How Valid is the ICD-9-CM Based AHRQ Patient Safety Indicator for Postoperative Venous Thromboembolism?

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Background: Hospital administrative data are being used to identify patients with postoperative venous thromboembolism (VTE), either pulmonary embolism (PE) or deep-vein thrombosis (DVT). However, few studies have evaluated the accuracy of these ICD-9-CM codes across multiple hospitals.

Methods and Materials: The Agency for Healthcare Research and Quality (AHRQ) Patient Safety Indicator (PSI)-12 was used to identify cases with postoperative VTE in 80 hospitals that volunteered for either an AHRQ or University HealthSystem Consortium (UHC) validation project. Trained abstractors using a standardized tool and guidelines retrospectively verified all coded VTE events.

Results: In the combined samples, the positive predictive value of the set of prespecified VTE codes for any acute VTE at any time during the hospitalization was 451 of 573 = 79% (95% CI: 75%–82%). However, the positive predictive value for acute lower extremity DVT or PE diagnosed after an operation was 209 of 452 = 44% (95% CI: 37%–51%) in the UHC sample and 58 of 121 = 48% (95% CI: 42–67%) in the AHRQ sample. Fourteen percent of all cases had an acute upper extremity DVT, 6% had superficial vein thrombosis and 21% had no acute VTE, however, 61% of the latter had a documented prior/chronic VTE. In the UHC cohort, the sensitivity for any acute VTE was 95.5% (95% CI: 86.4%–100%); the specificity was 99.5% (95% CI: 99.4%–99.7%).

Conclusion: Current PSI 12 criteria do not accurately identify patients with acute postoperative lower extremity DVT or PE. Modification of the ICD-9-CM codes and implementation of "present on admission" flags should improve the predictive value for clinically important VTE events.

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The patient safety indicators (PSIs) were developed as a user-friendly tool to screen for adverse events that patients experience as a result of exposure to the health care system.[1] The PSIs were intended to provide information to hospitals about specific, "potentially preventable" complications, using readily available and inexpensive hospital administrative data. One of these PSIs (PSI-12), focuses on identification of postoperative venous thromboembolism (VTE), specifically deep vein thrombosis (DVT) of the lower extremities and/or pulmonary embolism (PE).

Using this PSI, the cases identified as having a prespecified operating room procedure together with one or more prespecified VTE code are assumed to have a postoperative acute VTE. Although all PSIs rely on ICD-9-CM coding of hospitalization records, the coding process for VTE may be particularly prone to inaccuracy. First, objective documentation of the presence of a DVT or PE by imaging is neither sufficient nor required, because coding rules require that only diagnoses cited by physicians or other providers responsible for patient care can be recorded.[2] Second, the available ICD-9-CM codes for venous thrombosis are complex and do not match clinical nomenclature and priorities. For example, 451 series codes for thrombosis of certain veins (eg, "femoral vein" = 451.11, "deep veins of upper extremities" = 451.82) are only applicable if the physician explicitly describes the clot using terms that are seldom used today (eg, "phlebitis" or "thrombophlebitis"). In comparison, 453 series codes are used to identify "venous embolism and thrombosis," but these codes do not allow specification of upper extremity DVT or thrombosis of a superficial vein. Complicating the issue further is the absence of any specific code for a recent subacute or chronic DVT requiring active treatment with an anticoagulant such as warfarin.

Early validation studies suggested that VTE codes in the principal diagnosis field have a very high positive predictive value (PPV) of approximately 95%.[3] However, several studies have documented PPVs of 70% to 75% for VTE

codes in secondary diagnosis fields,[4–6] and these studies have not focused on surgery cases. Leibson et al from the Mayo Clinic reported a PPV of only 35% for hospital acquired VTE,[7] and Zhan reported that the sensitivity and PPV of the VTE codes used to define PSI 12 were 68% and 29%, respectively.[8] This latter study used Medicare data, which allow a maximum of 9 diagnoses per hospitalization. However, a recent study using richer administrative data from the Veterans Affairs Patient Treatment File, linked with data from the National Surgical Quality Improvement Program, reported that PSI 12 had similar sensitivity and PPV of 56% and 22%, respectively.[9]

Because of the potential shortcomings of VTE coding, a validation study was undertaken to estimate the positive and negative predictive value, sensitivity, and specificity of the ICD-9-CM codes used in PSI 12 to detect postoperative VTE. The overall aim was to provide guidance regarding appropriate interpretation and use of the postoperative VTE PSI, and to potentially refine and improve how this PSI is specified.

METHODS

Hospitals

This report includes a pair of multicenter retrospective validation studies conducted by AHRQ and the University HealthSystem Consortium (UHC) that used similar sampling methods and abstraction tools. UHC is an alliance of 102 academic medical centers and their affiliated hospitals that foster collaboration to promote improved quality medical care. AHRQ invited hospitals through its quality indicators technical support list-serve to participate in a PSI pilot validation project.[10] Participation was voluntary, without compensation. The 47 participating AHRQ hospitals from 29 states included a spectrum of different characteristics, although they overrepresented not-for-profit, nonreligious hospitals (78% vs. 49% nationally) and underrepresented religious (4% vs. 11% nationally), public or district (14% vs. 24% nationally), and for-profit (4% vs. 16% nationally) hospitals. No hospitals that volunteered were denied participation if they had the capacity to run the AHRQ quality indicators software and conduct the medical record abstraction. UHC conducted a parallel benchmarking initiative concerning acute VTE. Thirty-three UHC teaching hospitals ("UHC hospitals") from 21 states volunteered to participate; 4 of these hospitals also participated in the AHRQ project, but there was no overlap of sampled cases.

Sampling

Verification biased sampling was used.[11] AHRQ hospitals applied a modified version of the PSI Windows software (v3.1) to obtain a probability sample of cases that met PSI 12 criteria and that were discharged October 1, 2005–March 31, 2007. Eligible cases had to be age 18 or older and have undergone a "valid operating room procedure," as defined by the Center for Medicare and Medicaid Services (although some of these procedures often occur in other settings).[10] Cases were ineligible if assigned to Major Diagnostic Category 14 (pregnancy and post partum), if the principal diagnosis was VTE, if age was less than 18 years, or if an inferior vena cava filter was placed before or on the same day as the first operation (or was the only procedure).

The AHRQ PSI software identifies ("flags") specific ICD-9-CM codes that are consistent with clinically important acute PE and acute DVT in the lower extremity (Table 1). These VTE codes were selected, after expert consultation and review of

TABLE 1. Venous Thromboembolism ICD-9-CM Codes

ICD-9-CM codes specified in PSI 12 and consistent with acute lower extremity venous thrombosis or pulmonary embolism.
Pulmonary embolism:
415.11–Iatrogenic pulmonary embolism and infarction
415.19–Other pulmonary embolism and infarction
Phlebitis and thrombophlebitis:
451.11–Phlebitis and thrombophlebitis, of deep veins lower extremities, femoral vein
451.19–Phlebitis and thrombophlebitis, of deep veins of lower extremities, other
451.2–Phlebitis and thrombophlebitis, of lower extremities, unspecified
451.81–Phlebitis and thrombophlebitis, of other sites, iliac vein
451.9–Phlebitis and thrombophlebitis, of unspecified site
Deep vein thrombosis, not of upper extremity:
453.2–Other venous embolism and thrombosis, of vena cava
453.40–Venous embolism and thrombosis of unspecified deep vessels of lower extremity
453.41–Venous embolism and thrombosis of deep vessels of proximal lower extremity
453.42–Venous embolism and thrombosis of deep vessels of distal lower extremity
453.8–Other venous embolism and thrombosis, of other specified veins
453.9–Other venous embolism and thrombosis, of unspecified site
ICD-9-CM codes not used in PSI 12 to identify acute lower extremity venous thrombosis or pulmonary embolism.
Phlebitis and thrombophlebitis:
451.82–Phlebitis and thrombophlebitis, of superficial veins of upper extremities
451.83–Phlebitis and thrombophlebitis, of deep veins of upper extremities
451.84–Phlebitis and thrombophlebitis, of upper extremity, unspecified
451.89–Phlebitis and thrombophlebitis, other (eg axillary, jugular, subclavian)
453.1–Thrombophlebitis migrans
Obstetric codes for thromboembolism:*
671.3 (0, 1, 3)–Deep phlebothrombosis, antepartum
671.4 (0, 2, 4)–Deep phlebothrombosis, postpartum
671.9 (0 to 4)–Unspecified venous complication (in pregnancy and the puerperium)
673.2 (0 to 4)–Obstetrical pulmonary embolism, obstetrical blood clot embolism
Complications affecting specified body systems, not elsewhere classified:†
997.2–Peripheral vascular complications
Past history of thromboembolism:
V12.51–Personal history of certain other diseases, venous thrombosis and embolism
V12.52–Personal history of certain other diseases, thrombophlebitis

*Pregnancy/puerperium was an exclusion criteria.
†This code should be used in conjunction with another ICD-9-CM code to specify the complication. These codes alone do not specify acute lower extremity VTE or PE.

prior studies, to achieve the optimal balance of sensitivity and specificity.[12] Codes for upper extremity phlebitis or thrombophlebitis, pregnancy associated thrombosis, and past history of VTE were not included. AHRQ hospitals reviewed only cases flagged with one or more of these qualifying codes.

The UHC used the same AHRQ PSI software to identify all records submitted to its Clinical Database with discharge dates from January 1, 2006 through March 31, 2007. The only difference in these eligibility criteria between the AHRQ and UHC sampling frames was that UHC additionally excluded patients admitted for whom "comfort care only" was ordered on the first day. Eligible cases at each UHC hospital were stratified according to VTE flag-positive status and separate simple random samples were drawn from each stratum in each hospital Twenty-five cases from each hospital were randomly identified, and the first 15 cases on each list were abstracted, although some hospitals had fewer than 15 eligible records and some abstracted more than 15 cases on each list. Hospital- and stratum-specific sampling fractions were calculated based on the stratum population and achieved sample sizes, with the inverse used as the sampling weight. As shown in Figure 1, there were 6546 UHC eligible VTE flag-positive surgery cases and 326,619 UHC eligible VTE flag-negative cases that underwent an operating room procedure.

Abstraction Tool

The research team worked collaboratively with the UHC's Postoperative DVT/PE Steering Committee to develop an abstraction tool that included a core set of questions designed to determine if the patient underwent a procedure in an operating room, if a DVT or PE was diagnosed during the hospital stay, if the VTE was documented by an imaging study, if the VTE was characterized as acute, prior or chronic, if the patient was treated for acute VTE, if the VTE was diagnosed before or after the surgical procedure (based on dates of operation and VTE diagnosis), and the most proximal location of the thrombus. Study staff initially pretested the tool at a university hospital and at 2 private hospitals, and made adjustments as appropriate. The abstraction process was terminated if the patient did not undergo a procedure in an operating room. The abstraction tool and accompanying guidelines can be viewed at http://www.qualityindicators.ahrq.gov/validationpilot.htm.[1]

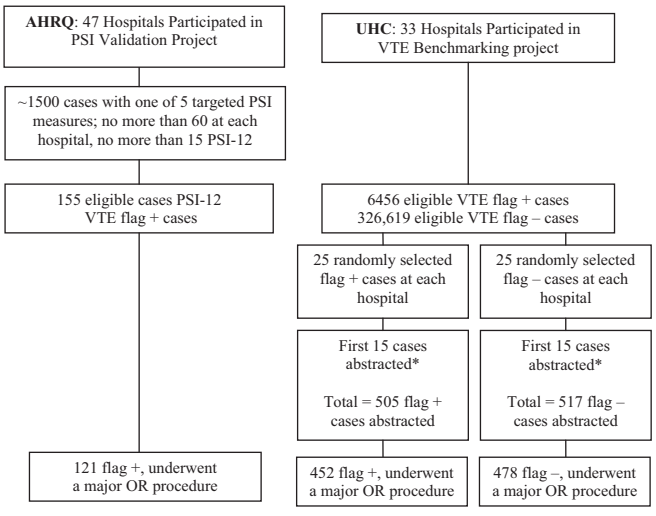

FIGURE 1. Flow diagram showing cases analyzed. *Some hospitals had fewer than15 eligible records, and some abstracted more than 15 cases on each list. AHRQ indicates Agency for Heathcare Research and Quality; UHC, University HealthSystem Consortium.

Abstraction Process

Abstractors were trained via teleconferences and/or web-based sessions led by study staff. The training sessions reviewed the rationale behind the instruments and provided guidance as to how to locate the required information in the medical record and how to complete the data collection tools. Data were either entered directly into a web-based application (UHC) or submitted on paper (AHRQ) before being entered into a database.

Variable Definitions

Each record was classified based on whether an operation was performed in an operating room (versus another location); the type of VTE event (acute, prior acute/chronic, or none); the timing of the VTE event (after vs. before operation); and the anatomic location (PE with or without venous thrombosis, lower extremity DVT without PE, upper extremity DVT without PE, or upper or lower extremity superficial vein thrombosis alone).

Because the PSI was intended to capture cases with lower extremity DVT or PE, cases flagged by PSI 12 were classified as true or false-positive based on 2 different gold standards: (*a*) evidence of any (including upper extremity or superficial venous thrombosis) acute hospital-acquired venous thrombotic event that was coded in compliance with current ICD-9-CM coding guidelines, and (*b*) evidence of a clinically more significant acute lower extremity/pelvic DVT or PE. For example, if a case that had an acute postoperative lesser saphenous vein (a superficial vein) thrombosis was coded as 453.8, this was classified as a true-positive for having an acute thrombosis and a valid code, but false-positive for having a lower extremity DVT or PE. These 2 approaches, which represent the professional coder's perspective and the clinician's perspective, respectively, provided high and low estimates of PPV because an acute VTE can be correctly coded but still not represent a clinically relevant DVT or PE.

Data Management and Analysis

Sensitivities, specificities, and predictive values were estimated using PROC SURVEYFREQ in SAS version 9.1 to adjust estimates for features of the sampling design, including the clustering of observations within hospital, the unequal sampling fractions and, for the UHC sample, the stratification of cases. Because AHRQ hospitals only abstracted flag-positive cases, the AHRQ sample was only used to estimate PPV. Because UHC assembled separate probability samples of approximately 15 flag-positive cases and approximately 15 denominator-eligible flag-negative cases from each hospital, the UHC sample was used to estimate sensitivity and

specificity, in addition to PPV and negative predictive value (NPV). Flag negative cases were sampled with much lower probability than flag-positive cases, resulting in a verification-biased sample. To correct for this, UHC estimates were computed using the inverse sampling fraction sampling weights described previously. Sampling weights were not used for estimates based on the AHRQ sample.

Sensitivity and specificity were estimated using ratio estimators, to properly account for the randomness in the identification of true case status. Exact binomial 95% confidence intervals were estimated for NPV, because the point estimate of NPV was 100%, which vitiated the use of the asymptotic variance estimators used in PROC SURVEYFREQ. Interval estimates for sensitivity were then estimated by first using Bayes' theorem to express sensitivity as a function of indicator prevalence and then substituting the endpoints of the reported 95% CI estimates for PPV and NPV into the expression to describe a range of plausible values. The AHRQ study was approved by the federal Office of Management and Budget and the Human Subjects Committee at the University of California, Davis. Each participating hospital was provided with a Notice of Data Use indicating that the collected data would be kept confidential, unless otherwise compelled by law, in compliance with the HIPAA provisions for disclosure of protected health information without subject authorization to a public health authority. Research use of the UHC data was also approved by the UC Davis Human Subjects Committee.

RESULTS

Figure 1 shows a flow diagram illustrating the case selection process for this study. We excluded 126 cases (11% of all 1177 abstracted records) from all analyses, either because the record was incomplete or because the patient did not undergo a procedure in an operating room. Review indicated that these cases frequently involved procedures performed in specialized suites, such as interventional cardiology procedures. No clinical information was abstracted from these records regarding VTE status.

Table 2 shows the demographic features of the study samples. Among flag + cases with a pre-specified VTE code, the mean age across both cohorts was 58 years and 46% were women. The most common types of operations were orthopedic, abdominal, peripheral vascular, and cardiac. The mean duration of hospital stay across both cohorts was 21 days, with a mode of 6 days. The non-VTE UHC cohort had a mean age of 53 years, 45% were women, and 88% underwent an operating room procedure on hospital day 0, 1, or 2.

As shown in Table 3, in the combined AHRQ and UHC samples, 451 of 573 (crude overall PPV = 79%, 95% CI: 75%–83%) VTE flag-positive cases identified using PSI-12

TABLE 2. Characteristics of the Study Groups

Variable	AHRQ Group VTE Flag Pos N (%)	UHC Groups	
		VTE Flag Pos N (%)	VTE Flag Neg N (%)
Total cases	155	505	517
Age, yr (mean ± SD)	62 ± 17	56 ± 17	53 ± 17
Gender (% female)	77 (50)	226 (45)	233 (45)
Operation, N			
Neurosurgery	16 (10.2)	20 (4.0)	34 (6.6)
Endocrine	1 (0.6)	0 (0.0)	3 (0.6)
Otolaryngologic	0 (0.0)	23 (4.6)	23 (4.5)
Thoracic	5 (3.2)	40 (8.0)	18 (3.5)
Cardiac	10 (6.5)	43 (8.5)	23 (4.5)
Vascular	16 (10.3)	46 (9.0)	29 (5.6)
Abdominal	29 (14.8)	74 (14.7)	82 (16.2)
Orthopedic	24 (15.5)	108 (21.4)	144 (27.9)
Urologic	3 (1.9)	15 (3.0)	39 (7.5)
Gynecologic	5 (3.2)	19 (3.8)	27 (5.2)
Skin breast	4 (2.6)	48 (9.5)	21 (4.1)
Lymph node/spleen	2 (1.3)	10 (2.0)	0 (0.0)
Other	6 (3.9)	4 (0.8)	22 (4.3)
No OR procedure or data missing, N	34 (22)	53 (10)	39 (8)
Underwent OR procedure, N	121	428*	465†
OR procedure before hospital day 3, N	69 (57)	272 (63.6)	407 (87.5)
OR procedure hospital day 3 or later, N	52 (43)	156 (36.4)	58 (12.5)
Length of stay, days (mean ± SD)	18.1 (±17.6)	22.5 (±24.4)	6.7 ± 9.1
Length of stay, d (mode)	7	6	2

*An additional 24 cases had an OR procedure but no date of surgery listed.
†An additional 13 cases had an OR procedure but no date of surgery listed.
SD indicates standard deviation; OR, operating room; Flag+, pre-specified VTE code present; Flag−, no pre-specified VTE code was present.

TABLE 3. Thromboembolism Among Cases Identified Using Patient Safety Indicator-12 That Underwent an Operating Room Procedure*

Group	AHRQ Sample (%)		UHC Sample (Weighted %)			Combined Sample (Crude %)		
Cases that underwent a major operating room procedure, N	121		452			573		
No acute VTE, N (%)	20 (17)		102 (23)			122 (21)		
Prior or chronic VTE, N (%)	12 (60)		62 (68)			74 (61)		
No mention of prior VTE, N (%)	8 (40)		40 (32)			48 (39)		
Acute venous thrombosis N (%)	101 (83)		350 (77)			451 (79)		
Acute Venous Thrombosis Events N (% of Acute VTE)	**Before Operation N (%)**	**After Operation N (%)**	**Before Operation N (%)**	**After Operation N (%)**	**Time of Event Not Documented N (%)**	**Before Operation N (%)**	**After Operation N (%)**	**Time of Event Not Documented N (%)**
Total acute VTE events	24 (24)	77 (76)	49 (11)	282 (86)	19 (3)	73 (16)	359 (80)	19 (3)
PE (with or without DVT)	2 (8)	16 (21)	13 (18)	106† (33)	6 (32)	15 (21)	122 (34)	6 (32)
Lower extremity DVT	14 (58)	42 (55)	15 (28)	103 (37)	5 (26)	29 (40)	145 (40)	5 (26)
Upper extremity DVT	7 (30)	11 (14)	13 (27)	47 (21)	5 (26)	20 (27)	58 (16)	5 (26)
Superficial vein phlebitis	1 (4)	4 (5)	6 (15)	21 (8)	2 (11)	7 (10)	25 (7)	2 (11)
Thrombosis, Unkn site	0 (0)	4 (5)	2 (12)	5 (1)	1 (5)	2 (3)	9 (3)	1 (5)

OR indicates operating room.

*Percentages for UHC sample reflect fully weighted estimates based on stratum-specific sampling fractions. The numbers of cases reflect the actual numbers in the abstracted sample. Hence, the percentages shown may differ from those that would be computed from the numbers shown.

†99 (93%) PE cases were clinically confirmed, 7 (7%) were treated for PE without radiographic confirmation.

TABLE 4. Predictive Value of PSI-12 Among Cases That Underwent an Operating Room Procedure

	AHRQ Sample (N = 121 Cases)		UHC Sample (N = 452 Cases)		Combined Sample (N= 573 Cases)	
Group Time	**Any Time During Hospitalization N, Crude PPV%* (95% CI)**	**After Operation N, Crude PPV%* (95% CI)**	**Any Time During Hospitalization N, Weighted PPV% (95% CI)**	**After Operation N, Weighted PPV% (95% CI)**	**Any Time During Hospitalization N, Crude PPV%* (95% CI)**	**After Operation N, Crude PPV%* (95% CI)**
Gold standard: any acute venous thrombosis or PE	101, 84% (CI: 72–95)	77, 64% (CI: 54–72)	350, 77% (CI: 69–84)	282, 63% (CI: 57–69)	451, 79% (CI: 75–82)	359, 63% (CI: 59–67)
Gold standard: acute lower extremity DVT or PE	74, 61% (CI: 50–72)	58, 48% (CI: 42–67)	248, 51% (CI: 44–58)	209, 44% (CI: 37–51)	322, 56% (CI: 52–60)	267, 47% (CI: 42–52)

*95% CI adjusted for clustering.

had *any* acute documented VTE at any time during the hospitalization. Three hundred fifty-nine of 573 (crude PPV = 63%, 95% CI: 59%–67%) cases had any acute VTE diagnosed after the operation, 73 (13%) had an acute VTE before the operation and 19 (3%) had an acute VTE event, but the time of the event relative to the day of surgery could not be determined.

Eighty-three (14%) of all the acute VTE cases had an acute upper extremity DVT, 34 (6%) had superficial vein thrombosis, and 12 (2%) had thrombosis at an unknown site. Among the 122 (21%) false-positive cases that did not have acute VTE, 74 (61%) had a documented prior/chronic VTE, which was presumably present at admission, and there simply was no mention of a prior/chronic VTE in the abstracted record in the remaining 48 (39%) cases.

Using as the gold standard criterion an objectively documented acute lower extremity DVT or PE, 322 of 573 cases (crude PPV = 56%, 95% CI: 52%–60%) had an acute event at any time during the hospitalization (Table 4). However, only 267 of 573 (crude PPV = 47%, 95% CI: 42%–52%) cases had a lower extremity DVT or PE that occurred after an operation: 209 of 452 (fully weighted PPV = 44%, 95% CI: 37%–51%) in the UHC cohort and 58 of 121 (crude PPV = 48%, 95% CI: 42%–67%) in the AHRQ cohort.

Among 517 UHC cases flag-negative (no VTE code) cases, 478 (92%) underwent a procedure in an operating room. Only 1 of these 478 cases had a confirmed VTE (NPV = 99.9%; 95% CI: 99.9%–100%). This single case involved a knee operation complicated by "thrombosis" of the lesser

saphenous vein, a superficial vein in the leg, which should have been coded as 453.8.

Among cases that underwent an operating room procedure, the adjusted sensitivity, specificity, and predictive values of VTE coding for events occurred at any time during the hospitalization are summarized in Table 5. Values based on the fully weighted UHC samples are compared with unweighted PPV estimates from the AHRQ sample. The PPV for any acute VTE at any time was 77% (95% CI: 69%–84%) in the UHC cohort and 84% (95% CI: 72%–95%) in the AHRQ sample. The sensitivity of coding for any acute VTE was 95.5% (95% CI: 86%–100%), due to the 1 false-negative case described above, but the sensitivity was 100% (95% CI: 48%–100%) for acute lower extremity DVT or PE.

A sensitivity analysis was performed to ascertain how restricting the PSI-12 definition to include only cases undergoing an operation on hospital day 0, 1, or 2 would affect its performance. In this analysis, 57 of the 73 (78%) cases diagnosed with acute VTE before surgery would not have been flagged, at the expense of excluding 205 (36%) of the confirmed VTE cases that underwent an operating room procedure.

DISCUSSION

The AHRQ PSI for postoperative VTE (PSI-12) uses ICD-9-CM coded hospital data to identify patients who underwent an operating room procedure and developed acute postoperative VTE before discharge, as evidenced by a secondary diagnosis of VTE. Prior studies using Medicare data have suggested that this PSI does not accurately identify postoperative acute VTE.[8] However, Medicare data are limited to only 8 secondary diagnoses, which may lead to significant underdetection of VTE. The present study was undertaken to determine the performance of the VTE PSI using all available diagnosis fields in data from a large number of hospitals throughout the United States.

We found that the PSI software identified not only patients who underwent an operating room procedure, but also patients who underwent other moderately invasive procedures. Fully 10% of the patients identified by the PSI underwent a procedure in a setting other than an operating room, such as a cardiac catheterization or interventional radiology suite. This finding was not unexpected because ICD-9-CM codes do not distinguish procedures performed in different settings. We excluded these patients from our primary analysis because the records were not fully abstracted, but we acknowledge that these patients were still at risk for developing VTE. Future studies will need to address the performance of PSI 12 in this subset of patients.

From the standpoint of identifying any acute hospital-acquired VTE, the PPV of PSI 12 was moderately high in both the AHRQ sample (83%) and the UHC sample (77%). The majority of false-positive cases were patients with a prior/chronic thrombosis that was either "present on admission" (POA) or a prior/chronic thrombosis that had clinically resolved, but that was still under treatment at admission. We were unable to estimate how many of the prior/chronic VTE events were diagnosed in the year before the index hospitalization. False-negative errors were extremely rare, with an estimated sensitivity in the UHC sample of 100% for identifying acute lower extremity or pelvic DVT or PE and 95.5% for identifying any acute venous thrombosis.

From a quality-of-care perspective, identification of patients with postoperative PE or lower extremity DVT is most salient. Of the abstracted cases that had any acute VTE event either before or after operation, only 72% had a documented lower extremity DVT or PE, and the remainder had thrombosis at other sites: 19% had upper extremity DVT, 8% had a superficial venous thrombosis alone, and in 1% the site was not specified. Applying our strictest definition of true positives, only 267 of the 573 (47%) patients who underwent an operating room procedure had an acute lower extremity DVT or a PE diagnosed after the operation. This estimate likely represents a lower bound for the true PPV of PSI-12, because some of the 55 cases with an acute lower extremity DVT or PE that was diagnosed before surgery (N = 44) or that occurred at an unknown time relative to surgery (N = 11) presumably developed in the hospital and were, therefore, potentially avoidable events.

The implications of these findings are straightforward. The PPV of this indicator, as presently constructed, appears to be too low to support some potential functions of a quality-of-care indicator, such as public comparison of hospitals and pay-for-performance. However, with specific changes to the PSI software and ICD-9-CM codes for VTE, the PPV could be greatly improved. First, if the PSI software were modified to require that all flagged events be coded as not present on admission (based on the new standard for Medicare inpatient claims), then most of the false-positive cases that had prior or chronic VTE would not have been captured. One study of New York and California hospitalizations suggested that POA coding may be particularly important in identifying in-hospital postoperative VTE because over 50% of secondary diagnoses of VTE were reported as present on admission.[13] POA reporting has been shown to improve the PPV of ICD-9-CM codes for hospital acquired VTE, but at the expense of a higher false-negative rate due to

TABLE 5. Fully Weighted and Adjusted Sensitivity, Specificity and Predictive Value of Patient Safety Indicator-12 for Acute VTE at Any Time During the Hospitalization

Parameter	Gold Standard: Any Acute VTE or PE* (95% CI)	Gold Standard: Acute Lower Extremity DVT or PE† (95% CI)
UHC cohort		
Sensitivity	95.5% (86.4–100)	100% (53.3–100)
Specificity	99.5% (99.4–99.7)	99% (98.8–99.2)
Positive predictive value	76.8% (69.2–84.4)	50.9% (43.7–58.1)
Negative predictive value	99.9% (99.8–100)	100% (99.2–100)
AHRQ cohort		
Positive predictive value	84% (72–95)	61% (50–72)

*Confirmed acute thrombotic event during hospital stay that included an operating room procedure, with an eligible ICD-9-CM code for VTE (Table 1).

†Lower Extremity DVT or PE: confirmed acute lower extremity deep vein thrombosis or pulmonary embolism, with an eligible ICD-9-CM code.

‡Based on fully weighted UHC samples.

misclassification of some acute events as POA,[7] presumably due to confusion about when the acute thrombosis began. Other recent studies have suggested that the PPV of coding for hospital-acquired VTE would be greatly improved if each diagnosis was marked as being either "present on admission" or developing during the hospitalization,[13–16] as recently required by Medicare. However, this change will not fully resolve the problem, because some subacute or chronic thromboses are initially diagnosed after admission. For this reason, AHRQ submitted a proposal to the ICD-9-CM Coordination and Maintenance Committee to create new ICD-9-CM codes to identify patients admitted on treatment for subacute or chronic VTE.[17]

Second, if the PSI software selected only cases that underwent an operative procedure on hospital day 0, 1, or 2, we estimate that the number of false-positive VTE cases occurring "before surgery" would decrease by 78%, and the PPV would increase from 76% to 84%, but the total number of cases identified would decrease by 36%.

Revision of ICD-9-CM coding is also necessary to properly categorize the anatomic location of some venous thromboses. In the proposal currently under consideration, new codes would specifically identify upper extremity DVT and both upper and lower extremity "superficial vein" thrombosis. In the current study, 18% of the patients who had an acute VTE event had an upper extremity DVT. The majority of these patients were coded as having "other venous thrombosis" (453.8) or "unspecified" site of venous thrombosis (453.9). In fact, there currently are *no* VTE codes that specify "superficial venous thrombosis" of veins in either the upper or lower extremity. Instead, the term "phlebitis" or "thrombophlebitis" has to be mentioned in order for a thrombotic event to be coded as involving the upper or lower extremity.

Although this is the first study to assemble data from a large and diverse sample of hospitals on the accuracy of ICD-9-CM codes for postoperative VTE, and to explore the reasons for false-positive errors, it has several limitations. First, all hospitals participated voluntarily, and may therefore have had better or worse coding practices relative to the national average. Empirically, the average rate of PSI 12 among AHRQ hospitals was 13.5 per 1000 eligible cases, compared with the national average among nonfederal hospitals of 10.4. Second, all data were collected by individuals working at the participating hospitals, with no mechanism for duplicate abstraction to ensure reliability. Third, abstractors could only review the information contained in sampled records, and were unable to query physicians to obtain additional data. For this reason, we were unable to explain all of the apparent false-positive cases. Fourth, coding practice may vary between coders and between coding teams, and this source of variation was not determined.

In summary, the accuracy of the ICD-9-CM codes used to define PSI 12 was relatively high, with an estimated sensitivity of 95.5% and an estimated PPV for any venous thrombotic event in the range of 77% to 83%. Many of the false-positive cases had chronic thromboses that probably would have been reported as POA and thereby excluded if POA reporting had been required at the time. Nevertheless, about 50% of the patients flagged by PSI 12 actually had a documented, clinically relevant, acute postoperative PE or lower extremity DVT. This discrepancy can be largely attributed to the absence of ICD-9-CM codes that specify prior acute or chronic thromboses, upper extremity and thoracic DVT, and superficial lower extremity thromboses, although poor physician documentation and overt coding errors also contributed. Revision of the relevant ICD-9-CM codes should narrow the discrepancy between the coding validity and the clinical validity of this indicator. By improving the ICD-9-CM codes for VTE, clarifying coding guidelines, and incorporating the recently implemented POA field into the indicator logic, the PPV of this indicator should increase sufficiently to make it a useful tool for identifying patients with clinically relevant postoperative venous thrombosis.

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