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Complications associated with staged versus simultaneous bilateral total knee arthroplasty: An analysis of 7747 patients

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ABSTRACT

Background: Benefits of simultaneous bilateral total knee replacement (TKR) include lower costs, decreased hospital stay, and shorter rehabilitation. This study evaluated complications associated with simultaneous versus staged bilateral TKR within 12 months. We hypothesized that after controlling for comorbidities, the simultaneous group would have the highest rate of complications.

Methods: This retrospective study analyzed the Humana subset of the PearlDiver Patient Records Database. CPT 27447 and associated modifiers were used to identify patients who underwent simultaneous or staged bilateral primary TKRs. Staged bilateral TKRs were performed within 12 months and were stratified by the time between procedures. Primary outcomes were the Centers for Medicare & Medicaid Services' publicly reported complications. Risks of complications were compared using multivariate logistic regression controlling for age, gender, and comorbidities.

Results: Seven thousand seven hundred forty-seven patients underwent simultaneous or staged bilateral TKRs between January 2007 and April 2015. There were lower odds of transfusion and all-cause 90-day readmission but higher odds of mechanical complications and infection for all staged groups compared to the simultaneous. Patients whose staged surgeries were ≪3 months apart had significantly higher odds of undergoing manipulation under anesthesia (MUA).

Conclusions: Higher rates of blood transfusion and readmission were associated with simultaneous bilateral TKR, while higher rates of mechanical complications and infection were associated with staged bilateral TKR. MUA risk was highest in patients staged ≪3 months apart. While there are inherent risks to simultaneous bilateral TKR, surgeons and patients should also be aware of risks associated with staging the procedures.

Level of evidence: III

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1. Introduction

Bilateral knee arthritis has been shown to be an independent predictor of poor physical function [1]. Total knee arthroplasty is a well-established treatment for knee arthritis and for patients with bilateral disease, simultaneous bilateral total knee replacement (TKR) has been shown to be more cost-effective than staged procedures [2], and leads to decreased hospital stay and shorter rehabilitation for the patient [2].

Prior studies and meta-analyses have compared unilateral TKRs to simultaneous bilateral TKRs and have shown higher complications rates in the simultaneous bilateral group [3,4]. However, these types of studies are not as helpful to the surgeon evaluating a patient with end-stage bilateral knee arthritis who will eventually need arthroplasty procedures to both knees. In counseling a patient with bilateral knee arthritis, the surgeon must consider the combined risks of two staged procedures versus the risk of a single bilateral procedure, rather than comparing the risk of one bilateral procedure to just one unilateral TKR. For example, Barrett et al. noted an 80% higher risk of pulmonary embolism in three months after a bilateral TKR compared to a unilateral TKR, but noted that the sum of the risks associated with two procedures for staged bilateral TKRs may equal or exceed the risk of simultaneous bilateral surgery [5].

Thus, the present study was undertaken to evaluate the complications associated with simultaneous bilateral TKR versus staged bilateral TKR with a delay between the first and second TKR of ≪3 months, three to six months, or six to 12 months. We hypothesized that after controlling for comorbidities, the simultaneous group with have the highest rate of complications and complications would diminish as the amount of time between the two surgeries was increased.

2. Materials and methods

This retrospective study analyzed the Humana insurance data set using the PearlDiver Patient Records Database (www.pearldiverinc.com, Fort Wayne, IN), which contains records for over 22 million patients. This database contains hospital and physician billing records. We used Current Procedural Technology (CPT) codes for operations as well as International Classification of Diseases (ICD) codes *Ninth Edition* for diagnosis of medical comorbidities and diagnosis of complications following total knee arthroplasty (Appendix A).

Patients who underwent primary total knee arthroplasty were identified via CPT code 27447. Laterality modifiers were then used to differentiate patients undergoing a unilateral TKR from patients undergoing simultaneous bilateral TKRs. Patients were included in the study if they underwent simultaneous bilateral TKRs or bilateral TKRs performed in a staged fashion with less than 12 months between surgeries. Staged surgeries were confirmed to be on contralateral limbs using laterality modifiers. Patients were excluded if they were active in the database for fewer than 90 days after their final procedure. 7747 patients who underwent primary total knee arthroplasty surgeries on both knees between January 2007 and April 2015 were identified.

Demographic information including age, gender, and comorbidities diagnosed prior to the first TKR were collected. Comorbidities were selected for inclusion based on prior work by Elixhauser et al. [6]. Patients were classified into four groups depending on timing of the contralateral arthroplasty. The first group consisted of patients who underwent simultaneous bilateral total knee arthroplasty. The other three groups were categorized based on whether the second TKR occurred less than three months after the initial TKR, three to six months after the initial TKR, or six to 12 months after the initial TKR. Among patients who had staged bilateral TKR within three months, 81 of 751 (10.8%) were staged within two weeks.

The primary outcomes were complications as defined by the 2016 Centers for Medicare & Medicaid Services' (CMS's) Complication Measure for TKR [7]. Additional complications were deep vein thrombosis (DVT) or transfusion within 30 days and all cause readmission or manipulation under anesthesia (MUA) within 90 days. Complications were identified using ICD-9 and CPT codes. Complications were included if they occurred within the specified CMS reported complications time period after the simultaneous bilateral or either of the staged bilateral surgical procedures.

2.1. Statistical analysis

Baseline cohort characteristics, including age groups, gender, and comorbidities, were compared among groups using a chi-squared comparison. Complication rates were calculated as the number of patients experiencing each complication divided by the number of patients in the cohort. Patients with staged TKR were considered at-risk for complication for 90 days after each procedure. Raw complication rates were compared with a chi-squared test. Multivariate logistic regression was then used to determine the odds ratio of each complication for each of the three staged groups compared to the simultaneous group. Regressions were controlled for age, gender, and comorbidities. Analyses were performed using the PearlDiver software as well as STATA (version 14.2, Statacorp, College Station, TX). A p-value of less than 0.05 was considered statistically significant.

3. Results

Seven thousand seven hundred forty-seven patients met the inclusion and exclusion criteria, of which 1637 underwent simultaneous bilateral TKRs (21.1%). Demographic characteristics of the cohorts are displayed in Table 1. 61.7% of patients were female. The most frequent age ranges for each group were 60–69 and 70–79.

Table 1
Demographics and Comorbidities.

Demographic	Simultaneous bilateral (N = 1637) (%)	Staged bilateral within 3 months (N = 751) (%)	Staged bilateral 3–6 months (N = 2664) (%)	Staged bilateral 6–12 months (N = 2695) (%)	P-value
Age 49 and under	1.34	2.00	1.61	1.19	0.009*
Age 50–59	11.12	14.25	11.71	9.87	
Age 60–69	41.42	38.35	39.53	37.70	
Age 70–79	38.36	38.22	38.55	41.26	
Age 80–89	6.60	6.26	7.36	8.68	
Age 90 and over	1.16	≪1.46	1.24	1.30	
Gender (F)	55.83	55.39	62.88	65.97	≪0.001*
Congestive Heart Failure	2.57	2.40	3.23	2.82	0.494
Cardiac Arrhythmias	9.59	10.52	9.16	8.35	0.245
Heart Valvular Disease	2.69	3.46	3.04	2.97	0.772
Pulmonary Circulation Disorders	0.92	≪1.46	0.75	0.59	0.677
Peripheral Vascular Disorders	1.22	2.13	1.76	2.12	0.167
Hypertension	63.96	67.91	70.31	72.21	≪0.001*
Paralysis	≪0.67	≪1.46	≪0.41	≪0.41	0.853
Other Neurologic Disorders	0.86	≪1.46	1.24	1.74	0.026*
Chronic Pulmonary Disease	12.46	13.32	15.35	13.36	0.038*
Diabetes	20.77	24.10	24.47	24.45	0.023*
Hypothyroidism	15.39	13.72	16.97	17.18	0.073
Renal Failure	≪0.67	≪1.46	≪0.41	≪0.41	0.721
Liver Disease	0.92	≪1.46	0.86	0.52	0.376
Peptic Ulcer Disease	0.98	≪1.46	1.24	1.19	0.874
HIV/AIDS	≪0.67	≪1.46	≪0.41	≪0.41	0.592
Lymphoma	≪0.67	≪1.46	≪0.41	≪0.41	0.783
Metastatic Cancer	≪0.67	≪1.46	≪0.41	≪0.41	0.290
Solid Tumors without Metastasis	7.39	7.32	6.91	8.24	0.318
Rheumatoid Arthritis/Collagen Vascular Diseases	6.17	5.19	5.22	4.79	0.268
Coagulopathy	3.18	1.86	2.18	1.86	0.031*
Obesity	19.49	22.64	22.18	22.63	0.079
Weight Loss	0.73	≪1.46	≪0.41	≪0.41	≪0.001*
Fluid and Electrolyte Disorders	13.07	6.66	8.22	9.02	≪0.001*
Blood Loss Anemia	2.87	1.86	1.01	1.56	≪0.001*
Deficiency Anemias	13.50	11.45	12.01	11.32	0.181
Alcohol Abuse	≪0.67	≪1.46	0.68	0.59	0.841
Drug Abuse	≪0.67	≪1.46	≪0.41	≪0.41	0.811
Psychoses	1.53	1.60	1.69	1.45	0.912
Depression	10.20	10.52	12.54	11.50	0.100
Smoking	4.46	5.06	5.18	3.75	0.074

A comparison of age, gender, and comorbidities between the simultaneous and staged bilateral TKR cohorts. P-values reflect chi-squared comparisons between groups. P-values of less than 0.05 are considered statistically significant.

* Significant P-value.

Table 2
Raw Percentages of Patients with Complications Based on Timing of Bilateral TKR Surgery.

Complication	Simultaneous bilateral (N = 1637)	Staged bilateral within 3 months (N = 751)	Staged bilateral 3–6 months (N = 2664)	Staged bilateral 6–12 months (N = 2695)	P-value
DVT (30 d)	3.54	3.20	3.08	3.34	0.862
Transfusion RBCs (30 d)	35.00	18.64	15.28	15.55	≪0.001*
Myocardial Infarction (7 d)	≪0.67	≪1.46	≪0.41	≪0.41	0.560
Pneumonia (7 d)	1.34	1.73	1.69	2.45	0.049*
Sepsis (7 d)	≪0.67	≪1.46	0.45	0.59	0.856
Surgical Site Bleeding (30 d)	≪0.67	≪1.46	≪0.41	≪0.41	0.181
Pulmonary Embolism (30 d)	2.26	≪1.46	1.31	2.26	0.018*
Mechanical Complications (90 d)	≪0.67	1.60	1.65	1.67	0.010*
Infection (90 d)	1.77	3.46	4.32	5.19	≪0.001*
Readmission (90 d)	28.28	4.26	11.19	12.76	≪0.001*
MUA (90 d)	1.83	3.86	2.63	2.49	0.033*

An uncontrolled comparison of complication rates between the simultaneous and staged bilateral TKR cohorts. P-values reflect chi-squared comparisons between groups. P-values of less than 0.05 are considered statistically significant.

* Significant P-value.

Table 3
Odds Ratio of Complications Based on Timing of Bilateral TKR Surgery.

Complication	Simultaneous bilateral		Stage bilateral within 3 months		Staged bilateral 3–6 months		Staged bilateral 6–12 months	
	OR	P-value	OR	P-value	OR	P-value	OR	P-value
DVT (30 d)	1.00	N/A	0.88	0.607	0.88	0.485	0.97	0.861
Transfusion RBCs (30 d)	1.00	N/A	0.44	≪0.001*	0.32	≪0.001*	0.32	≪0.001*
Myocardial Infarction (7 d)	1.00	N/A	0.81	0.761	0.80	0.633	0.70	0.469
Pneumonia (7 d)	1.00	N/A	1.49	0.271	1.39	0.218	2.13	0.003*
Sepsis (7 d)	1.00	N/A	0.78	0.708	0.91	0.833	1.29	0.553
Surgical Site Bleeding (30 d)	1.00	N/A	N/A[a]	1.000	N/A[a]	0.997	N/A[a]	0.997
Pulmonary Embolism (30 d)	1.00	N/A	0.60	0.182	0.67	0.104	1.19	0.450
Mechanical Complications (90 d)	1.00	N/A	3.15	0.015*	3.29	0.002*	3.32	0.002*
Infection (90 d)	1.00	N/A	1.89	0.025*	2.57	≪0.001*	3.19	≪0.001*
Readmission (90 d)	1.00	N/A	0.11	≪0.001*	0.30	≪0.001*	0.35	≪0.001*
MUA (90 d)	1.00	N/A	2.15	0.004*	1.52	0.064	1.45	0.106

Multivariate logistic regression comparing the odds of complications between simultaneous and staged bilateral TKR cohorts. Regressions were controlled for age, gender, and comorbidities. The simultaneous cohort was used as the baseline. P-values of less than 0.05 are considered statistically significant. Mechanical Complications include mechanical loosening of implants, dislocation, peri-prosthetic fracture, and other mechanical complications.

* Significant P-value.

[a] Number of surgical site bleeding complications in simultaneous bilateral cohort was 0, thus an odds ratio was unable to be calculated.

Patients in the simultaneous bilateral group were more likely to be male and had a lower incidence of hypertension, neurologic disorders, chronic obstructive pulmonary disease, and diabetes compared to the staged bilateral group. Patients in the simultaneous group had a higher incidence of perioperative coagulopathy, weight loss, fluid and electrolyte disorders, and blood loss anemia compared to the staged groups.

Multivariate analysis showed that compared to the simultaneous bilateral group, there was a decreased chance of transfusion and all cause readmission within 90 for all staged groups compared to the simultaneous group (Tables 2, 3). However, there was a higher chance of mechanical complications (such as implant loosening, dislocation, periprosthetic fracture or other implant problem) and infection for all staged groups compared to the simultaneous bilateral group. Patients in the staged bilateral TKR group at least six to 12 months apart had a significantly higher chance of pneumonia within seven days in comparison to the simultaneous bilateral group.

The patients who underwent staged bilateral TKR within three months were significantly more likely to require MUA compared to the simultaneous bilateral group. Among patients undergoing MUA, 57 (34.3%) underwent MUA after the first surgery, 76 (45.8%) underwent MUA after the second surgery, and 33 (19.9%) underwent MUA after both surgeries. There were no statistically significant differences between groups for the risk of DVT, PE, myocardial infarction, sepsis, and surgical site bleeding.

4. Discussion

Among 7747 patients undergoing simultaneous or staged bilateral TKR, we found higher rates of blood transfusion and readmission in patients who underwent simultaneous bilateral TKR, versus higher rates of mechanical complications and infection in patients who underwent staged bilateral TKR. There was a higher risk of MUA in patients who underwent staged procedures within three months compared to patients who underwent simultaneous procedures or procedures staged three to 12 months apart. There were no statistically significant differences between the staged and simultaneous groups in the rates of thromboembolic complications. While some prior authors have argued against performing simultaneous bilateral TKR due to a perceived increased risk profile [8], the results of this study show that there are specific complications associated with both simultaneous and staged bilateral TKR that must be taken into account in counseling patients on the best procedure. These complication rates reflect the sum of complications after all procedures.

There was no statistically significant difference in the rates of DVT or PE diagnosed in the staged versus simultaneous TKR groups in this study. In a prior meta-analysis, Restrepo et al. examined PE risk in simultaneous bilateral versus unilateral TKR [3]. They found an odds ratio of 1.82 for increased risk of PE in the bilateral group. However, our results are more consistent with the study by Barrett et al. which noted that the sum of the risks of PE after each staged procedure may be equal to or exceeding the risk of PE with simultaneous bilateral TKR [5]. Furthermore, Poultsides et al. found no significant difference in rate of PE in patients undergoing simultaneous bilateral TKR versus staged TKR at either 0 to three months or three to 12 months [9]. Although our data did not show a statistically significant difference in the odds of PE between groups, there may be a trend towards lower odds of PE in the staged cohorts that did not reach statistical significance due to insufficient power. This appears to be less likely in the case of DVT. Future studies specifically powered to evaluate the PE risk in simultaneous versus staged bilateral TKR are needed.

We found a significantly increased rate of MUA in patients staged less than three months apart compared to simultaneous bilateral TKR and patients staged in three to 12 months. MUA is used to treat a stiff TKR after physical therapy has failed [10]. Inadequate pain control has been associated with decreased range of motion and formation of adhesions after TKR, and may be a contributing factor to the increased rate of MUA in patients who undergo staged bilateral TKR in a short time period [10,11]. Arthrofibrosis and the need for subsequent MUA has also been linked to an increased inflammatory state [12]. It is possible that an increased overall inflammatory state of patients who have undergone TKR in the prior three months may predispose

them to an increased incidence of arthrofibrosis and subsequent need for MUA. The Consensus Conference [13] in bilateral total knee arthroplasty group made the recommendation that for staged procedures, the second knee should be scheduled at least three months after the first. This recommendation was made on theoretical grounds given that there is a lack of evidence to guide this decision. However, based on the MUA risk evident in our study, we agree with the recommendation to leave at least a three-month period between staged procedures. More research is needed to elucidate the connection between recent surgery, an increased inflammatory state, and a subsequent need for MUA.

An increased incidence of infection was noted in patients who were staged compared to patients who underwent simultaneous bilateral TKR. This is in contrast to some prior studies in the arthroplasty literature which have found simultaneous bilateral surgery to be a risk factor for infection [14,15]. However, a recent cohort study of nearly 18,000 patients demonstrated that staged bilateral TKR patients had a higher rate of in-hospital infection compared to simultaneous bilateral TKR and the rate of late infections was comparable between groups [16]. The reason for the increased infection risk in the staged groups in the present study is unknown. We hypothesize that two separate operative procedures allows for additional exposure to infectious organisms. Furthermore, longer hospitalization has been associated with increased risk of infection, and the increased total hospital days that are typically associated with staged bilateral TKR compared to simultaneous bilateral TKR may be a confounding factor [14,15].

Mechanical complications, including failure of implant, dislocation, or periprosthetic fracture, within 90 days of procedure were also higher in all staged bilateral groups compared to the simultaneous bilateral group. The precise reasons for this difference are unknown. We hypothesize that after the second procedure, patients may rely too much on the first knee that is likely not yet at full strength, thereby adding excessive stress to the initial implant. Further research is needed to evaluate the reasons for increased mechanical complications in the staged setting.

Additionally, rates of pneumonia were higher in the staged bilateral groups with procedures six to 12 months apart. Our analysis did show that, as expected, patients in the simultaneous bilateral group were generally healthier with fewer chronic diseases compared to the staged groups. However, as comorbidity data is coded only as present or not present, and without a measure for severity, it is possible that the multivariate model could not fully control for comorbidities between the simultaneous and six to 12 month staged groups. Thus, the higher rate of pneumonia may have reflected the inherent characteristics of the patient population, rather than anything related to the surgical procedures. Future randomized controlled trials would help to elucidate the reasons for this finding.

Awareness of the specific complications associated with staged versus simultaneous bilateral TKR may be helpful in preoperative planning and patient counseling. For example, preoperative autologous donation of blood has been shown to have the most benefit in cases of simultaneous bilateral surgery, though it is not supported by the overall literature in unilateral TKR [17]. It should be noted that due to the time period examined in this study many patients may not have received tranexamic acid perioperatively, and thus the transfusion rates may be higher than expected with current treatment practices. In patients with a significant expected blood loss, low starting hematocrit, or who are deemed poor candidates for tranexamic acid administration, surgeons may consider using autologous blood donation. Similarly, given the higher risk of readmission after simultaneous TKR, increased efforts to prevent readmission, such as arrangements for early postoperative visits with primary care doctors, outpatient workup of minor complications, and patient education on the postoperative course, may help to mitigate this risk [18].

This study has certain limitations. First, it is limited by factors inherent to analysis of large administrative databases. We were not able to identify the specific factors that led surgeons and patients to choose a simultaneous versus staged bilateral procedure. Patients indicated for simultaneous bilateral TKR are typically younger and healthier and thus are likely at an overall lower complication risk; we attempted to control for this using multivariate logistic regression. We were unable to analyze specific surgeon factors, such as surgical volume or surgical time, which may indicate surgeon skill and thus influence outcomes. Secondly, we looked at complications only up to 90 days postoperatively and thus were unable to evaluate any long-term outcomes of simultaneous versus staged TKR. Third, there may be a group of patients who were planned for staged bilateral procedures but for whom the second surgery was canceled due to a complication or medical comorbidity. We were unable to account for this potential group of patients in our dataset. Finally, our study utilized administrative claims data, which relies on accurate reporting of diagnosis and procedure codes. We attempted to account for all major medical comorbidities, but were not able to account for the severity of individual comorbidities, which may factor in to the complication rate of staged versus simultaneous bilateral TKR.

Nonetheless, this study has several strengths. It compares bilateral TKR in the simultaneous versus staged setting which is particularly useful to surgeons who are treating patients with severe knee arthritis bilaterally. We included a large sample size in order to improve ability to capture more rare complications such as pulmonary embolism and infection and attempt to determine differences between groups. By ensuring that patients were active in the database for 90 days postoperatively, there was no loss to follow-up.

5. Conclusions

We found higher rates of blood transfusion and readmission in patients who underwent simultaneous bilateral TKR, while there were higher rates of mechanical complications and infection in patients who underwent staged bilateral TKR. While there are inherent risks to simultaneous bilateral TKR, surgeons and patients should also be aware of risks associated with staging the procedures.

Source of funding

Funding for this project was provided by our healthcare institution to allow access to the PearlDiver database.

Appendix A. ICD-9 complication codes utilized

Complication	Codes utilized
DVT (30 d)	ICD-9-D-45340, ICD-9-D-45341, ICD-9-D-45342
Transfusion RBCs (30 d)	ICD-9-P-9900, ICD-9-P-9902, ICD-9-P-9903, ICD-9-P-9904
Myocardial infarction (7 d)	ICD-9-D-410, ICD-9-D-4100, ICD-9-D-41000, ICD-9-D-41001, ICD-9-D-4101, ICD-9-D-41010, ICD-9-D-41011, ICD-9-D-4102, ICD-9-D-41020, ICD-9-D-41021, ICD-9-D-4103, ICD-9-D-41030, ICD-9-D-41031, ICD-9-D-4104, ICD-9-D-41040, ICD-9-D-41041, ICD-9-D-4105, ICD-9-D-41050, ICD-9-D-41051, ICD-9-D-4106, ICD-9-D-41060, ICD-9-D-41061, ICD-9-D-4107, ICD-9-D-41070, ICD-9-D-41071, ICD-9-D-4108, ICD-9-D-41080, ICD-9-D-41081, ICD-9-D-4109, ICD-9-D-41090, ICD-9-D-41091
Pneumonia (7 d)	ICD-9-D-480, ICD-9-D-4800, ICD-9-D-4801, ICD-9-D-4802, ICD-9-D-4803, ICD-9-D-4808, ICD-9-D-4809, ICD-9-D-481, ICD-9-D-482, ICD-9-D-4820, ICD-9-D-4821, ICD-9-D-4822, ICD-9-D-4823, ICD-9-D-48230, ICD-9-D-48231, ICD-9-D-48232, ICD-9-D-48239, ICD-9-D-4824, ICD-9-D-48240, ICD-9-D-48241, ICD-9-D-48242, ICD-9-D-48249, ICD-9-D-48281, ICD-9-D-48282, ICD-9-D-48283, ICD-9-D-48284, ICD-9-D-48289, ICD-9-D-4829, ICD-9-D-483, ICD-9-D-4830, ICD-9-D-4831, ICD-9-D-4838, ICD-9-D-485, ICD-9-D-486, ICD-9-D-4870, ICD-9-D-48801, ICD-9-D-48811, ICD-9-D-5070, ICD-9-D-99732
Sepsis (7 d)	ICD-9-D-038, ICD-9-D-0380, ICD-9-D-0381, ICD-9-D-03810, ICD-9-D-03811, ICD-9-D-03812, ICD-9-D-03819, ICD-9-D-0382, ICD-9-D-0383, ICD-9-D-0384, ICD-9-D-03840, ICD-9-D-03841, ICD-9-D-03842, ICD-9-D-03843, ICD-9-D-03844, ICD-9-D-03849, ICD-9-D-0388, ICD-9-D-0389, ICD-9-D-78552, ICD-9-D-78559, ICD-9-D-7907, ICD-9-D-99591, ICD-9-D-99592, ICD-9-D-9980, ICD-9-D-99800, ICD-9-D-99801, ICD-9-D-99802, ICD-9-D-99809
Surgical site bleeding (30 d)	One of the following diagnosis codes: ICD-9-D-9981, ICD-9-D-99811, ICD-9-D-99812, ICD-9-D-99813, ICD-9-D-71910, ICD-9-D-71916, ICD-9-D-71917, ICD-9-D-3998 AND the following procedure code: ICD-9-P-8604
Pulmonary embolism (30 d)	ICD-9-D-4151, ICD-9-D-41511, ICD-9-D-41513, ICD-9-D-41519
Mechanical complications (90 d)	ICD-9-D-9964, ICD-9-D-99640, ICD-9-D-99641, ICD-9-D-99642, ICD-9-D-99644, ICD-9-D-99647, ICD-9-D-99649
Infection (90 d)	One of the following diagnosis codes: ICD-9-D-9986, ICD-9-D-99883, ICD-9-D-9983, ICD-9-D-99830, ICD-9-D-99831, ICD-9-D-99832, ICD-9-D-99833, ICD-9-D-9985, ICD-9-D-99851, ICD-9-D-99859, ICD-9-D-99667, ICD-9-D-99666 AND one of the following procedures: ICD-9-P-8622, ICD-9-P-8628, ICD-9-P-8604, ICD-9-P-8153, ICD-9-P-8155, ICD-9-P-8159, ICD-9-P-0070, ICD-9-P-0071, ICD-9-P-0072, ICD-9-P-0073, ICD-9-P-0080, ICD-9-P-0081, ICD-9-P-0082, ICD-9-P-0083, ICD-9-P-0084, ICD-9-P-8005, ICD-9-P-8006, ICD-9-P-8009, ICD-9-P-7865, ICD-9-P-7866, ICD-9-P-7867
Readmission (90 d)	n/a
MUA (90 d)	CPT-27570

A listing of the codes used to identify complications analyzed in the study.

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