Supplementary Online Content

Bilimoria KY, Chung J, Ju MH, et al. Evaluation of Surveillance Bias and the Validity of the Venous Thromboembolism Quality Measure. *JAMA*. doi: 10.1001/jama.2013.280048.

eTable 1. Codes Used to Identify Study Population, VTE Imaging, and VTE Events

eTable 2. Variables Included in the Risk-Adjusted Analysis with Additional Patient-Level Risk Factors

eTable 3. Hospital Characteristics and VTE Process and Outcome Measure Performance by Quartile of Hospital Structural Quality Score

eTable 4. Comparison of Patients Included vs. Excluded from the Analytic Cohort (Medicare Claims Dataset)

eTable 5. Results of Quantile Regression Examining the Association between Hospital VTE Imaging Rates and Hospital VTE Event Rates

eTable 6. Mean Risk-Adjusted VTE Rate per 1,000 Discharges by VTE Imaging Use Rate Quartile with Adjustment Based on Alternative Modeling Approaches

This supplementary material has been provided by the authors to give readers additional information about their work.

eTable 1. Codes used to Identify Study Population, VTE Imaging, and VTE Events.

Study Population

Our study population was composed of all Medicare beneficiaries who underwent one of the following types of surgeries as an inpatient stay in 2009 or 2010, as identified on the basis of the following *International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM), 9th Edition* procedure codes for principal procedure (and diagnosis codes for some procedures) recorded in the Centers for Medicare and Medicaid Services (CMS) Medicare Provider Analysis and Review (MedPAR) File:

1. Colon Surgery (procedure codes *17.3, 17.31, 17.32, 17.33, 17.34, 17.35, 17.36, 17.39, 45.7, 45.71, 45.72, 45.73, 45.74, 45.75, 45.76, 45.79, 45.8, 45.81, 45.82, or 45.83*)
2. Rectal Surgery (procedure codes *48.4, 48.40, 48.41, 48.42, 48.43, 48.49, 48.5, 48.50, 48.51, 48.52, 48.59, 48.6, 48.61, 48.62, 48.63, 48.64, 48.65, or 48.69*)
3. Total Knee Surgery (procedure codes *81.54 or 81.55*)
4. Craniotomy (procedure codes *01.51, 01.59, 01.6, 04.01, 07.59, 07.61, 07.62 07.63, 07.64, 07.65, 07.68, 07.69, 38.31, 38.32, 38.41, 38.81, 38.82, 39.28, 01.21, 01.23, 01.24, 01.25, 01.31, 01.32 or 01.39*)
5. Pancreas Surgery (procedure codes *52.5, 52.51, 52.52, 52.53, 52.59, 52.6 or 52.7*)
6. Esophagus Surgery (procedure codes *42.4, 42.40, 42.41, 42.42 or 43.99*)
7. Lung Resection (procedure codes *32.3, 32.30, 32.39, 32.4, 32.41, 32.49, 32.5, 32.50, 32.59, 32.1x, 32.29 32.3x, 32.5x or 32.4x*)
8. Gastric Bypass (procedure codes *44.31, 44.38 or 44.39*; and diagnosis codes *278.01, 278.00, 289.0, 278.1 or 278.8*)
9. Abdominal Aortic Aneurysm Surgery (procedure codes *38.34, 38.44, 38.64, 39.25 or 39.71;* and diagnosis codes *441.4 or 441.9*)
10. Coronary Artery Bypass Graft Surgery (procedure codes *36.10, 36.11, 36.12, 36.13, 36.14, 36.15, 36.16, 36.17, 36.19*)
11. Cystectomy (procedure codes *57.6, 57.7, 57.71, 57.79*)

Our study population was based on denominator definitions in the Technical Specifications for the Agency for Healthcare Research and Quality (AHRQ) Patient Safety Indicator (PSI) #12 *Postoperative Pulmonary Embolism or Deep Vein Thrombosis Rate* (available at http://www.qualityindicators.ahrq.gov). Specifically, our sample excluded observations from our study population according to the PSI-12 specifications:

- A principal diagnosis of deep vein thrombosis (DVT) or pulmonary embolism (PE) (ICD-9-CM diagnosis codes *45111, 45119, 4512, 45181, 4519, 45340, 45341, 45342, 4538, 4539, 4151, 41511, 4513 or 4519*)
- A secondary diagnosis of DVT or PE that was present on admission
- For whom interruption of vena cava was the only surgical procedure performed (ICD-9-CM procedure code *387*)
- For whom an interruption of vena cava was not performed on or prior to the day of the first surgical procedure

- Who had missing data on patient age, sex, date of discharge, and/or principal diagnosis

Identification of VTE, DVT, and PE Events

Identification of DVT and PE events were based on AHRQ PSI-12 numerator definitions using up to 24 secondary diagnosis codes in MedPAR. These codes were as follows:

- DVT (diagnosis codes *45111, 45119 , 4512, 45181, 4519, 45340, 45341, 45342, 4538, 4539*)
- PE (diagnosis codes *4151, 41511, 41513, 41519*)

Condition-Present-On-Admission indicators associated with each secondary diagnosis field were used to eliminate preexisting DVT and PE. VTE events were identified by the presence of DVT or PE, as defined above.

Identification of VTE/DVT/PE Surveillance Imaging

Surveillance imaging for DVT and PE was identified using administrative codes located in MedPAR, CMS Carrier Claims (physician billing), and CMS Institutional Outpatient Claims Research Identifiable Files.

MedPAR. DVT and PE-related imaging was identified in MedPAR by searching up to 24 secondary procedure codes for the following ICD-9-CM procedure codes:

- DVT imaging
  - *8877 Venous Duplex Ultrasound*
- PE Imaging
  - *8843 CT Pulmonary Arteriography*
  - *8866 Venogram*
  - *9215 Ventilation-Perfusion Scan*

VTE imaging was defined as receipt of any of the above imaging procedures.

Imaging for DVT and PE was identified in Inpatient and Outpatient Revenue Center and Carrier Line Item files using the following Healthcare Common Procedure Coding System (HCPCS) codes for procedures occurring on or after the index surgery date and prior to the date of discharge:

- DVT imaging
  - *93970, 93971 Venous Duplex*
- PE imaging
  - *71260, 71250, 71270, 71275 CT Chest Scan*
  - *78585, 78584, 78580,l 78599, 78598, 78597, 78582 Ventilation-Perfusion Scan*
  - *71550, 71551,l 71552, 71555 Chest MRI*
  - *75741, 75743, 75746, 75820, 75822, 78445, 78456, 78457, 78458 Venogram*

eTable 2. Variables Included in the Risk-Adjusted Analysis with Additional Patient-Level Risk Factors

- Patient age (continuous)
- Patient sex: male (reference category); female
- Patient race: White (reference category), Black, Asian, Hispanic, Other
- ICD-9 Procedure Group: <*Colon Surgery*> 1 (ICD-9 Procedure Codes 17.3X); 2 (45.7X); 3(45.8X); <*Rectal Surgery*> 4 (48.4X); 5 (48.5X); 6 (48.6X); <*Total Knee Surgery*> 7 (81.5X); <*Craniotomy*> 8 (01.2X); 9 (01.3X); 10 (01.5X); 11 (04.0X); 12 (07.6X); 13 (38.3X, 38.4X, 39.2X); <*Pancreas Surgery*> 14 (52.5X); 15 (52.6X); 16 (52.7X); <*Esophagus Resection*> 17 (42.4X); 18 (43.9); < *Lung Resection* > 20 (32.1, 32.2); 21 (32.3); 22 (32.4); 23 (32.5); <*Gastric Bypass*> 24 (44.3X); <*Abdominal Aortic Aneurysm Repair*> 25 (38.X); 26 (39.X); <*Coronary Artery Bypass Graft Surgery*> 27 (36.1X); <*Cystectomy*> 28 (57.6X); 29 (57.7X)
- Admission Source: physician referral (reference category); clinic referral; transfer from hospital; transfer from SNF or other healthcare facility; emergency room; other
- Admission Type: elective (reference category); emergency; urgent; other/unknown; trauma
- Elixhauser comorbidities (a set of dichotomous indicators for each comorbidity): congestive heart failure; valvular disease; pulmonary circulation disorders (not included in models of pulmonary embolism); peripheral vascular disorders; hypertension – uncomplicated; hypertension – complicated; paralysis; other neurological disorders; chronic pulmonary disease; diabetes – uncomplicated; diabetes – complicated; hypothyroidism; renal failure; liver disease; peptic ulcer disease excluding bleeding; AIDS; lymphoma; metastatic cancer; solid tumor; rheumatoid arthritis/collagen vascular disease; coagulopathy; obesity; weight loss; fluid and electrolyte disorders; blood loss anemia; deficiency anemias; alcohol abuse; drug abuse; psychoses; depression. (VTE risk factors include many of the above, particularly solid organ malignancy, metastatic cancer, obesity, paralysis, diabetes, and many other potential risk factors)

eTable 3. Hospital Characteristics and VTE Process and Outcome Measure Performance by Quartile of Hospital Structural Quality Score

	Total	Structural Quality Score Quartiles*			
		Quartile 1	Quartile 2	Quartile 3	Quartile 4
Hospitals from Hospital Compare, n (%)	2838	700 (24.67%)	760 (26.78%)	562 (19.80%)	816 (28.75%)
Structural quality characteristics					
Total Bed Size >= 300 beds, n (%)	768 (27.06%)	5 (0.71%)	43 (5.66%)	104 (18.51%)	616 (75.49%)
Joint Commission Accreditation, n (%)	2428 (85.55%)	417 (59.57%)	694 (91.32%)	528 (93.95%)	789 (96.69%)
ACS CoC Accreditation, n (%)	1303 (45.91%)	12 (1.71%)	155 (20.39%)	414 (73.67%)	722 (88.48%)
ACGME Accreditation, n (%)	746 (26.29%)	7 (1.00%)	48 (6.32%)	95 (16.90%)	596 (73.04%)
Level I Trauma Certification, n (%)	309 (10.89%)	2 (0.29%)	21 (2.76%)	35 (6.23%)	251 (30.76%)
Burn Service	130 (4.58%)	0 (0.00%)	5 (0.66%)	10 (1.78%)	115 (14.09%)
Transplant Service	381 (13.42%)	1 (0.14%)	22 (2.89%)	31 (5.52%)	327 (40.07%)
Quality and Cost Reporting to Community, n (%)	1853 (65.29%)	115 (16.43%)	532 (70.00%)	469 (83.45%)	737 (90.32%)
Number of structural quality characteristics					
Mean (SD)	2.79 (1.77)	0.80 (0.40)	2.00 (0.00)	3.00 (0.00)	5.09 (1.22)
Range (minimum, maximum)	(0, 8)	(0, 1)	(2, 2)	(3, 3)	(4, 8)
VTE Measure Performance					
SCIP-VTE-2 adherence rate, mean (95% CI)	94.51 (94.29 - 94.73)	93.27 ‡ (92.65 - 93.90)	94.31 ‡ (93.88 - 94.73)	94.94 (94.56 - 95.31)	95.47 (95.19 - 95.74)
PSI-12 VTE rate per 1,000 discharges, mean (95% CI)	5.35 (5.24 - 5.45)	4.77 ‡ (4.59 - 4.95)	4.98 ‡ (4.79 - 5.17)	5.07 (4.87 - 5.28)	6.37 (6.16 - 6.58)
SCIP-VTE-2 poor performers, n (%)§	828 (29.18%)	249 (35.57%)	245 (32.24%)	147 (26.16%)	187 (22.92%)
PSI-12 poor performers, n (%)§	742 (26.15%)	134 (19.14%)	162 (21.32%)	131 (23.31%)	315 (38.60%)

*Quartiles based on total number of hospital structural quality characteristics.

‡ p<0.001, two-tailed test for differences in means compared to Quartile 4 mean after Bonferroni correction for multiple pairwise comparisons.

§ p<0.001, Cochran-Armitage trend test across ordered groups of hospitals categorized by the structural quality score

eTable 4. Comparison of Patients Included vs. Excluded from the Analytic Cohort (Medicare Claims Dataset)

	Included in Analytic Cohort	Excluded from Analytic Cohort
Number of Hospitals (from the patient-level Medicare dataset)	2,786	518
Number of Medicare beneficiaries (from the patient-level Medicare dataset)	954,926	9,421
Age in years, mean (SD)	74.68 (6.6)	74.51 (6.7)
Number of Elixhauser comorbidities, mean (SD)	2.04 (1.2)	1.86 (1.3)
Transfer status, n (%)	33,863 (3.6)	73 (0.8)
Type of surgery, n (%)		
Abdominal aortic aneurysm repair	42,429 (4.5)	49 (0.5%)
Colectomy	159,058 (16.7)	2,941 (31.2)
Coronary artery bypass graft surgery	131,949 (13.8)	91 (1.0)
Craniotomy	54,597 (5.7)	137 (1.5)
Cystectomy	10,023 (1.1)	43 (0.5)
Esophageal resection	4,423 (0.5)	15 (0.2)
Gastric bypass	3,641 (0.4)	85 (0.9)
Lung resection	39,390 (4.1)	83 (0.9)
Pancreatic resection	9,180 (1.0)	24 (0.3)
Proctectomy	18,871 (2.0)	214 (2.3)
Total knee arthroplasty	480,965 (50.4)	5,739 (60.9)

eTable 5. Results of Quantile Regression Examining the Association between Hospital VTE Imaging Rates and Hospital VTE Event Rates

	Quantile Regression Coefficient for VTE Imaging Rate (95% Confidence Interval)					
	25th Quantile	Median	75th Quantile	85th Quantile	95th Quantile	99th Quantile
VTE						
Observed	0.024‡ (0.015-0.032)	0.085‡ (0.079-0.092)	0.012‡ (0.107-0.125)	0.136‡ (0.125-0.146)	0.200‡ (0.173-0.227)	0.229‡ (0.118-0.339)
Risk-Adjusted	0.025‡ (0.016-0.033)	0.061‡ (0.056-0.067)	0.066‡ (0.060-0.073)	0.079‡ (0.068-0.089)	0.129‡ (0.102-0.156)	0.457‡ (0.293-0.620)
DVT						
Observed	*	0.055‡ (0.049-0.060)	0.121‡ (0.114-0.127)	0.146‡ (0.136-0.156)	0.207‡ (0.183-0.230)	0.294‡ (0.205-0.383)
Risk-Adjusted	*	0.050‡ (0.045-0.055)	0.098‡ (0.091-0.104)	0.116‡ (0.106-0.125)	0.186‡ (0.162-0.210)	0.263‡ (0.136-0.390)
PE						
Observed	*	0.088‡ (0.078-0.098)	0.157‡ (0.145-0.169)	0.167‡ (0.148-0.187)	0.200‡ (0.156-0.244)	0.307‡ (0.149-0.464)
Risk-Adjusted	*	0.086‡ (0.076-0.096)	0.131‡ (0.119-0.143)	0.141‡ (0.123-0.158)	0.180‡ (0.139-0.222)	0.250‡ (0.133-0.368)

*Could not be estimated because of excess zeroes. ‡p<0.01 for test that coefficient is significantly different from zero. N=2,787 hospitals with non-zero VTE imaging rates and/or total observations ≥10.

eTable 6. Mean Risk-Adjusted VTE Rate per 1,000 Discharges by VTE Imaging Utilization Rate Quartile
with Adjustment Based on Alternative Modeling Approaches

	VTE Imaging Utilization Rate Quartiles			
	Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
Number of hospitals	697	696	708	685
VTE imaging rate per 1,000 discharges				
Mean, (95% C.I.)	31.53‡ (30.68-32.39)	61.61‡ (61.06-62.17)	91.21‡ (90.43-91.98)	167.05 (161.95-172.15)
Range (minimum, maximum)	2.72, 48.54	48.57, 74.69	74.70, 111.11	111.52, 612.90
VTE event rate per 1,000 discharges *(Adjustment Based on More Comprehensive Patient-Level Risk-Adjustment Model)*	4.97‡ (4.36-5.58)	7.50‡ (6.87-8.13)	10.06‡ (9.29-10.83)	13.37 (11.98-14.77)
VTE event rate per 1,000 discharges *(Adjustment Based on Hierarchical Risk-Adjustment Model with Hospital Random Intercepts)*	4.96‡ (4.49-5.42)	7.39‡ (6.93-7.85)	9.06 (8.53-9.60)	9.91 (9.25-10.58)

‡p<0.001, two-tailed test for differences in means compared to Quartile 4 mean after Bonferroni correction for multiple pairwise comparisons.