Abstract

Objectives This study aimed to compare the concordance of pressure injury (PI) site, stage, and count documented in electronic health records (EHRs); explore if PI count during each patient hospitalization is consistent based on PI site or stage count in the diagnosis or chart event records; and examine if discrepancies in PI count were associated with patient characteristics.

Methods Hospitalization records with the International Classification of Diseases ninth edition (ICD-9) codes, chart events from two systems (CareVue, MetaVision), and clinical notes on PI were extracted from the Medical Information Mart for Intensive Care (MIMIC)-III database. PI site and stage counts from individual hospitalization were computed. Hospitalizations with the same or different counts of site and stage according to ICD-9 codes (site and stage), CareVue (site and stage), or MetaVision (stage) charts were defined as consistent or discrepant reporting. Chi-squared, independent *t*-, and Kruskal–Wallis tests were examined if the count discrepancy was associated with patient characteristics. ICD-9 codes and charts were also compared for people with one site or stage.

Results A total of 31,918 hospitalizations had PI data. Within hospitalizations with ICD-9-coded sites and stages, 55.9% reported different counts. Within hospitalizations with CareVue charts on PI, 99.3% reported the same count. For hospitalizations with stages based on ICD-9 codes or MetaVision chart data, only 42.9% reported the same count. Discrepancies in counts were consistently and significantly associated with variables including PI recording in clinical notes, dead/hospice at discharge, more caregivers, longer hospitalization or intensive care unit stays, and more days to first transfer. Discrepancies between ICD-9 code and chart values on the site and stage were also reported.

Conclusion Patient characteristics associated with PI count discrepancies identified patients at risk of having discrepant PI counts or worse outcomes. PI documentation quality could be improved with better communication, care continuity, and integrity. Clinical research using EHRs should adopt systematic data quality analysis to inform limitations.

Keywords
- clinical data management
- pressure injury
- documentation concordance

received
March 7, 2021
accepted after revision
July 20, 2021

Georg Thieme Verlag KG,
Rüdigerstraße 14,
70469 Stuttgart, Germany

DOI https://doi.org/10.1055/s-0041-1735179.
ISSN 1869-0327.

Background and Significance

Pressure injury (PI), which replaced the "pressure ulcer" terminology in 2016, is defined as a localized injury to the skin or underlying tissue due to pressure with or without shear.[1,2] The skin or underlying tissue affected is usually located over a bony prominence and may be related to the placement of a device.[1,2] Based on the severity and level of tissue injury, PI is usually classified from stages I to IV, while some could be deep tissue injuries or unstageable.[1,2] Over 2.5 million Americans develop PI each year.[3] A retrospective study with the U.S. Nationwide Inpatient Sample data from 2009 to 2012 found that the 5-year average number of admitted patients with at least one PI diagnosis was 670,767 (average overall rate: 1.8%).[4] The prevalence differed by patient demographics, risk factors, injury count, site, stage, and debridement.[4] The most affected PI site was lower back/sacral/coccygeal (47%), and the most frequently occurred stages were stages II (38%) and III (20%).[4] Patients with PI diagnoses have significantly longer lengths of stay, higher total hospital charges, and higher mortality rates than those without PI.[4]

As a key indicator of patient safety and health care quality,[3,5] PI prevention and management in hospitals require integrative care from each unit and member of the wound care team.[3] Nurses play the leading roles and responsibilities in recognizing, assessing, notifying, and documenting skin integrity changes in the health care records.[3] At admission and within 24 hours of postadmission, head-to-toe skin assessments and PI risk screenings are expected to identify patients who either have PI at admission or are at higher risk of developing PI. Routine skin assessments and PI staging follow to inform hospital-acquired PI which develops after admission or heals before discharge. From October 2008, hospitals do not receive payments from the Centers for Medicare and Medicaid Services or even get a penalty for hospital-acquired stage III and IV PIs.[6]

The documentation quality of PI could influence care quality and inform existent care integrity gaps that have not been identified.[7] Documented PI electronic health record (EHR) data have helped identify the PI prevalence, incidence, and hospital-acquired PI to inform health care outcome quality,[8] and are used to develop personalized risk prediction tools nowadays.[9] However, as EHRs are designed for clinical administrative purposes, additional validations of documentation accuracy or data quality are needed for epidemiological or clinical research.[10,11] Internal validation using additional parameters or free text for concordance in the database helps validate EHRs.[10,12] Studies on the accuracy of PI coding have found great discordances based on the International Classification of Diseases-ninth edition (ICD-9) site and stage in Medicare claims[13] or across interfacility transfers.[14] For example, 54% of Medicare claims with a secondary diagnosis of the PI site not present on admission did not have an accompanying PI stage code reported based on the count difference.[13] The rates differed by hospital characteristics.[13] In addition to diagnosis codes, staging charts have also been used to classify PI groups.[15] A recent study using the Medical Information Mart for Intensive Care (MIMIC)-III,[16] a large clinical EHR database, to predict hospital-acquired PI, also found many discordances in classifying hospital-acquired PI using data with diagnosis codes, charts, and clinical notes for PI stage.[17] The Clinical Documentation Improvement programs use the concurrent query process to improve the documentation of PI by health care providers.[18] Our recent study found that PI sites were not always concurrently documented with its stage by ICD-9 codes or charts in MIMIC-III, making the actual PI count and stage changes unclear during a hospitalization.[19]

Objectives

With the MIMIC-III database, this study aims to (1) further compare the concordance of documentations and data related to PI site, stage, and the count of site or stage records in ICD-9 coded diagnoses and chart events; and (2) explore if the discrepancy in PI count versus consistency of PI count in site and stage records differs by or is associated with patient characteristics at admission and during hospitalization.

Methods

Dataset

This study used the openly available MIMIC-III dataset.[16] MIMIC is developed by the Massachusetts Institute of Technology Laboratory for Computational Physiology. MIMIC-III v1.4 comprises deidentified clinical data of 61,532 intensive care unit (ICU) patient admissions to Beth Israel Deaconess Medical Center at Boston in Massachusetts from June 2001 to October 2012. It includes 53,432 stays for adult patients and 8,100 for neonatal patients. Data were downloaded from hospital EHR databases, critical care information systems, and the Social Security Administration Death Master File. The archived data went through deidentification, date shifting, and format conversion before being integrated, and user feedback and corrections were tracked. MIMIC-III mainly includes demographics, vital signs, laboratory tests, medications, observations, notes charted by care providers, procedure codes, diagnostic codes, and imaging reports. Data tables were linked by unique subject, hospital administration, intensive care unit stay, caregiver, laboratory, and chart event item IDs. A portion of the MIMIC-III chart event data was extracted from the Philips CareVue Clinical Information System (models M2331A and M1215A; Philips Health-care, Andover, Massachusetts, United States). The other portion was extracted from the iMDsoft MetaVision ICU (iMDsoft, Needham, Massachusetts, United States). MetaVision was adopted after CareVue. Chart event data were stored with different ITEMIDs for each event in the two systems. A more detailed description of MIMIC-III development could be found elsewhere.[16]

Pressure Injury Data in Medical Information Mart for Intensive Care-III

►Table 1 shows the available data elements related to PI in MIMIC-III. A subset of PI hospitalizations was composed of

Table 1 Pressure injury data elements in MIMIC-III

Concepts	Operational definitions	Variables, keywords, or computations
Risk	Chart events\risk (Braden's scale)	CHARTEVENTS\CareVue\ITEMID = 82–88 (total score: 87)
Site	Site or location	CHARTEVENTS\ITEMID = 554, 576–577 (CareVue), 228506–228515[a] (MetaVision)
Site	Diagnosis	DIAGNOSIS_ICD\ICD9_CODE = 707.20–707.25
Stage	Chart events\stage (NPUAP pressure injury stages)	CHARTEVENTS\ITEMID = 551–553 (CareVue), 224631, 224965–224971, 227618–227619[a] (MetaVision)
Stage	Diagnosis	DIAGNOSIS_ICD\ICD9_CODE = 707.00–707.09
Depth	Chart events\depth	CHARTEVENTS\ITEMID = 555–557 (CareVue), 228610–228619[a] (MetaVision)
Drainage	Chart events\drainage	CHARTEVENTS\CareVue\ITEMID = 558–560
Width	Chart events\width	CHARTEVENTS\ITEMID = 561–563 (CareVue), 228620–228629[a] (MetaVision)
Cleansing	Chart events\cleansing	CHARTEVENTS\CareVue\ITEMID = 564–566
Treatment	Chart events\treatment	CHARTEVENTS\ITEMID = 567–569 (CareVue), 228539–228548[a] (MetaVision)
Wound base	Chart events\wound base	CHARTEVENTS\CareVue\ITEMID = 570–572
Type[a]	Chart events\type[a]	CHARTEVENTS\MetaVision\ITEMID = 228549–228558[a]
Odor	Chart events\odor	CHARTEVENTS\CareVue\ITEMID = 573–575
Pressure reduce device	Chart events\pressure reduce device	CHARTEVENTS\CareVue\ITEMID = 579
Heal	Chart events\heal	CHARTEVENTS\CareVue\ITEMID = 8457–8459
Amount (drainage)	Chart events\amount	CHARTEVENTS\CareVue\ITEMID = 8460–8462
Length	Chart events\length	CHARTEVENTS\CareVue\ITEMID = 8463–8465
Procedures and services	CPT codes	CPTEVENTS\COSTCENTER, CPT_NUM = 11042–11047, 15920–15999[a], 97597–97598[29]
Notes	Noted pressure injury keywords	NOTEEVENTS\TEXT, CHARTDATE, CHARTTIME, CATEGORY; keywords: "bed sore, bed ulcer, pressure sore, pressure ulcer, decub* sore, decub* ulcer"[17]; negative keywords: "no" + keywords

Abbreviations: CPT, current procedural terminology; MIMIC, Medical Information Mart for Intensive Care.
[a]Data unavailable.

the following: (1) PI-related ICD-9 codes on the site or stage; (2) available chart items on PI Braden's risk total score, prevention, or features such as site, stage, and depth; or (3) PI keywords in the clinical notes after excluding negative findings, such as "no pressure ulcer." Based on the PI data elements in MIMIC-III, all potentially PI-positive hospitalization cases ($n = 31{,}918$) were identified via ICD-9 codes, CareVue, or MetaVision chart events, and clinical notes were extracted and linked based on the unique subject, hospital-administration, ICU stay, caregiver, or item ID. The two clinical information systems, CareVue and MetaVision, captured different PI features or variables in the charts. Only data on PI stage but not site were found available for the charts recorded in MetaVision in MIMIC-III.

Determining the Pressure Injury Count

The PI site and stage data from ICD-9 diagnoses and chart events were used to calculate the PI count, potentially resulting in the same or different numbers if a stage does not accompany a site. The counts of PI site and stage diagnoses were calculated by counting the number of ICD codes[13] for each separately. The ICD codes captured up to 39 diagnoses. The counts of PI stage and site in CareVue chart events were calculated by counting the number of unique items of PI stage and site, as three unique items have recorded the site or stage value of PI no. 1 (first occurrence of PI) and up to no. 3 (third occurrence of PI). Similarly, MetaVision chart events could have recorded the stage value of PI no. 1 (first occurrence of PI) and up to no. 10 (tenth occurrence of PI). The PI count of some hospitalizations in MetaVision with, for example, only PI nos. 3 and 4 data in the charts were computed as two instead of four.

Determining Consistencies and Discrepancies in Pressure Injury Counts

The PI MIMIC-III dataset was divided into three subsets to determine the consistency and discrepancy between the obtained PI counts. These subsets were as follows: (1)

hospitalizations with ICD-9 codes for PI site or stage; (2) hospitalizations with CareVue chart event data on PI; and (3) hospitalizations with ICD-9 codes for PI stage or MetaVision chart event data containing PI stage. The consistency and discrepancy of PI counts were determined as the difference between the counts of the PI site and stage in the diagnosis or chart events. This led to two groups: (1) hospitalizations reporting the same PI count as consistent cases and (2) hospitalizations reporting different PI count as discrepant cases.

Patient Characteristics at Admission and during Hospitalization

Associations between discrepancies in the PI count and patient characteristics at admission or during hospitalization were explored to shed more light on potential causes of this mismatch and possibly use them to inform documentation and care improvements. ►Table 2 shows the list of patient characteristics that was available for comparisons.

Data Analysis

Descriptive statistics were used to summarize patient characteristics and PI counts according to the stages and sites reported in ICD-9 diagnoses and/or charts. The independent *t*-test, Kruskal–Wallis test (for nonnormally distributed continuous variables, according to skewness, kurtosis and Shapiro–Wilk tests), or Chi-squared test was used to analyze associations between PI count discrepancies and the above-mentioned patient characteristics. Missing data were excluded during the analysis. ICD-9 diagnoses and chart values for sites or stages were also compared for hospitalizations with one PI based on ICD-9 codes and chart events. The National Pressure Ulcer Advisory Panel staging criteria[8,20] were used to code and compare the PI stage of hospitalizations with one stage recorded via ICD-9 codes and chart events. The R packages deplyr, tidyverse, stringr, and tableone were used for analyses.[21–25] The open-source codes of cleaning and analysis can be found on the GitHub repository.[26]

Results

►Table 3 shows the differences between the count of PI ICD-9 site and stage codes, where zero means that they reported a consistent count, and thus each PI stage code was accompanied by a site code. Similarly, ►Table 4 shows the differences between the count of the PI sites and stages based on the CareVue chart data. ►Table 5 shows the differences between the count of PI ICD-9 stage codes and MetaVision stages since only PI stage data were available in MIMIC-III. More than half (55.9%) of the PI counts based on ICD-9-coded sites and stages were different. Almost all (99.3%) PI counts based on the site and stage data in CareVue charts were the same, whereas only less than half (42.9%) of the PI counts based on the stage data were the same comparing the ICD-9 codes and the MetaVision charts.

The comparisons between consistent or discrepant PI counts and patient characteristics are shown in ►Tables 6, 7, 8. Overall, having a discrepant PI count was significantly associated with PI recording in clinical notes, discharge status of dead/hospice, more unique caregivers for PI, longer hospitalization or ICU stays, and more days to first transfer. Comparisons based on ICD-9 codes revealed additional significant associations between discrepant PI counts and younger age, admission to emergency Rooms, non-English speaking status, or an initial ICD-coded PI sequence less than the median of 8. Comparisons based on CareVue chart events identified significant associations between discrepant PI counts and older age, use of Medicare insurance, or non-English speaking status. Those with discrepant PI counts reported more ICU transfers and were more likely to use a medical service, transfer care, or ICU as the first department, ward, or unit. Comparisons based on the number of PI stages according to ICD-9 codes and MetaVision chart events additionally identified significant associations between PI count discrepancy and admission to emergency rooms or more ICU transfers.

►Supplementary Table S1 (available in the online version) shows the discrepancies between ICD-9 diagnosis codes and charted PI stage values, and ►Supplementary Table S2 (available in the online version) shows the discrepancies between ICD-9 diagnosis codes and charted PI sites for hospitalizations with only one PI across the ICD-9-coded PI diagnoses and charts of site or stage. Of the 235 hospitalizations that reported one PI both according to ICD-9 codes and chart site data, 75% reported consistent PI sites. The discrepancies primarily were due to the reporting of the site as "coccyx" and "70705 (buttock)" via charts and ICD-9 codes. Of the 334 hospitalizations that reported one PI both according to ICD-9 codes and chart stage data, 49% reported consistent PI stages. The discrepancies mainly came from chart-reported stage values, such as "Red; unbroken," "Full thickness skin loss that may extend down to underlying fascia; injury may have tunneling or undermining," "Partial thickness skin loss through epidermis and/or dermis; injury may present as an abrasion, blister, or shallow crater," "Deep tissue injury," and "Unable to stage; wound is covered with eschar." ICD-9 codes of "70720 (unspecified)," "70722 (stage II)," and "70723 (stage III)" also contributed to the discrepancies.

Discussion

This study evaluated the concordance of PI site, stage, and count data documented in the MIMIC-III EHRs using ICD-9 diagnosis codes, CareVue, and MetaVision chart events. Associations between discrepancies in the PI count and patient characteristics at admission and during hospitalization were also explored. Data were available from ICD-9 codes on PI site and stage, CareVue chart events on PI features, such as site and stage, and MetaVision chart events on PI stage only. The CareVue chart documented much more accurate and consistent counts of PI than ICD-9 codes or MetaVision charts. The PI count discrepancy rate in ICD-9 codes was 55.9%, similar to the reported rate of 54% in a national study from the Center for Medicare and Medicaid Services.[13] The relatively higher consistency of CareVue in recording PI counts could be explained by the facts that (1)

Table 2 Patient characteristics' data elements in MIMIC-III

Concepts	Operational definitions	Variables, categories, or computations
Admission type	Admission type	ADMISSION\ADMISSION_TYPE: emergency versus others
Admission location	Admission location	ADMISSION\ADMISSION_LOCATION: emergency room versus others
Insurance	Insurance at admission	ADMISSION\INSURANCE: Medicare versus non-Medicare
Discharge location	Discharge location	ADMISSION\DISCHARGE_LOCATION: dead/hospice, home/left against advice, long-term care, short-term care
Gender	Patient's gender	PATIENTS\GENDER: male versus female
Language	Language at admission	ADMISSION\LANGUAGE: English versus non-English
Religion	Religion at admission	ADMISSION\RELIGION: Christian versus non-Christian others
Marital status	Marital status at admission	ADMISSION\MARITAL_STATUS: married/significant others versus unmarried others
Race/ethnicity	Race/ethnicity at admission	ADMISSION\ETHNICITY: White versus non-White, African American versus non-African American, White versus African American
Age	Patient's age at admission	ADMISSION\ADMISSIONDATE-PATIENTS\DOB (Ages over 90 were recoded as 90 years)
Time in emergency room	Time from emergency room registration to discharge	ADMISSION\EDOUTTIM–EDREGTIME (days): same day versus second day Emergency Room discharge
First PI ICD code sequence	The sequence of the first PI ICD code in all ICD codes	First PI ICD code sequence <8 vs. ≥ 8
Pressure injury recorded in note	Whether PI is noted in the clinical notes	Yes versus no
Number of unique caregivers for pressure injury	Number of unique caregiver IDs in the chart events for PI	CAREGIVERS\CGID and CHARTEVENTS for PI
Number of service transfers	Number of unique service transfers	SERVICES\PRE_SERVICE, CURR_SERVICE
Number of transfers	Number of unique transfers	TRANSFERS\PREV_CAREUNIT, PREV_WARDID, CURR_CAREUNIT, CURR_WARDID
Number of ICUs	Number of unique ICU stays	ICUSTAYS\ICUSTAY_ID
Total length of ICU stays	Total length of ICU length of stays	ICUSTAYS\LOS
Total length of hospitalization	Total length of hospitalization	ADMISSION\DISCHTIME–ADMITTIME (d)
Time to the first service transfer	Time to the first service transfer after admission	SERVICES\TRANSFERTIME–ADMISSION\ADMISSIONDATE (d)
Time to the first transfer	Time to the first transfer after admission	TRANSFERS\OUTTIME–ADMISSION\ADMISSIONDATE (d)
Time from admission to first ICU	Time to the first ICU stay after admission	ICUSTAYS\INTIME–ADMISSION\ADMISSIONDATE (d)
First service department	First service department	SERVICES\CURR_SERVICE
First care unit	First care unit	TRANSFERS\CURR_CAREUNIT
First ICU	First ICU	ICUSTAYS\FIRST_CAREUNIT
Last ICU	Last ICU	ICUSTAYS\LAST_CAREUNIT

Abbreviations: ICD, International Classification of Diseases; ICU, intensive care unit; MIMIC, Medical Information Mart for Intensive Care; PI, pressure injury.

Table 3 Differences in recorded pressure injury counts between ICD-9-coded sites and stages

N (site)–N (stage)	−2	−1	0	1	2	3	4
Number of hospitalizations	1	13	810	839	137	33	4

Abbreviation: ICD, International Classification of Diseases.

Table 4 Differences in recorded pressure injury counts between CareVue site and stage charts

N (site)–N (stage)	−2	−1	0	1	2	3
Number of hospitalizations	1	24	26,687	150	18	7

Table 5 Differences in recorded pressure injury counts between ICD-9-codes and MetaVision charts

N (ICD-9 stage)–N (chart stage)	−8	−7	−6	−5	−4	−3	−2	−1	0	1	2
Number of hospitalizations	3	4	16	16	36	57	120	208	357	14	3

Abbreviation: ICD, International Classification of Diseases.

CareVue had more PI items on different features, such as width and depth, which could have reinforced the quality of data entry; (2) chart events came mostly from bed-side nurses and were likely to be more accurate than ICD-9 diagnosis codes, as there could be communication gaps between caregivers, especially for the stage; (3) comparisons within one data source (e.g., charts) were generally more consistent than comparisons across data sources (e.g., between charts and ICD-9 diagnoses); (4) MetaVision captured up to 10 PI stages and they were not fully available in the MIMIC-III database; (5) MetaVision was adopted after CareVue and caregivers need to adapt to the new chart system; (6) potential restrictions in hospital ICD-9 coding guideline or system design may only allow one diagnosis code to be listed once; or (7) patients might have more than 39 diagnoses.

Comparisons by patient characteristics at admission and during hospitalization identified patients at risk of having discrepant PI counts in their records and informed potential factors that could be associated with the discrepancies. PI count discrepancies were associated with younger age (ICD-9 and MetaVision) or older age (CareVue), admission to emergency rooms (ICD-9 and MetaVision), non-English speaking status (ICD-9 and CareVue), Medicare or medical service use (CareVue), more caregivers (both ICD-9 and charts), the recording of PI in clinical notes (both ICD-9 and charts), more ICU transfers (charts), longer hospitalization or ICU stays, more days to the first transfer, and a discharge status of as dead/hospice (both ICD-9 and charts). Discrepancies associated with patients being non-English speakers could be due to language barriers and communication gaps between patients and caregivers. Discrepancies associated with admissions to emergency rooms, more caregivers, first PI ICD sequences less than the median of 8, recording of PI in clinical notes, medical service use, or more ICU transfers could be explained by care discontinuities. The consistently significant differences in the length of hospitalization, ICU stays, or more days to the first transfer by PI discrepancies could be explained by the discontinuity of care with more caregivers or adverse outcomes of care discontinuity.[4] Although whether and how PI discrepancy was associated with age was not consistent in the three comparisons, the significant and positive relationship between PI count discrepancy and older age in the CareVue data was consistent with its significant association with being a Medicare user. However, since people over the age of 90 years were all recoded as aged 90 years, it is too early to draw this conclusion. Findings on the association between PI count discrepancy and having a first PI ICD sequence less than the median of 8 was consistent with the coding issues raised by the previous Center for Medicare and Medicaid Services study, showing that coding guidelines could influence PI site and stage coding consistencies.[13] Interestingly, discrepancies in the PI count were consistently and significantly associated with PI recording in clinical notes. This suggests that clinical notes could act as a supplemental data source for PI, and studies could consider using them to verify PI features. This is consistent with studies that used clinical notes to detect PI in MIMIC-III data.[17,27] Future studies need to investigate how coding guidelines (e.g., ICD-10) influence PI documentation quality and validate PI prediction models with clinical notes. Other PI features in addition to ICD codes and charts should also be considered to inform the truth.

Comparisons between ICD-9 codes and chart values identified discrepancies in the records that could be improved in the future with more guidelines. For example, "coccyx" should be coded as "lower back" instead of "buttock" in the ICD-9 site. As for stage coding, there were more mismatches between the most frequent stage values and ICD-9 stage codes, especially for nonspecific values ("Red; unbroken," "Deep tissue injury," "Unable to stage; wound is covered with eschar") or ICD-9 codes (e.g., "70720 [unspecified]," "70722 [stage II]," or "70723 [stage III]"). Future guidelines should also provide clear instructions on which ICD-9 code to use for stages, as they may change dynamically. ICD-10 codes (e.g., "Pressure ulcer of right

Table 6 Comparing the consistency of pressure injury counts recorded in ICD-coded site versus stage diagnoses by patient characteristics ($n = 1,837$)

Patient characteristics	Categories	Same count *n* (%)	Different count *n* (%)	*p*-Value
n (%)		810 (44.1)	1,027 (55.9)	
Admission type	Emergency	755 (93.2)	951 (92.6)	0.679
	Others	55 (6.8)	76 (7.4)	
Admission location	Emergency room	260 (32.1)	652 (63.5)	<0.001[c]
	Non-emergency room	550 (67.9)	374 (36.5)	
Insurance	Medicare	614 (75.8)	766 (74.6)	0.586
	Others	196 (24.2)	261 (25.4)	
Discharge location	Dead/hospice	140 (17.7)	198 (19.6)	<0.001[c]
	Home/left against advice	99 (12.5)	116 (11.5)	
	Long-term care	198 (25.1)	104 (10.3)	
	Short-term care	352 (44.6)	590 (58.5)	
Gender	Female	336 (41.5)	426 (41.5)	1
	Male	474 (58.5)	601 (58.5)	
Language	Non-English	73 (9.0)	523 (50.9)	<0.001[c]
	English	737 (91.0)	504 (49.1)	
Religion	Christian	459 (58.2)	551 (55.8)	0.726
	Non-Christian	109 (19.2)	123 (18.2)	
Marital status	Married/significant others	360 (45.9)	440 (45.5)	0.884
	Unmarried	424 (54.1)	528 (54.5)	
Race/ethnicity	Non-white	156 (20.6)	172 (18.0)	0.201
	White	603 (79.4)	784 (82.0)	
Race/ethnicity	Non-African American	671 (88.4)	848 (88.7)	0.908
	African American	88 (11.6)	108 (11.3)	
Race/ethnicity	African American	88 (12.7)	108 (12.1)	0.765
	White	603 (87.3)	784 (87.9)	
Age (y)	Median [IQR]	73.00 [63.00, 82.75]	71.00 [60.00, 81.00]	0.038[b,a]
Time in emergency room	Same-day emergency room discharge	429 (76.2)	507 (70.8)	0.036[b]
	Second-day emergency room discharge	134 (23.8)	209 (29.2)	
First pressure injury ICD code sequence	≥8	540 (66.7)	413 (40.2)	<0.001[c]
	<8	270 (33.3)	614 (59.8)	
Pressure injury recorded in note or not	No	365 (45.1)	327 (31.8)	<0.001[c]
	Yes	445 (54.9)	700 (68.2)	
Number of unique caregivers for pressure injury	Median [IQR]	5.00 [3.00, 10.00]	9.00 [5.00, 20.00]	<0.001[c,a]
Number of service transfers	Median [IQR]	0.00 [0.00, 0.00]	0.00 [0.00, 1.00]	0.366[a]
Number of transfers	Median [IQR]	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.969[a]
Number of ICUs	Median [IQR]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	0.114[a]
Total length of ICU stays (d)	Median [IQR]	3.35 [1.74, 8.21]	4.90 [2.20, 12.37]	<0.001[c,a]

(*Continued*)

Table 6 (*Continued*)

Patient characteristics	Categories	Same count *n* (%)	Different count *n* (%)	*p*-Value
Total length of hospitalization (d)	Median [IQR]	11.00 [6.00, 19.00]	13.00 [7.00, 24.00]	<0.001[c,a]
Time to the first service transfer (d)	Median [IQR]	3.85 [1.79, 8.70]	4.49 [1.90, 10.54]	0.188[a]
Time to the first transfer (d)	Median [IQR]	1.83 [0.83, 4.83]	2.83 [0.83, 5.83]	<0.001[c,a]
Time from admission to first ICU (d)	Median [IQR]	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.418[a]
First service department	Medical	600 (75.0)	772 (75.8)	0.722
	Surgical	200 (25.0)	246 (24.2)	
Last service department	Medical	611 (75.8)	774 (75.7)	1
	Surgical	195 (24.2)	248 (24.3)	
First transfer care unit	Medical ICU	371 (73.5)	488 (74.7)	0.674
	Surgical ICU	134 (26.5)	165 (25.3)	
Last transfer care unit	Medical ICU	157 (77.3)	245 (71.6)	0.173
	Surgical ICU	46 (22.7)	97 (28.4)	
First ICU	Medical ICU	547 (67.9)	699 (68.2)	0.921
	Surgical ICU	259 (32.1)	326 (31.8)	
Last ICU	Medical ICU	560 (69.5)	705 (68.8)	0.787
	Surgical ICU	246 (30.5)	320 (31.2)	

Abbreviations: ICD, International Classification of Diseases; ICU, intensive care unit; IQR, interquartile range.
[a]Kruskal–Wallis test.
[b]$p < 0.05$.
[c]$p < 0.001$.
Note: Missing data were excluded.

elbow stage 1") have combined the site and stage but may have the same coding concerns.

This study examined the data concordance, a key data quality metric,[12] within and between PI outcome quality indicators, site, and stage, documented in EHR diagnosis codes and chart events. For research studies that adopt MIMIC or such EHR databases, systematic data quality evaluation and validation will inform potential limitations or bias to generalize the findings. For example, our explorations in this study found that the chart events could be better PI outcome quality indicators in terms of occurrence and stage than the diagnosis codes.[8] Moreover, findings on the patient subgroups with more discrepancies may need further sensitivity validations to generalize the findings of predictive studies. Our future research will explore PI documentation and data quality by combining the PI process quality indicators that has listed PI care documentation standards and the 3×3 Data Quality Assessment framework.[12] For example, we will examine if "every individual is assessed for PI risk as soon as possible after admission/transfer and periodically thereafter, and the assessment is documented in the medical record"[8] to inform the data quality metric "3C: Data were recorded with the desired regularity over time."[12] We will further develop systematic documentation or data quality analytical tools on PI for clinical documentation improvement or care quality performance dashboards to inform real-time clinical documentation and care quality.

Limitations

This study has several limitations. First, discrepancies in PI counts could be attributed to the maximum limit of 39 ICD codes for each record. However, only a few PIs were recorded at the end of the diagnosis sequence, and PI count discrepancy was associated with having a first PI ICD sequence number less than the median of 8. Second, there may not have been a one-to-one relationship between the documentation of the site and the stage. Therefore, one PI site could be linked to several PI stages or vice versa. However, these cases were likely to be rare in this study, as more sites were reported than stages, and the findings were consistent across different comparisons. Third, the keyword detection with clinical notes may be limited in capturing all PI cases or

Table 7 Comparing the consistency of pressure injury counts recorded in CareVue site and stage charts by patient characteristics ($n = 26,887$)

Patient characteristics	Categories	Same count *n* (%)	Different count *n* (%)	*p*-Value
n (%)		26,687 (99.3)	200 (0.74)	
Admission type	Emergency	21,841 (81.8)	174 (87.0)	0.073
	Others	4,846 (18.2)	26 (13.0)	
Admission location	Emergency room	15,178 (56.9)	113 (56.5)	0.97
	Non-emergency Room	11,505 (43.1)	87 (43.5)	
Insurance	Medicare	14,614 (54.8)	148 (74.0)	<0.001[d]
	Others	12,073 (45.2)	52 (26.0)	
Discharge location	Dead/hospice	3,290 (12.8)	59 (30.7)	<0.001[d]
	Home/left against advice	13,856 (53.7)	29 (15.1)	
	Long-term care	394 (1.5)	1 (0.5)	
	Short-term care	8,240 (32.0)	103 (53.6)	
Gender	Female	11,626 (43.6)	84 (42.0)	0.709
	Male	15,061 (56.4)	116 (58.0)	
Language	Non-English	18,420 (69.0)	153 (76.5)	0.028[b]
	English	8,267 (31.0)	47 (23.5)	
Religion	Christian	13,907 (82.2)	122 (83.6)	0.744
	Non-Christian	3,016 (17.8)	24 (16.4)	
Marital status	Married/significant others	12,985 (51.9)	93 (50.5)	0.763
	Unmarried	12,018 (48.1)	91 (49.5)	
Race/ethnicity	Non-White	4,486 (19.2)	29 (16.7)	0.446
	White	18,828 (80.8)	145 (83.3)	
Race/ethnicity	Non-African American	21,001 (90.1)	156 (89.7)	0.953
	African American	2,313 (9.9)	18 (10.3)	
Race/ethnicity	African American	2,313 (10.9)	18 (11.0)	1
	White	18,828 (89.1)	145 (89.0)	
Age (y)	Median [IQR]	66.00 [52.00, 78.00]	74.00 [61.75, 81.25]	<0.001[d,a]
Time in emergency room	Same-day emergency room discharge	11,128 (72.4)	89 (76.1)	0.439
	Second-day emergency room discharge	4,236 (27.6)	28 (23.9)	
First pressure injury ICD code sequence	≥8	301 (39.1)	11 (35.5)	0.825
	<8	468 (60.9)	20 (64.5)	
Pressure injury recorded in note or not	No	25,033 (93.8)	142 (71.0)	<0.001[d]
	Yes	1,654 (6.2)	58 (29.0)	
Number of unique caregivers for pressure injury	Median [IQR]	5.00 [3.00, 9.00]	10.00 [5.00, 20.25]	<0.001[d,a]
Number of service transfers	Median [IQR]	0.00 [0.00, 0.00]	0.00 [0.00, 1.00]	0.242[a]
Number of transfers	Median [IQR]	0.00 [0.00, 0.00]	0.00 [0.00, 1.00]	0.04[b,a]
Number of ICUs	Median [IQR]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	<0.001[d,a]
Total length of ICU stays (d)	Median [IQR]	2.46 [1.33, 5.00]	5.90 [2.29, 15.29]	<0.001[d,a]
	Median [IQR]	7.00 [4.00, 13.00]	13.02 [6.00, 23.00]	<0.001[d,a]

(*Continued*)

Table 7 (*Continued*)

Patient characteristics	Categories	Same count *n* (%)	Different count *n* (%)	*p*-Value
Total length of hospitalization (d)				
Time to the first service transfer (d)	Median [IQR]	2.82 [1.50, 5.69]	3.42 [1.52, 7.47]	0.329[a]
Time to the first transfer (d)	Median [IQR]	1.79 [0.83, 3.79]	2.79 [0.83, 6.82]	0.001[c,a]
Time from admission to first ICU (d)	Median [IQR]	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.288[a]
First service department	Medical	16,520 (62.9)	144 (73.1)	0.004[c]
	Surgical	9,744 (37.1)	53 (26.9)	
Last service department	Medical	14,807 (56.3)	136 (68.3)	0.001[c]
	Surgical	11,477 (43.7)	63 (31.7)	
First transfer care unit	Medical ICU	9,150 (64.4)	87 (76.3)	0.011[b]
	Surgical ICU	5,053 (35.6)	27 (23.7)	
Last transfer care unit	Medical ICU	3,537 (68.3)	51 (68.0)	1
	Surgical ICU	1,645 (31.7)	24 (32.0)	
First ICU	Medical ICU	14,165 (53.1)	139 (69.5)	<0.001[d]
	Surgical ICU	12,494 (46.9)	61 (30.5)	
Last ICU	Medical ICU	14,063 (52.8)	131 (65.5)	<0.001[d,b]
	Surgical ICU	12,596 (47.2)	69 (34.5)	

Abbreviations: ICD, International Classification of Diseases; ICU, intensive care unit; IQR, interquartile range.
[a]Kruskal–Wallis test.
[b]$p < 0.05$.
[c]$p < 0.01$.
[d]$p < 0.001$.
Note: Missing data were excluded.

excluding all negative cases and thus need future explorations. Finally, findings in this study may not be generalizable to the up-to-date ICD-10 codes or other data sources or hospitals as MIMIC-III data come from a single hospital system. More experiments and case studies will be conducted with Emory Healthcare's EHRs in our NeLL database[28] with ICD-9 and ICD-10 codes, flow charts, and clinical notes from 2012 to 2020.

Conclusion

This study analyzed and compared the documentation and data concordance of PI site, stage, and count in MIMIC-III. In addition, associations between patient characteristics at admission or during hospitalization and PI count discrepancies in the diagnoses and charts were assessed. The findings suggest that PI documentation quality could be improved by using better communication, care continuity, and more integrative care to pay more attention to patients at risk for the discrepancies, such as patients with language barriers. Systematic documentation or data quality analysis is necessary for practice and EHR-based clinical research.

Clinical Relevance Statement

This study has several clinical implications. For clinical practice, nurses and clinicians strive to improve the documentation quality for PI to increase consistencies among pressure injury (PI) stage, site, and other features to improve the quality of care and efficient management and administration. Patients at risk for PI count discrepancies require additional attention. Researchers who wish to adopt electronic health records (EHRs) to study the PI prevalence and predict PI should first examine the quality of the documentation or data and may validate with additional data sources, such as clinical notes. It is important to be aware of the potential bias and limitations associated with data quality. For health information technology developers, PI count should be included in the chart as a PI feature. Tools monitoring the documentation or data quality, especially the concurrency and concordance across different sources, of EHR data will help improve the data quality for practice and research purposes. For the health care administration, routine documentation quality monitoring, and even real-time analysis will inform the gaps in the care for continuing education,

Table 8 Comparing the consistency of pressure injury counts recorded in MetaVision stage and ICD-coded stage diagnoses by patient characteristics ($n = 831$)

Patient characteristics	Categories	Same count *n* (%)	Different count *n* (%)	*p*-Value
n (%)		357 (42.9)	477 (57.4)	
Admission type	Emergency	330 (92.4)	449 (94.1)	0.404
	Others	27 (7.6)	28 (5.9)	
Admission location	emergency room	112 (31.4)	183 (38.4)	0.044[b]
	Non-emergency room	245 (68.6)	294 (61.6)	
Insurance	Medicare	263 (73.7)	367 (76.9)	0.315
	Others	94 (26.3)	110 (23.1)	
Discharge location	Dead/hospice	54 (15.7)	104 (22.4)	<0.001[d]
	Home/left against advice	53 (15.4)	34 (7.3)	
	Long-term care	78 (22.6)	149 (32.0)	
	Short-term care	160 (46.4)	178 (38.3)	
Gender	Female	154 (43.1)	187 (39.2)	0.284
	Male	203 (56.9)	290 (60.8)	
Language	Non-English	27 (7.6)	48 (10.1)	0.26
	English	330 (92.4)	429 (89.9)	
Religion	Christian	191 (78.3)	281 (83.1)	0.171
	Non-Christian	53 (21.7)	57 (16.9)	
Marital status	Married/Significant others	145 (41.7)	211 (45.8)	0.275
	Unmarried	203 (58.3)	250 (54.2)	
Race/ethnicity	Non-white	65 (19.3)	97 (21.8)	0.442
	White	272 (80.7)	348 (78.2)	
Race/ethnicity	Non-African American	296 (87.8)	392 (88.1)	1
	African American	41 (12.2)	53 (11.9)	
Race/ethnicity	African American	41 (13.1)	53 (13.2)	1
	White	272 (86.9)	348 (86.8)	
Age (y)	Median [IQR]	73.00 [62.00, 83.00]	72.00 [62.00, 83.00]	0.722[a]
Time in emergency room	Same-day emergency room discharge	202 (79.8)	251 (74.5)	0.153
	Second-day emergency room discharge	51 (20.2)	86 (25.5)	
First pressure injury ICD code sequence	≥8	230 (64.4)	288 (60.4)	0.263
	<8	127 (35.6)	189 (39.6)	
Pressure injury recorded in note or not	No	161 (45.1)	162 (34.0)	0.001[c]
	Yes	196 (54.9)	315 (66.0)	
Number of unique caregivers for pressure injury	Median [IQR]	4.00 [2.00, 7.00]	7.00 [4.00, 13.00]	<0.001[d,a]
Number of service transfers	Median [IQR]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.681[a]
Number of transfers	Median [IQR]	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.289[a]
Number of ICUs	Median [IQR]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	0.043[b,a]
Total length of ICU stays (d)	Median [IQR]	3.12 [1.58, 6.00]	4.92 [2.26, 12.99]	<0.001[d,a]
Total length of hospitalization (d)	Median [IQR]	10.00 [6.00, 17.00]	11.96 [6.00, 22.00]	0.025[b,a]

(*Continued*)

Table 8 (*Continued*)

Patient characteristics	Categories	Same count *n* (%)	Different count *n* (%)	*p*-Value
Time to the first service transfer (d)	Median [IQR]	3.78 [1.68, 8.23]	4.60 [2.24, 10.35]	0.163[a]
Time to the first transfer (d)	Median [IQR]	1.79 [0.83, 3.83]	2.79 [0.83, 5.83]	0.001[c,a]
Time from admission to first ICU (d)	Median [IQR]	0.00 [0.00, 1.00]	0.00 [0.00, 0.00]	0.106[a]
First service department	Medical	269 (76.9)	367 (77.8)	0.826
	Surgical	81 (23.1)	105 (22.2)	
Last service department	Medical	265 (74.6)	380 (80.2)	0.071
	Surgical	90 (25.4)	94 (19.8)	
First care unit	Medical ICU	169 (77.2)	259 (78.5)	0.796
	Surgical ICU	50 (22.8)	71 (21.5)	
Last care unit	Medical ICU	60 (77.9)	132 (78.1)	1
	Surgical ICU	17 (22.1)	37 (21.9)	
First ICU	Medical ICU	253 (70.9)	340 (71.3)	0.958
	Surgical ICU	104 (29.1)	137 (28.7)	
Last ICU	Medical ICU	255 (71.4)	353 (74.0)	0.454
	Surgical ICU	102 (28.6)	124 (26.0)	

Abbreviations: ICD, International Classification of Diseases; ICU, intensive care unit; IQR, interquartile range.
[a]Kruskal–Wallis test.
[b]$p < 0.05$.
[c]$p < 0.01$.
[d]$p < 0.001$.
Note: Missing data were excluded.

especially emphasizing the importance and effects of coding accuracy in evidence-based practice.[18]

Multiple Choice Questions

1. Which of the following pressure injury data elements was not included in this study?
   a. ICD-9 codes
   b. CareVue chart events on PI stage
   c. MetaVision chart events on PI site
   d. Clinical notes

   Correct Answer: The correct answer is option c. MetaVision chart events on PI site were not available in MIMIC-III and were not included in the study.

2. Which of the following patient characteristics was not significantly associated with discrepancies in pressure injury counts in every comparison in the study?
   a. Age
   b. Recording of PI in clinical notes
   c. More unique caregivers for PI
   d. Longer ICU stays

   Correct Answer: The correct answer is option a. Age was not significantly associated with PI count discrepancies in all three comparisons.

3. Which conclusion could not be drawn from the study?
   a. Compared with ICD-9 codes the CareVue chart events recorded more consistent counts of pressure injury sites and stages
   b. Clinicians may pay more attention to the coding of pressure injuries on the coccyx
   c. Studies using electronic health records to predict pressure injury may want to validate their data quality first
   d. MetaVision was better than the CareVue chart event system

   Correct Answer: The correct answer is option d. The data and evidence reported in the study were not enough to judge which chart event system was better. CareVue seemed to act better in MIMIC-III, but the count of missing data in MetaVision in MIMIC-III prevented the ability to make more detailed comparisons.

Author Contributions

All authors conceptualized the study. W.Z. designed and conducted the data analysis. M.S. conducted the data management. W.Z. is responsible for the integrity of the work. W.Z. drafted the manuscript. All authors participated in writing and revising the paper. All aspects of the study (design; management, analysis, and interpretation of data; preparing report; and decision to publish) were led by the authors. All authors read and approved the final manuscript.

Protection of Human and Animal Subjects

No human subjects were recruited for this study.

Funding

This study was supported with grant funding from the National Institutes of Health and National Library of Medicine (grant no.: NIH/NLM 1R01 LM013323–01, PIs: Vicki Hertzberg, Joyce Ho, Roy Simpson).

Conflict of Interest

None declared.

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