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FULL PAPER

Large hospital variation in the utilization of Post-procedural CT to detect pulmonary embolism/Deep Vein Thrombosis in Patients Undergoing Total Knee or Hip Replacement Surgery: Japanese Nationwide Diagnosis Procedure Combination Database Study

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Objective: The purpose of the study was to investigate variation in the use of in-hospital CT for venous thromboembolism (VTE) detection after total knee or hip replacement (TKR/THR) among surgical patients, using a nationwide Japanese in-hospital administrative database.

Methods: This retrospective study using a national administrative database (4/2012–3/2013) extracted patients who underwent TKR/THR surgeries at hospitals meeting the annual case-volume threshold of ≥ 30 . Hospitals were categorized into three equally sized groups by frequency of postoperative CT use (low, middle, and high CT use group) to compare baseline patient-level and hospital-level characteristics. To further investigate between-hospital variation in CT usage, we fitted a hierarchical logistic regression model including hospital-specific random intercepts and fixed patient- and hospital-level effects. The intra class correlation coefficient was used to measure the amount of variability in CT use attributable to between-hospital variation.

Results: A total of 39,127 patients discharged from 447 hospitals met the inclusion criteria. The median hospital stay was 25 days (interquartile range, 20 – 32) and 7,599 (19.4%) patients underwent CT for VTE. CT utilization varied greatly among the hospitals; the crude frequency ranged from 0 to 100 % (median, 7.3 %; interquartile range, 1.8 – 18.3 %). After adjustment for known hospital- and patient-level factors related to CT use, 47 % of the variation in CT use remained attributable to the behavior of individual hospitals.

Conclusion: We observed large inter hospital variability in the utilization of post-procedure CT for VTE detection in this Japanese TKR/THR cohort, suggesting that CT utilization is not optimized across the nation.

Advances in knowledge: We observed significant variability in the utilization of post-procedure CT for VTE detection among inpatients who underwent TKR/THR surgeries in a large sample of Japanese hospitals. The large variation suggests that CT utilization is not optimized across the nation, and that there may be potential overutilization of the technology in the highest CT use hospitals.

INTRODUCTION

Improved access to CT imaging, its high diagnostic accuracy and ability to detect ancillary findings or to make an alternative diagnosis, and a recent trend toward defensive medicine have lowered the threshold for performing CT to

detect pulmonary embolism (PE), and the overuse of this technology in outpatient clinics and emergency departments has been discussed.^{1–4} However, recent data derived from a nationwide database in the United States showed that in-hospital post-procedural CT for PE after total knee

replacement (TKR) or total hip replacement (THR) surgery may not be overused,⁵ while acute PE is a widely acknowledged in-hospital complication after TKR/THR surgery.^{6,7} One possible reason for a relatively homogeneous CT use in TKR/THR patients in the United States may be the fixed payment for inpatient services, which drives hospitals to refrain from performing costly examinations.

The United States introduced the fixed payment system for inpatient services in Medicare, known as the Prospective Payment System (PPS), in 1983. The PPS is based on diagnosis-related groups (DRGs) and was designed primarily to control health care spending and to reduce the variation in the level of health spending across hospitals. All hospitals were required to participate in the Medicare PPS if they met certain criteria. Japan implemented a per diem payment system based on diagnosis procedure combination for inpatient care for hospitalizations, termed the Diagnosis Procedure Combination (DPC), in 2003.⁸ However, variation in in-hospital use of CT for PE detection after TKR/THR in Japan remains unknown.

The purpose of the present study was to demonstrate the variation in the overall use of CT for PE/DVT detection among TKR/THR surgical inpatients, using a nationwide Japanese administrative database.

METHODS AND MATERIALS

This retrospective cohort study was approved by the Institutional Review Board of [blinded], which waived the requirement for patient informed consent because of the anonymous nature of the data.

Data source

We used the DPC database created utilizing the Japanese case-mix system, which is similar to the DRG classification system. The DPC database contains data from the admission/discharge abstracts and administrative claims of approximately 7,000,000 inpatients in more than 1000 hospitals throughout Japan,^{9,10} covering approximately half of all inpatient admissions to acute-care hospitals in Japan. All 82 teaching hospitals in Japan are obligated to adopt the DPC system, and adoption by community hospitals is voluntary. The DPC Study Group (<http://www.dpcsg.jp/>), funded by the Ministry of Health, Labor and Welfare of Japan, collected anonymous data under an agreement of data use for research purposes made between the Study Group and each hospital.

The DPC data on inpatient care include age, sex, body mass index (BMI), smoking status, main diagnoses, comorbidities at admission, and complications during hospitalization, all of which were recorded by attending physicians using the International Classification of Diseases and Related Health Problems 10th Revision (ICD-10) codes. The database also contains detailed medical information: interventional/surgical procedures indexed by the original Japanese codes, activity of daily living (ADL) on admission, duration of (anesthesia in minutes, length of hospital stay in days, and status at admission and discharge. Each hospital's structural factors (e.g. teaching status, number of physicians)

were obtained from the Survey of Medical Institutions conducted in 2012.¹¹

Patient cohort

We enrolled patients who underwent elective TKR/THR surgeries (Japanese K-procedure code: K0821) from April 2012 to March 2013. We restricted our analysis to hospitals where at least 30 procedures were performed during the study period, because smaller numbers of procedures would yield unstable estimates of CT use. Because the database did not include detailed information regarding the CT protocols, we excluded hospitalizations with any admission codes indicating malignancies (ICD-10 code: C00–97). We also excluded hospitalizations that recorded any post-surgical complications for which CT can be performed; for example, patients who had a diagnosis of aortic dissection after the surgery were excluded (exclusion diagnoses are listed in the supplemental table). By excluding these hospitalizations where in-hospital CT might have been performed to evaluate other than PE/DVT, we defined CT for PE/DVT detection.

Outcomes

The primary outcome of interest was the use of CT performed for PE/DVT detection during the hospitalization. We identified the CT examinations using the charge codes used for radiological studies. The secondary outcomes of interest were in-hospital mortality and the length of hospital stay.

Covariates

We considered the following covariates that may influence the use of CT: (1) patient demographics (age and sex); (2) type of procedure (hip or knee); (3) duration of anesthesia; (4) transfusion during surgery; (5) risk factors for PE (BMI, smoking status, ADL at admission, pre-procedural DVT, hypercoagulable state [D66–68], polycythemia [D75.0, 1, 2], heart failure [I11, I50], and cardiac pacemaker [Z950]); (6) other comorbidities (atrial fibrillation [I48], diabetes [E10–E14], chronic renal insufficiency [N18], chronic obstructive pulmonary disease [J41–44], and Charlson Comorbidity Index as a measure of comorbidity burden¹²; 7) postoperative events (anemia, shock, and other complications); and (8) hospital characteristics (teaching status, number of beds [*i.e.* hospital size], number of full-time radiologists, and annual hospital volume). We categorized the hospitals into three equal-sized groups based on the annual hospital volume of TKR/THR during the study period.

Statistical analysis

All analyses were performed using SAS Version 9.3 (SAS Institute, Cary, NC), and two-tailed *p* values < 0.05 were considered significant. A crude analysis of the data involved the division of the hospitals into tertiles based on the proportion of patients undergoing postoperative CT. Baseline patient and hospital characteristics were compared across the three groups using Pearson's chi-squared test. We also compared in-hospital mortality and the length of hospital stay across CT usage tertiles using Pearson's chi-squared test and ANOVA to determine the association between CT use and these outcomes.

To investigate inter hospital variation and identify the predictors of CT usage, we developed a two-level hierarchical logistic

regression model with a binary outcome indicating whether or not a patient underwent CT. The model included patient- and hospital-level covariates as fixed effects and hospital-specific random intercepts. To quantify the variability attributable to hospital differences in this adjusted model, we computed the intra class correlation coefficient (ICC) as $\sigma^2 / [\sigma^2 + (\pi^2/3)]$, where σ^2 is the estimated variance of the hospital-specific random intercepts. The ICC for the model is interpreted as the proportion of total variation attributable to the hospital level, after accounting for differences in patient and known hospital characteristics across hospitals.^{5,13} We also obtained the ICCs from two reduced models: (i) a base model including hospital-specific random intercepts and (ii) a patient characteristic-adjusted model including hospital-specific random intercepts and patient risk factors, comorbidities, and demographic information. The base model served as a reference to identify whether or not inter hospital variation existed, the patient characteristic-adjusted model was used to investigate whether inter hospital variability is affected by patient-level factors, and our final model including both patient- and hospital-level effects determined the extent to which inter hospital variation can be accounted for by known hospital characteristics when adjusting for patient-level variables. We therefore expected the ICC to be significantly lower for model (ii) than for model (i) if measured patient-level variables largely explained the variability in CT utilization across hospitals; we expected the ICC to be much lower in the full model than in model (ii) if known hospital factors meaningfully accounted for the between-hospital variation that remained after accounting for measured patient-specific differences.

RESULTS

The cohort included 39,127 discharges (Figure 1) from 447 hospitals (median discharge per hospital: 61; 25th and 75th percentiles: 40, 104), with 7,599 CT (19.4%) examinations performed for PE/DVT detection during the period of hospitalization. Hospitals in the highest tertile of CT use had higher proportions of patients with pre-procedural DVT and with longer duration of

anesthesia. They were also relatively larger hospitals (Table 1). Hospitals in the middle tertile tended to have higher proportions of patients with more complications (e.g. atrial fibrillation, lower ADL at admission, postoperative anaemia, or other post-procedural complications). In-hospital mortality was significantly higher and the length of hospital stay was significantly longer in the middle-tertile hospitals (Table 1).

The crude proportion of patients undergoing post-procedural CT varied significantly among the hospitals, ranging from 0 to 100% (median: 7.4%; IQR: 3.5–18.2%) (Figure 2). More than 50% of TKR/THR patients at the 47 (10.5%) “high utilization” hospitals underwent CT. At one hospital, all 495 patients underwent CT prior to discharge.

The ICC for the base model including only hospital-specific random intercepts as covariates was 46.6%. The ICC was 47.4% for the model adding additional patient-level covariates and 47.3% for the full model accounting for both patient-level and known hospital-level covariates (Table 2). This indicates that the variation in CT use between hospitals was minimally explained by measured patient case-mix or by known hospital-level covariates.

In the fully adjusted model, knee (vs hip) surgery was strongly associated with a decreased probability of undergoing post-procedure CT (adjusted odds ratio [OR]: 0.27; 95% confidence interval [CI]: 0.25–0.30; $p < 0.001$). Significant factors related to an increased probability of performing CT scans included the academic status of the hospital (349/448 hospitals; adjusted OR: 3.69; 95% CI: 1.65–8.24) pre-existing DVT (adjusted OR: 1.49; 95% CI: 1.26–1.78), longer (> 75th percentile) duration of anesthesia (adjusted OR: 1.40; 95% CI: 1.28–1.53), blood transfusion during surgery (adjusted OR: 1.42; 95% CI: 1.27–1.59), atrial fibrillation (adjusted OR: 1.40; 95% CI: 1.07–1.82), diabetes (adjusted OR: 1.17; 95% CI: 1.06–1.30), other operation-related complications (adjusted OR: 1.21; 95% CI: 1.04–1.41), and older age (Table 3).

DISCUSSION

We observed significant variability in the utilization of post-procedure CT among inpatients who underwent TKR/THR surgeries in a large sample of Japanese hospitals. The variation in the current cohort was much larger compared with the variation in the United States cohort. In our study, approximately 47% of the variation in CT use was attributable to the behavior of individual hospitals, after adjustment for measured patient-level and known hospital-level factors; this rate was only 9.0% in the United States study.⁵ At one hospital in our study, all 495 patients underwent CT before discharge, possibly reflecting the hospital’s “routine” use of CT as a screening test. We are unable to directly assess whether these CT examinations were clinically appropriate or not, but the large variation found suggests that CT utilization is not optimized across the nation, and that there may be potential overutilization of the technology in the highest CT use hospitals.

DVT and acute PE are major complications after TKR/THR.^{7,14} In the present study, hospitals in the middle tertile of CT use

Figure 1. Flowchart of study cohort.

Table 1. Patient and hospital characteristics compared across low, medium and high CT use hospitals

		Tertiles based on CT use				
		All	Lowest	Medium	Highest	<i>p</i> -value
	N of hospitals	447	149	149	149	-
	N of admissions to above hospitals	3,9127	1,4923	1,0904	1,3300	-
Patient-level						
Age	<45 years, N (%)	392 (1.0)	130 (0.9)	76 (0.7)	186 (1.4)	<0.001
	45–64 years, N (%)	1,0342 (26.4)	3984 (26.7)	2568 (23.6)	3790 (28.5)	
	65–74 years, N (%)	1,2380 (31.6)	4761 (31.9)	3475 (31.9)	4144 (31.2)	
	75 years, N (%)	1,6013 (40.9)	6048 (40.5)	4785 (43.9)	5180 (39.0)	
Female gender, N (%)		3,2425 (82.9%)	1,2439 (83.4)	9005 (82.6)	1,0981 (82.6)	0.14
Knee surgery, N (%)		2,1484 (54.9%)	8218 (55.1)	6532 (59.9)	6734 (50.6)	<0.001
Duration of anesthesia (min), mean (SD)		177.8 (109.3)	156.43 (64.4)	189.3 (68.8)	191.7 (160.5)	<0.001
Blood transfusion during surgery, N (%)		4346 (11.1)	1298 (8.7)	1493 (13.7)	1555 (11.7)	<0.001
Risk factors of PE	BMI, mean (SD)	24.9 (4.1)	25.0 (4.1)	25.0 (4.1)	24.8 (4.1)	<0.001
	Smoking, N (%)	7579 (19.4%)	2326 (15.6)	2360 (21.6)	2893 (21.8)	<0.001
	Pre-procedural DVT, N (%)	2151 (5.5%)	831 (5.5)	394 (3.7)	926 (7.0)	<0.001
	Hypercoagulable state, N (%)	49 (0.13)	20 (0.13)	7 (0.06)	22 (0.17)	0.08
	Heart failure, N (%)	1058 (2.7)	404 (2.7)	326 (3.0)	328 (2.5)	0.04
	Cardiac pacemaker, N (%)	104 (0.3)	30 (0.2)	33 (0.3)	41 (0.3)	0.15
Other comorbidities	Atrial fibrillation, N (%)	628 (1.6)	222 (1.5)	209 (1.9)	197 (1.5)	0.01
	Diabetes, N (%)	5754 (14.7)	2119 (14.2)	1753 (16.1)	1882 (14.2)	<0.001
	COPD, N (%)	117 (0.3)	29 (0.2)	44 (0.4)	44 (0.3)	0.01
	CCI >2 (%)	3,1311 (8.0)	948 (6.4)	987 (9.1)	1176 (8.8)	<0.001
ADL at admission <full mark		7795 (19.9)	2736 (18.3)	2293 (21.0)	2766 (20.8)	<0.001
Post-operative anaemia, N (%)		6214 (15.9)	2230 (14.9)	2048 (18.8)	1936 (14.6)	<0.001
Post-operative complications, N (%)		2427 (6.2)	635 (4.3)	833 (7.6)	959 (7.2)	<0.001
Post-operative shock, N (%)		1559 (4.0)	685 (4.6)	466 (4.3)	408 (3.1)	<0.001
Patients undergoing CT, N (%)		7599 (19.4)	380 (2.6)	858 (7.9)	6361 (47.8)	<0.001
Hospital-level						
Annualized hospital volumea, median (25–75 percentile)		61 (40–105)	60 (39–112)	56 (39–91)	66 (43–112)	0.02

(Continued)

Table 1. (Continued)

		Tertiles based on CT use			
Number of beds, median (25–75 percentile)	446 (320–600)	410 (306–563)	408.5 (300.5–572.5)	557.5 (390.5–692)	<0.001
Teaching hospital, N (%)	99 (22.2)	12 (8.1)	22 (15.8)	65 (43.6)	<0.001
Full-time radiologist at the hospital	397 (88.8)	131 (87.9)	127 (85.2)	139 (93.3)	0.08
In-hospital mortality at the hospital	20 (0.05)	2 (0.01)	11 (0.1)	7 (0.05)	0.01
Length of hospital stay	25 (20–32)	23 (18–31)	28 (22–36)	25 (21–31)	<0.001

CCI: Charlson Comorbidity Index, COPD: Chronic obstructive pulmonary disease, PE: Pulmonary embolism.

^aAnnualized hospital volume was defined by dividing the total number of TKR/THR patients for each hospital during the study time period by the number of years.

had more patients with more complications, and hospitals in the highest tertile of CT use had more patients with more PE risk factors, indicating that these hospitals had some reasons to perform more CT scans. However, even after adjusting for these factors, large differences remained; there are several possible reasons for this. We postulate that one of the main reasons for the variation in CT utilization is the variation in access to vascular ultrasonography. There are only about 1000 technologists specialized in vascular ultrasonography throughout Japan.¹⁵ At institutions where vascular ultrasonography is not readily available, CT is performed to check for DVT, coupled with a chest scan to evaluate PE. Other reasons include variation among hospitals regarding the education of physicians about calculating pretest probability. Although not directly described in the Japanese guidelines on referring for imaging,^{16–18} international guidelines recommend avoiding CT in patients for whom clinically important PE can be excluded using simple clinical prediction tools such as the Wells or Geneva score.^{19,20} It has been suggested

that these criteria may have insufficient discriminatory power in the postoperative period¹⁴; thus, improvement or customization of the prediction rules for postoperative patients is warranted.

The current study evaluated in-hospital mortality and length of hospital stay as secondary outcomes. The frequency of in-hospital mortality was quite low (total $N = 20$), which made fulfilling discussion difficult. Hospital stays were longer in hospitals in the middle tertile of CT use, which may be because of higher complication rates in this group. As noted, generally, the median length of hospital stay is much higher compared to those in other countries. This is in part explained by the DPC per diem payment system and reimbursement for healthcare related expenditures above a certain threshold for most patients.²¹ The number of hospital beds per capita in Japan which is highest among OECD countries may also contribute to the situation.²² We observed that hospitals in the highest CT-use tertile were more likely to be academic hospitals. There are several possible reasons for this: 1)

Figure 2. The observed proportion of patients undergoing post-TKR/THR CT at each hospital. Each data point represents one hospital. Hospitals are ranked (x-axis) based on the CT utilization, i.e. #1 has the lowest CT utilization (0%), and #448 has the highest (CT was performed in 100% of patients). The y-axis is the proportion of patients undergoing CT at each hospital.

Table 2. Inter hospital variance and intra class correlation coefficient (ICC) in the three random intercept logistic models

Covariates included in the model	Intercept (base model)	+Patient-level characteristics*	+Hospital-level characteristics** (full model)
Inter hospital variance, σ^2	2.869	2.967	2.954
ICC, %	46.6%	47.4%	47.3%

ICC: Intra class correlation coefficient.

advanced imaging may be more readily available in these hospitals, lowering the threshold for each scan; and 2) academic status may be a proxy for unmeasured patient characteristics that lead

to higher CT use. We will need further investigation to clarify this. Although many patient-level factors associated with CT usage varied significantly among hospitals in the low, middle,

Table 3. Estimates of the patient- and hospital-level fixed-effects in the full hierarchical multivariable logistic regression model

Variables	Odds ratio	95% CI		P-value
Patient level				
Age (vs 75 years)				
<45 years, N (%)	0.88	0.64	1.20	0.42
45–64 years, N (%)	0.74	0.67	0.81	<0.001
65–74 years, N (%)	0.84	0.77	0.92	<0.001
Female gender	1.04	0.94	1.15	0.41
Knee surgery (vs hip)	0.27	0.25	0.30	<0.001
Long duration of anesthesia (>75 percentile)	1.40	1.28	1.53	<0.001
Blood transfusion during surgery	1.42	1.27	1.59	<0.001
Risk factors of PE				
BMI	1.00	0.99	1.01	0.82
Smoking	0.99	0.89	1.09	0.77
Pre-procedural DVT	1.49	1.26	1.78	<0.001
Hypercoagulable state	0.97	0.39	2.44	0.95
Heart failure	1.14	0.92	1.42	0.24
Cardiac pacemaker	0.74	0.38	1.44	0.37
Other comorbidities				
Atrial fibrillation	1.40	1.07	1.82	0.013
Diabetes	1.17	1.06	1.30	0.003
COPD	0.56	0.28	1.11	0.10
Charlson Comorbidity Index > 2	1.05	0.90	1.21	0.55
ADL at admission <full	1.08	0.99	1.18	0.081
Post-operative anaemia	1.03	0.92	1.16	0.61
Post-operative complications	1.21	1.04	1.41	0.015
Post-operative shock	0.99	0.80	1.22	0.94
Hospital level				
Annualized hospital volumea	1.00	1.00	1.00	0.89
Number of beds	1.00	1.00	1.00	0.73
Academic status	3.69	1.65	8.24	<.0001
At least one full-time radiologist	0.84	0.45	1.56	0.58

COPD: Chronic obstructive pulmonary disease, PE: Pulmonary embolism.

^aAnnualized hospital volume was defined by dividing the total number of TKR/THR patients for each hospital during the study time period.

and high CT-use tertiles, adjusting for these factors minimally affected the inter hospital variation as measured by the ICC. This may be related to the fact that these risk factors were not always the most prevalent in the highest tertile, but rather in the middle tertile. It may also be because of CT use in the highest CT-usage hospitals that is not based on known and measured risk factors, or it may result from incomplete measurement of the true risk factors in our database.

This study evaluated the utilization rates of CT after TKR/THR procedures in Japan using a large administrative database. The study's strength lies in the size of the population, and in its near national-level representativeness, covering all teaching hospitals and about 50% of all acute-care beds in Japan. Our study is also subject to certain limitations. First, as with any health care utilization database study, complete and detailed clinical data on patients' medical histories, procedures, and clinical events were limited. For instance, the detailed scanning protocol used in each CT examination was not available. Thus, to define CT for PE/DVT, we captured all CT scans performed and then excluded patients with discharge codes suggesting that another type of CT was performed. Although we acknowledge that a direct query of CT scans for PE/DVT, if possible, would in theory be more accurate, we expect any difference to be small. We did not evaluate other imaging modalities as it was difficult to identify the purpose of these imaging studies in the in-hospital administrative database. Similarly, for the outcome, we did not include the PE/DVT-positive rate, as the capture of true PE/DVT events using the administrative database with high sensitivity and specificity is difficult.^{23–25} Second, we could only capture CT scans conducted at hospitals where the surgery was performed; we could not track CT scans performed after transfer or discharge. However, reassuringly, it has been reported that the majority of CT examinations for PE are performed within the first few days of TKR/THR surgery,¹⁴ and, as our data show, the length of hospital stay in Japanese hospitals is quite long. Third, the adjustment for hospital-level factors in the full hierarchical model may

lead to an underestimation of the between-hospital variation if these variables are unrelated to unobserved factors relating to patient case mix. However, in our study, the small difference in the estimated ICCs between the full model and the patient-level characteristics-adjusted model suggests minimal impact from this issue. Forth, there are several methods to calculate ICC with binary outcomes, which may give different point estimates.²⁶ We assessed the ICC from the random intercept model, following the examples of previous literatures,^{5,13} and to assess the strength of the association between patient / hospital level predictors and CT use. We are unable to present a measure for the accuracy of the ICC, since there are no established ways to calculate confidence intervals using this method. However, given the variability in the crude frequency of CT use among the hospitals, together with how little patient / hospital level factors varied across hospitals, we believe that our main message should be robust to these limitations. The Japanese guideline on the management of PE/DVT was first published in 2004 and revised in 2009 and in 2017.²⁷ Since our study enrolled patients who underwent elective TKR/THR surgeries from April 2012 to March 2013, the guideline revision in 2017 may have changed the practice pattern, and may need to be further studied. Finally, although our sample is large, the results are most likely not generalizable to other settings, such as other countries or different payer-provider relationships, which may influence surgeons' test-ordering behavior for imaging exams.

CONCLUSION

In conclusion, in contrast to previous reports based on United States patients, we observed a large inter hospital variation in the utilization of in-hospital CT for PE/DVT detection among patients undergoing TKR/THR. A large fraction of the variation in CT use was attributable to the behavior of individual hospitals irrespective of patient-level risk factors. For more appropriate utilization of CT, investigation of the clinical workflows in high-utilization hospitals is warranted.

REFERENCES

1. Smith-Bindman R, Lipson J, Marcus R, Kim K-P, Mahesh M, Gould R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. *Arch Intern Med* 2009; **169**: 2078–86. doi: <https://doi.org/10.1001/archinternmed.2009.427>
2. Prologo JD, Gilkeson RC, Diaz M, Asaad J. CT pulmonary angiography: a comparative analysis of the utilization patterns in emergency department and hospitalized patients between 1998 and 2003. *AJR Am J Roentgenol* 2004; **183**: 1093–6. doi: <https://doi.org/10.2214/ajr.183.4.1831093>
3. Corwin MT, Donohoo JH, Partridge R, Eggin TK, Mayo-Smith WW. Do emergency physicians use serum D-dimer effectively to determine the need for CT when evaluating patients for pulmonary embolism? review of 5,344 consecutive patients. *AJR Am J Roentgenol* 2009; **192**: 1319–23. doi: <https://doi.org/10.2214/AJR.08.1346>
4. Costantino MM, Randall G, Gosselin M, Brandt M, Spinning K, Vegas CD. CT angiography in the evaluation of acute pulmonary embolus. *AJR Am J Roentgenol* 2008; **191**(August): 471–4. doi: <https://doi.org/10.2214/AJR.07.2552>
5. Kumamaru KK, Kumamaru H, Bateman BT, Gronsbell J, Cai T, Liu J, et al. Limited Hospital variation in the use and yield of CT for pulmonary embolism in patients undergoing total hip or total knee replacement surgery. *Radiology* 2016; **281**: 826–34. doi: <https://doi.org/10.1148/radiol.2016152765>
6. Parvizi J, Huang R, Raphael IJ, Arnold WV, Rothman RH. Symptomatic pulmonary embolus after joint arthroplasty: stratification of risk factors. *Clin Orthop Relat Res* 2014; **472**: 903–12. doi: <https://doi.org/10.1007/s11999-013-3358-z>
7. Bozic KJ, Grosso LM, Lin Z, Parzynski CS, Suter LG, Krumholz HM, et al. Variation in hospital-level risk-standardized complication rates following elective primary total hip and knee arthroplasty. *J Bone Joint Surg Am* 2014; **96**: 640–7. doi: <https://doi.org/10.2106/JBJS.L.01639>
8. Ikegami N, Yoo B-K, Hashimoto H, Matsumoto M, Ogata H, Babazono A,

- et al. Japanese universal health coverage: evolution, achievements, and challenges. *Lancet* 2011; **378**: 1106–15. doi: [https://doi.org/10.1016/S0140-6736\(11\)60828-3](https://doi.org/10.1016/S0140-6736(11)60828-3)
9. Yasunaga H, Horiguchi H, Kuwabara K, Matsuda S, Fushimi K, Hashimoto H, et al. Outcomes after laparoscopic or open distal gastrectomy for early-stage gastric cancer: a propensity-matched analysis. *Ann Surg* 2013; **257**: 640–6. doi: <https://doi.org/10.1097/SLA.0b013e31826fd541>
 10. Yasunaga H, Hashimoto H, Horiguchi H, Miyata H, Matsuda S. Variation in cancer surgical outcomes associated with physician and nurse staffing: a retrospective observational study using the Japanese diagnosis procedure combination database. *BMC Health Serv Res* 2012; **12**: 129. doi: <https://doi.org/10.1186/1472-6963-12-129>
 11. Yamana H, Moriwaki M, Horiguchi H, Kodan M, Fushimi K, Yasunaga H. Validity of diagnoses, procedures, and laboratory data in Japanese administrative data. *J Epidemiol* 2017; **27**: 476–82. doi: <https://doi.org/10.1016/j.je.2016.09.009>
 12. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987; **40**: 373–83. doi: [https://doi.org/10.1016/0021-9681\(87\)90171-8](https://doi.org/10.1016/0021-9681(87)90171-8)
 13. Safavi KC, Li S-X, Dharmarajan K, Venkatesh AK, Strait KM, Lin H, et al. Hospital variation in the use of noninvasive cardiac imaging and its association with downstream testing, interventions, and outcomes. *JAMA Intern Med* 2014; **174**: 546–53. doi: <https://doi.org/10.1001/jamainternmed.2013.14407>
 14. Allen C, Seinge R, Maxwell R, Thind D. CT pulmonary angiography and pulmonary embolism following 5809 primary joint arthroplasties. *N Z Med J* 2015; **128**: 41–9.
 15. Hirai T. Recent trend in vascular ultrasonography. *Innervision* 2017; **32**: 21–3.
 16. Japanese Imaging Referral Guideline 2016. Tokyo: KANEHARA & Co., LTD; 2016.. Available from: <http://www.kanehara-shuppan.co.jp/books/detail.html?isbn=9784307071055>.
 17. Yamashita Y, Murayama S, Okada M, Watanabe Y, Kataoka M, Kaji Y, et al. The essence of the Japan radiological Society/ Japanese College of radiology imaging guideline. *Jpn J Radiol* 2016; **34**: 43–79. doi: <https://doi.org/10.1007/s11604-015-0499-x>
 18. Kumamaru KK, Murayama S, Yamashita Y, Nojo T, Watanabe Y, Goto M, et al. Appropriate imaging utilization in Japan: a survey of accredited radiology training hospitals. *Jpn J Radiol* 2017; **35**: 648–54. doi: <https://doi.org/10.1007/s11604-017-0677-0>
 19. Stein PD, Hull RD, Patel KC, Olson RE, Ghali WA, Brant R, et al. D-dimer for the exclusion of acute venous thrombosis and pulmonary embolism: a systematic review. *Ann Intern Med* 2004; **140**: 589–602.
 20. Roy P-M, Colombet I, Durieux P, Chatellier G, Sors H, Meyer G. Systematic review and meta-analysis of strategies for the diagnosis of suspected pulmonary embolism. *BMJ* 2005; **331**: 259. doi: <https://doi.org/10.1136/bmj.331.7511.259>
 21. Hamada H, Sekimoto M, Imanaka Y. Effects of the per diem prospective payment system with DRG-like grouping system (DPC/ PDPS) on resource usage and healthcare quality in Japan. *Health Policy* 2012; **107**(2–3): 194–201. doi: <https://doi.org/10.1016/j.healthpol.2012.01.002>
 22. . OECD data.. Available from: [Length of hospital stay https://data.oecd.org/healthcare/length-of-hospital-stay.htm](https://data.oecd.org/healthcare/length-of-hospital-stay.htm).
 23. Zhan C, Battles J, Chiang Y-P, Hunt D. The validity of ICD-9-CM codes in identifying postoperative deep vein thrombosis and pulmonary embolism. *Jt Comm J Qual Patient Saf* 2007; **33**: 326–31. doi: [https://doi.org/10.1016/S1553-7250\(07\)33037-7](https://doi.org/10.1016/S1553-7250(07)33037-7)
 24. White RH, Garcia M, Sadeghi B, Tancredi DJ, Zrelak P, Cuny J, et al. Evaluation of the predictive value of ICD-9-CM coded administrative data for venous thromboembolism in the United States. *Thromb Res* 2010; **126**: 61–7. doi: <https://doi.org/10.1016/j.thromres.2010.03.009>
 25. Tamariz L, Harkins T, Nair V. A systematic review of validated methods for identifying venous thromboembolism using administrative and claims data. *Pharmacoepidemiol Drug Saf* 2012; **21 Suppl 1**(SUPPL. 1): 154–62. doi: <https://doi.org/10.1002/pds.2341>
 26. Wu S, Crespi CM, Wong WK. Comparison of methods for estimating the intraclass correlation coefficient for binary responses in cancer prevention cluster randomized trials. *Contemp Clin Trials* 2012; **33**: 869–80. doi: <https://doi.org/10.1016/j.cct.2012.05.004>
 27. . Guidelines for Diagnosis, Treatment and Prevention of Pulmonary Thromboembolism and Deep Vein Thrombosis (JCS 2017) .. Available from: http://www.j-circ.or.jp/guideline/pdf/JCS2017_ito_h.pdf [Accessed January 2018].