

Costs and Clinical Outcomes of Conventional Single Port and Micro-laparoscopic Cholecystectomy

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ABSTRACT

Background and Objective: This study compares hospital costs and clinical outcomes for conventional laparoscopic, single-port, and mini-laparoscopic cholecystectomy from US hospitals.

Methods: Eligible patients were aged ≥ 18 years and undergoing laparoscopic cholecystectomy with records in the Premier Hospital Database from 2009 through the second quarter of 2010. Patients were categorized into 3 groups—conventional laparoscopic, single port, or mini-laparoscopic—based on the *International Classification of Diseases, Ninth Revision* and Current Procedural Terminology codes and hospital charge descriptions for surgical tools used. A procedure was considered mini-laparoscopic if no single-port surgery products were identified in the charge master descriptions and the patient record showed that at least 1 product measuring < 5 mm was used, not more than 1 product measuring > 5 mm was used, and the measurements of the other products identified equaled 5 mm. Summary statistics were generated for all 3 groups. Multivariable analyses were performed on hospital costs and clinical outcomes. Models were adjusted for demographics, patient severity, comorbid conditions, and hospital characteristics.

Results: In the outpatient setting, for single-port surgery, hospital costs were approximately \$834 more than those for mini-laparoscopic surgery and \$964 more than those for conventional laparoscopic surgery ($P < .0001$). Ad-

verse events were significantly higher ($P < .0001$) for single-port surgery compared with mini-laparoscopic surgery (95% confidence interval for odds ratio, 1.38–2.68) and single-port surgery versus conventional surgery (95% confidence interval for odds ratio, 1.37–2.35). Mini-laparoscopic surgery hospital costs were significantly ($P < .0001$) lower than the costs for conventional surgery by \$211, and there were no significant differences in adverse events.

Conclusions: These findings should inform practice patterns, treatment guidelines, and payor policy in managing cholecystectomy patients.

Key Words: Abdominal, Cholecystectomy, Laparoscopic.

INTRODUCTION

Cholecystectomy is one of the most frequently performed abdominal surgery procedures in the United States, with $> 750,000$ cholecystectomies performed laparoscopically each year.^{1,2} Laparoscopic cholecystectomy evolved from surgical attempts to improve patient outcomes, including postoperative morbidity, cosmetic results, hospital length of stay, and duration of convalescence.^{3–5} Continued attempts to improve these outcomes have led to the development of alternatives to conventional laparoscopic cholecystectomy (CLC), including micro- or mini-laparoscopic cholecystectomy (MLC) and, more recently, single-port cholecystectomy surgery (SPS).⁶ However, understanding the effect of these emerging techniques on clinical and economic outcomes is critical to guiding practice patterns, clinical guidelines, and payor decisions.

SPS is a technical departure from CLC in that it uses a single, transabdominal incision rather than multiple incisions for trocar insertion.^{7,8} This procedure is typically performed with several trocars spaced closely together or with a multi-instrument port.^{7–9}

MLC is performed by use of percutaneous instrumentation or trocars that are significantly smaller in size than those used in conventional laparoscopic procedures. The procedure was primarily developed to reduce incisional pain.

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Studies have reported improvements in cosmetic outcome, pulmonary function, and overall satisfaction.^{10–14} One small study did report that up to 38% of patients (5 of 13) required conversion from MLC to CLC.¹⁰

The purpose of this article is a cost comparison of cholecystectomy approaches including conventional, single-port, and mini-laparoscopic surgeries. We performed our analysis using the Premier Hospital Database as a source of cost from the hospital perspective.

METHODS

A protocol describing the analysis objectives, criteria for patient selection, data elements of interest, and statistical methods was submitted to the New England Institutional Review Board, and exemption was obtained (No. 11–240).

Data Source

The Premier Hospital Database, which contains clinical and utilization information on patients receiving care in 442 hospitals and ambulatory surgery centers across the United States during the period of interest, was used. Specifically, this database contains complete patient billing, hospital cost, and coding histories from more than 25 million inpatient discharges and 175 million hospital outpatient visits.¹⁵ Data for 2009 through the second quarter of 2010 were used and anonymized with regard to patient identifiers.

Patients and Procedures

Eligible patients were those aged ≥ 18 years undergoing an outpatient laparoscopic cholecystectomy. *International Classification of Diseases, Ninth Revision* and Current Procedural Terminology codes for identifying the laparoscopic cholecystectomy, diagnosis codes for identifying patient comorbid conditions, and all adverse events are listed in Appendices A, B, and C, respectively.

Eligible patients with procedure codes identifying a laparoscopic cholecystectomy were then subdivided into 3 mutually exclusive groups: CLC, SPS, or MLC. Hospital charge descriptions for the surgical tools used were text mined to identify SPS procedures. The distinction between MLC and CLC was based on the size of the surgical instrument. MLC was defined by records of no SPS products identified in the charge master descriptions, record of at least 1 product < 5 mm used; not more than 1 product > 5 mm used, and any other products identified equaled 5 mm. Procedures that were not identified as SPS or MLC were considered CLC procedures.

Statistical Analyses

Initial counts, percentages, means, and standard deviations for demographics, comorbid conditions, hospital characteristics, safety, and cost outcomes were summarized for CLC, SPS, and MLC by use of descriptive statistics for patients in the outpatient setting. Safety outcomes of interest were selected from adverse events occurring during or up to 30 days after surgery. Cost outcomes were total hospital costs per patient, both fixed and variable.

Because the sample size for the SPS group was very limited in the inpatient setting, univariate and multivariable analyses were performed on outpatient procedures only. Furthermore, by examining patients in the outpatient setting only, it was possible to analyze a more homogeneous patient population.

Multivariable logistic regression analyses were run for binary outcomes, such as adverse events. Ordinary least squares regressions were used for the continuous outcome of hospital costs. For all models, the following explanatory variables were included: age, sex, race, marital status, insurance type, comorbid conditions (e.g., diabetes), census region of the hospital, rural versus urban hospitals, teaching versus nonteaching hospitals, and number of hospital beds. By use of these explanatory variables, multivariable models were estimated to isolate the effects of SPS versus CLC, SPS versus MLC, and MLC versus CLC on hospital costs. To eliminate cost outliers, both the upper 0.5% and lower 0.5% of costs were set to missing values. In addition to the trimming of outliers, a natural-log transformation of the costs was used as the dependent variable in multivariate models. Smearing estimates were then used to avoid the introduction of bias when we converted back to the untransformed dollar scale.¹⁶ All analyses were performed with SAS software, version 9.2 (SAS Institute, Cary, NC, USA).

RESULTS

There were a total of 193,014 eligible laparoscopic cholecystectomy procedures identified in the database from the period from the first quarter of 2009 through the second quarter of 2010. A patient attrition diagram is shown in **Figure 1**. The majority of all procedures (59%, 116,823 of 196,628) were performed in the outpatient setting, with 98% (114,356) of these patients undergoing a CLC. For the remaining 2% of outpatient procedures (2,467), 527 SPS procedures and 1,940 MLC procedures were identified. As summarized in **Table 1**, characteristics of eligible outpatient procedures show that there were substantially more

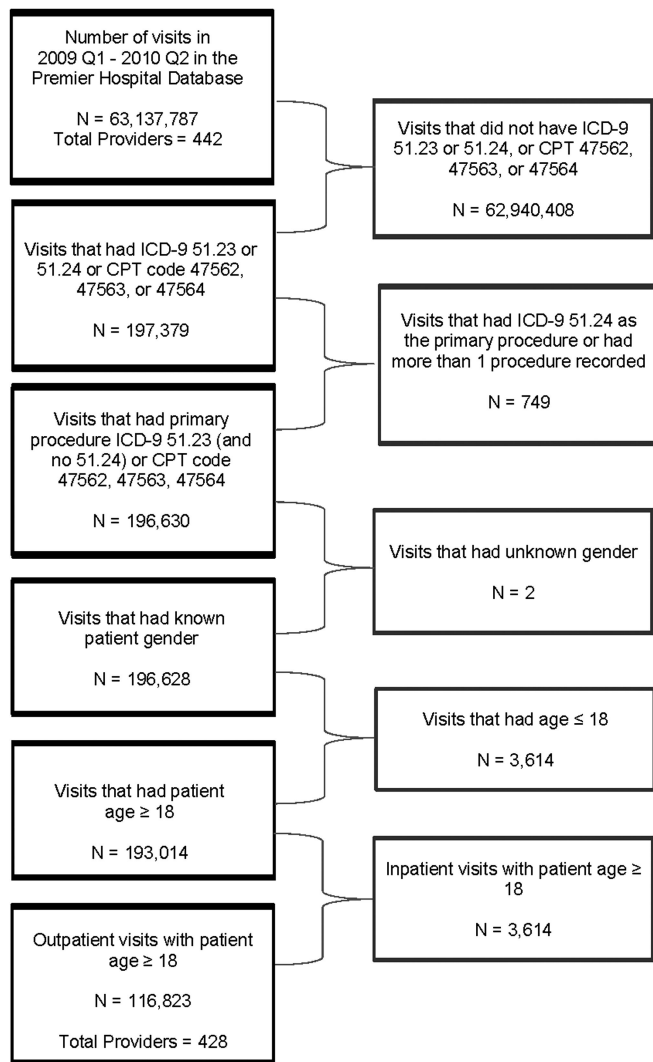


Figure 1. Patient attrition is shown from all data from the first quarter (Q1) of 2009 to the second quarter (Q2) of 2010 to the subset used in our analysis. The analysis included patients with *International Classification of Diseases, Ninth Revision (ICD-9)* code 51.23 or Current Procedural Terminology (CPT) code 47562, 47563, or 47564 whose gender was known, who were aged ≥ 18 years, and who underwent outpatient visits.

women than men, with rates for both dropping off after age 50 years. Regarding insurance, more patients had managed care than government or other sources of insurance. In the outpatient setting, the 3 procedure groups (SPS, MLC, and CLC) appear to be very well balanced overall in terms of patient demographics.

The distribution of patient comorbidities is shown in **Table 2** and suggests a lower percentage of comorbidities overall in the SPS population, with the rates of many of the

Table 1.
Patient Characteristics

	SPS (n = 527) (%)	MLC (n = 1,940) (%)	CLC (n = 114,356) (%)
Age			
18–40 yr	282 (53.5)	751 (38.7)	43,452 (38.0)
41–50 yr	113 (21.4)	411 (21.2)	23,364 (20.4)
51–60 yr	76 (14.4)	361 (18.6)	21,703 (19.0)
61–70 yr	35 (6.6)	258 (13.3)	15,413 (13.5)
71–80 yr	17 (3.2)	124 (6.4)	8,068 (7.1)
>80 yr	4 (0.8)	35 (1.8)	2,356 (2.1)
Gender			
Female	445 (84.4)	1,443 (74.4)	86,757 (75.9)
Male	82 (15.6)	497 (25.6)	27,599 (24.1)
Insurance			
Government	108 (20.5)	582 (30.0)	35,410 (31.0)
Managed care	331 (62.8)	1,090 (56.2)	56,228 (49.2)
Other	88 (16.7)	268 (13.8)	22,718 (19.9)
Race			
White	418 (79.3)	1,318 (67.9)	81,096 (70.9)
African American	22 (4.2)	109 (5.6)	8,358 (7.3)
Hispanic	27 (5.1)	172 (8.9)	7,509 (6.6)
Other	60 (11.4)	341 (17.6)	17,307 (15.1)
Invalid code	0 (0.0)	0 (0.0)	86 (0.1)

conditions as low as half of the rates in the other cohorts. Hypertension was the most common comorbid condition across all 3 groups.

Unadjusted Analysis

The cholecystectomies studied were performed in 428 hospitals. Most procedures, as well as most patients, derived from urban, nonteaching, moderate- to large-sized hospitals in the South.¹⁵ As noted earlier for the overall patient population, hospital characteristics were well balanced across all 3 surgical cohorts (CLC, MLC, and SPS).

All adverse events are reported in **Table 3**. Events are subdivided into 5 categories: procedure related, systemic, other events, death, and bleeding. The most common complications were in the category of other events and included abdominal rigidity/tenderness, digestive system complications, gastroparesis paralytic ileus, nausea and vomiting, operative complications, and

Table 2.
Comorbid Conditions

	SPS (n = 527) (%)	MLC (n = 1,940) (%)	CLC (n = 114,356) (%)
Cardiomyopathy	2 (0.4)	15 (0.8)	778 (0.7)
Cerebrovascular accident	1 (0.2)	11 (0.6)	548 (0.5)
Chronic obstructive pulmonary disease	14 (2.7)	73 (3.8)	4,232 (3.7)
Diabetes	23 (4.4)	170 (8.8)	9,904 (8.7)
Ischemic heart disease, including myocardial infarction	17 (3.2)	131 (6.8)	7,108 (6.2)
Hypertensive heart disease without heart failure	2 (0.4)	8 (0.4)	566 (0.5)
Heart failure	8 (1.5)	40 (2.1)	2,145 (1.9)
Hypertension	86 (16.3)	414 (21.3)	24,664 (21.6)
Chronic liver disease/disorders	14 (2.7)	75 (3.9)	6,425 (5.6)
Transient ischemic attack	1 (0.2)	16 (0.8)	754 (0.7)

Table 3.
Adverse Events

	SPS (n = 527) (%)	MLC (n = 1,940) (%)	CLC (n = 114,356) (%)
Procedure related			
Bile duct fistula	0 (0.0)	0 (0.0)	7 (0.0)
Bile duct obstruction	2 (0.4)	2 (0.1)	195 (0.2)
Bile duct perforation	0 (0.0)	0 (0.0)	6 (0.0)
Systemic adverse events			
Cerebrovascular accident	0 (0.0)	1 (0.1)	43 (0.0)
Acute myocardial infarction	0 (0.0)	2 (0.1)	37 (0.0)
Transient ischemic attack	0 (0.0)	2 (0.1)	46 (0.0)
Other embolism	0 (0.0)	3 (0.2)	120 (0.1)
Pneumothorax	0 (0.0)	0 (0.0)	16 (0.0)
Pulmonary embolism	1 (0.2)	3 (0.2)	95 (0.1)
Other adverse events			
Abdominal rigidity/tenderness	0 (0.0)	0 (0.0)	114 (0.1)
Digestive system complications	8 (1.5)	15 (0.8)	735 (0.6)
Gastroparesis paralytic ileus	4 (0.8)	7 (0.4)	438 (0.4)
Nausea and vomiting	45 (8.5)	86 (4.4)	4,874 (4.3)
Operative complication	19 (3.6)	30 (1.6)	2,006 (1.8)
Peritonitis (not specified)	1 (0.2)	3 (0.2)	103 (0.1)
Death			
Death during procedure	0 (0.0)	0 (0.0)	2 (0.0)
Death after procedure	0 (0.0)	2 (0.1)	35 (0.0)
Hemorrhage/bleeding			
Minor bleeding	0 (0.0)	0 (0.0)	9 (0.0)
Major bleeding	0 (0.0)	0 (0.0)	20 (0.0)
Any one or more adverse event	62 (11.8)	123 (6.3)	7,307 (6.4)

peritonitis. The overall adverse event rate was higher for SPS (12%) than for MLC (6%) and CLC (6%), with most of the events in all 3 groups falling into the “other events” category. The procedure-related systemic events, death and bleeding, were very infrequent (<0.5%) for all 3 groups.

Table 4 shows the unadjusted means and medians for hospital costs, as well as median surgery time, for each group. In the outpatient setting, CLC (median, \$3,600.37) costs slightly more than MLC (median, \$3,357.01) but less than SPS (median, \$4,367.93). It is essential to adjust for a number of potential confounders in multivariable regression analyses, including patient demographics, comorbid conditions, and hospital characteristics.

Adjusted Analysis

The results of adjusted analyses of costs and complication rates are shown in **Table 5**. After we adjusted for the aforementioned variables, adjusted mean hospital costs remained significantly higher ($P < .0001$) for SPS versus MLC (\$4,680.40 vs \$3,846.19) and SPS versus CLC (\$5,313.96 vs \$4,350.29). When we compared MLC versus CLC, cost differences were lower but still significant ($P < .0001$), with MLC at \$4,137.23 versus CLC at \$4,349.06.

Results of the multivariable logistic regressions for the likelihood of patients having an adverse event showed significant ($P < .0001$) odds ratios of 1.92 (95% confidence interval, 1.38–2.68) for SPS compared with MLC and 1.80 (95% confidence interval, 1.37–2.35) for SPS compared with CLC. However, when MLC was compared with CLC, the difference was not significant.

DISCUSSION

This retrospective analysis of a large, nationally representative database of hospitals and procedures found that

patients undergoing SPS had higher adverse event rates than those undergoing MLC or CLC. The analysis also showed that SPS was associated with higher adjusted hospital outpatient costs than CLC but that MLC, when performed in this setting, was the least expensive. These findings are somewhat consistent with a recent review of SPS, which also raised concerns about the safety of the procedure, and a recent meta-analysis of primarily MLC procedures, which found similar rates of adverse events compared with patients undergoing CLC.^{17,18}

Clinical Implications

Innovations in the surgical approach to performing cholecystectomy represent an important potential pathway to improving patient outcomes. The development and diffusion of laparoscopic cholecystectomy to the United States that began more than 20 years ago heralded a reduction in postoperative mortality rates and days of convalescence for patients who would have otherwise been treated with open cholecystectomy.² This pattern of innovation continues with both SPS and MLC. However, continued improvements in patient outcomes can only be ensured with careful attention to the comparative effectiveness of these procedures relative to CLC, which constitutes most cholecystectomies currently performed in developed countries.¹⁹

Adverse event rates in patients undergoing cholecystectomy in outpatient hospital centers were highest in patients treated with SPS compared with MLC and CLC and were comparable between patients treated with MLC and those treated with CLC. This difference appears to be driven by higher rates of bile duct obstruction, digestive system complications, gastroparesis, paralytic ileus, postoperative nausea and vomiting, and operative complications in the SPS population. The incidence of serious adverse events, including bile duct injury, thromboembolic events (including stroke and myocardial infarction), and hemorrhage, was low across all proce-

Table 4.
Unadjusted Utilization and Cost Outcomes

	SPS (n = 527)	MLC (n = 1,940)	CLC (n = 114,356)
Surgery time (median, h)	1.60	1.26	1.35
Anesthesia time (median, h)	1.57	1.50	1.47
No. of readmissions (30 days after surgery) (%)	20 (3.8)	71 (3.7)	3,200 (2.8)
Total hospital costs (\$)			
Median	4,367.93	3,357.01	3,600.37
Mean	4,573.74	3,814.35	3,964.67
SD	1,664.17	1,992.26	1,967.81

Table 5.
Multivariable Cost and Adverse Event Findings^a

	LS ^b Mean	95% CI ^b for LS Mean	OR ^b	95% CI for OR	P Value
SPS/MLC outpatients (n = 2,535)					
Total hospital costs (\$)					
SPS	\$4,680.40	\$4,480.96–\$4,888.73			< .0001
MLC	\$3,846.19	\$3,722.38–\$3,974.11			
Adverse events (any adverse event/none)					
SPS vs MLC			1.92	1.38–2.68	.0001
SPS/CLC outpatients (n = 114,883)					
Total hospital costs (\$)					
SPS	\$5,313.96	\$5,119.09–\$5,516.25			< .0001
CLC	\$4,350.29	\$4,276.75–\$4,425.09			
Adverse events (any adverse event/none)					
SPS vs CLC			1.80	1.37–2.35	< .0001
MLC/CLC outpatients (n = 116,296)					
Total hospital costs (\$)					
MLC	\$4,137.23	\$4,037.97–\$4,238.93			< .0001
CLC	\$4,349.06	\$4,275.54–\$4,423.85			
Adverse events (any adverse event/none)					
MLC vs CLC			1.01	0.84–1.21	.9333

^aAll models are adjusted for patient demographics, comorbid conditions, patient severity, and hospital characteristics.

^bCI=confidence interval; LS=least square; OR=odds ratio.

dures and did not appear to be substantially different in patients undergoing SPS.

Economic Implications

Adjusted hospital outpatient costs were highest in patients undergoing SPS: SPS cost 18% more than MLC and 18% more than CLC, with a difference of \$834 and \$964, respectively (**Table 5**). The analyses also showed that MLC was associated with the lowest hospital costs. It is likely that the differences in adverse event rates detailed earlier contributed to the cost differences.

Because otherwise healthy patients with reliable home support can leave the hospital within 6 hours of undergoing cholecystectomy, outpatient models of cholecystectomy are increasingly used.²⁰ The sources of variation in costs of cholecystectomy procedures performed in an outpatient setting should be explored further in future studies, but these findings of statistically significant differences between the cost of SPS and the cost of MLC or CLC may have important implications with regard to the cost of the procedure to the hospital or outpatient facility. With

approximately 750,000 laparoscopic cholecystectomies performed in the United States each year, any differences in procedure-related costs or savings could be significant and realizable.^{1,2}

Limitations

This analysis was limited by the lack of more detailed information about patients and procedures. For instance, it would have been of interest to examine the influence of additional patient characteristics, such as weight or body mass index, and more procedure-related details. In the future, this may be possible as clinically rich datasets become available from greater use of electronic medical records in hospital settings, thereby facilitating analyses in these directions.

The analyses of adverse event rates and the specific types of complications constituting these rates in patients undergoing SPS were also limited by a small sample size, particularly compared with the number of patients in the database who underwent MLC or CLC. Surgeon experience is a well-established predictor of the overall inci-

dence of laparoscopic complications, and we were unable to adjust for this important variable.^{21,22} The available data will likely become more robust over time as procedure volume increases.

Even without access to the additional clinical detail available in electronic medical records, the Premier Hospital Database provides a strong basis for this analysis, given the very large numbers of patients and procedures that it provides, as well as the nationwide scope it represents.¹⁵ Thus the cost of each procedure was based on costs across the Premier network. This analysis found MLC to have a statistically lower cost to the hospital in comparison with CLC. The reasons for these differences were not ascertained, and further study to understand these differences would be of interest.

CONCLUSION

The analysis of a large, nationally representative hospital claims database provides evidence that, in the outpatient setting, SPS costs approximately 18% more than MLC and CLC. Mini-laparoscopic surgery costs approximately 5% less than traditional laparoscopy. Although additional studies may be useful, these findings could help shape practice patterns, treatment guidelines, and payor policy in the management of patients requiring cholecystectomy.

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Appendix A.

Procedure Codes for Laparoscopic Cholecystectomy

	Description
ICD-9 ^a code	
51.23	Laparoscopic cholecystectomy
51.24	Laparoscopic partial cholecystectomy
CPT ^a code	
47562	Laparoscopic cholecystectomy
47563	Laparoscopic cholecystectomy with cholangiography
47564	Laparoscopic cholecystectomy with exploration of common duct

^aCPT=Current Procedural Terminology; ICD-9= *International Classification of Diseases, Ninth Revision*.

Appendix B.

Diagnosis Codes for Comorbid Conditions

Event	ICD-9 ^a Code	Description
Transient ischemic attack	435.8	Other specified transient cerebral ischemia
	435.9	Unspecified transient cerebral ischemia
Cerebrovascular accident	430	Subarachnoid hemorrhage
	431	Intracerebral hemorrhage
	432	Nontraumatic extradural hemorrhage
	432.1	Subdural hemorrhage
	432.9	Unspecified intracranial hemorrhage
	433.01	Occlusion and stenosis, basilar artery, with cerebral infarction
	433.11	Occlusion and stenosis, carotid artery, with cerebral infarction
	433.21	Occlusion and stenosis, vertebral artery, with cerebral infarction
	433.31	Occlusion and stenosis, multiple and bilateral precerebral arteries, with cerebral infarction
	433.81	Occlusion and stenosis, other specified precerebral artery, with cerebral infarction
	433.91	Occlusion and stenosis, unspecified precerebral artery, with cerebral infarction
	434.01	Cerebral thrombosis, with cerebral infarction
	434.11	Cerebral embolism, with cerebral infarction
	434.91	Cerebral artery occlusion, unspecified, with cerebral infarction
	997.02	Iatrogenic cerebrovascular infarction or hemorrhage
Diabetes	249	Secondary diabetes mellitus
	249.01	Secondary diabetes mellitus without mention of complication, uncontrolled
	249.1	Secondary diabetes mellitus with ketoacidosis
	249.11	Secondary diabetes mellitus with ketoacidosis, uncontrolled
	249.2	Secondary diabetes mellitus with hyperosmolarity
	249.21	Secondary diabetes mellitus with hyperosmolarity, uncontrolled
	249.3	Secondary diabetes mellitus with other coma
	249.31	Secondary diabetes mellitus with other coma, uncontrolled
249.4	Secondary diabetes mellitus with renal manifestations	

Appendix B. (continued)		
Diagnosis Codes for Comorbid Conditions		
Event	ICD-9 ^a Code	Description
	249.41	Secondary diabetes mellitus with renal manifestations, uncontrolled
	249.5	Secondary diabetes mellitus with ophthalmic manifestations
	249.51	Secondary diabetes mellitus with ophthalmic manifestations, uncontrolled
	249.6	Secondary diabetes mellitus with neurological manifestations
	249.61	Secondary diabetes mellitus with neurological manifestations, uncontrolled
	249.7	Secondary diabetes mellitus with peripheral circulatory disorders
	249.71	Secondary diabetes mellitus with peripheral circulatory disorders, uncontrolled
	249.8	Secondary diabetes mellitus with other specified manifestations
	249.81	Secondary diabetes mellitus with other specified manifestations, uncontrolled
	249.9	Secondary diabetes mellitus with unspecified complication
	249.91	Secondary diabetes mellitus with unspecified complication, uncontrolled
	250	Diabetes mellitus
	250.01	Diabetes mellitus without mention of complication, type I (juvenile type), not stated as uncontrolled
	250.02	Diabetes mellitus without mention of complication, type II or unspecified type, uncontrolled
	250.03	Diabetes mellitus without mention of complication, type I (juvenile type), uncontrolled
	250.1	Diabetes with ketoacidosis, type II or unspecified type, not stated as uncontrolled
	250.11	Diabetes with ketoacidosis, type I (juvenile type), not stated as uncontrolled
	250.12	Diabetes with ketoacidosis, type II or unspecified type, uncontrolled
	250.13	Diabetes with ketoacidosis, type I (juvenile type), uncontrolled
	250.2	Diabetes with hyperosmolarity
	250.21	Diabetes with hyperosmolarity, type I (juvenile type), not stated as uncontrolled
	250.22	Diabetes with hyperosmolarity, type II or unspecified type, uncontrolled
	250.23	Diabetes with hyperosmolarity, type I (juvenile type), uncontrolled
	250.3	Diabetes with other coma
	250.31	Diabetes with other coma, type I (juvenile type), not stated as uncontrolled
	250.32	Diabetes with other coma, type II or unspecified type, uncontrolled
	250.33	Diabetes with other coma, type I (juvenile type), uncontrolled
	250.4	Diabetes with renal manifestations
	250.41	Diabetes with renal manifestations, type I (juvenile type), not stated as uncontrolled
	250.42	Diabetes with renal manifestations, type II or unspecified type, uncontrolled
	250.43	Diabetes with renal manifestations, type I (juvenile type), uncontrolled
	250.5	Diabetes with ophthalmic manifestations
	250.51	Diabetes with ophthalmic manifestations, type I (juvenile type), not stated as uncontrolled
	250.52	Diabetes with ophthalmic manifestations, type II or unspecified type, uncontrolled

Appendix B. (continued)
Diagnosis Codes for Comorbid Conditions

Event	ICD-9 ^a Code	Description
	250.53	Diabetes with ophthalmic manifestations, type I (juvenile type), uncontrolled
	250.6	Diabetes with neurological manifestations, type II or unspecified type, not stated as uncontrolled
	250.61	Diabetes with neurological manifestations, type I (juvenile type), not stated as uncontrolled
	250.62	Diabetes with neurological manifestations, type II or unspecified type, uncontrolled
	250.63	Diabetes with neurological manifestations, type I (juvenile type), uncontrolled
	250.7	Diabetes with peripheral circulatory disorders
	250.71	Diabetes with peripheral circulatory disorders, type I (juvenile type), not stated as uncontrolled
	250.72	Diabetes with peripheral circulatory disorders, type II or unspecified type, uncontrolled
	250.73	Diabetes with peripheral circulatory disorders, type I (juvenile type), uncontrolled
	250.8	Diabetes with other specified manifestations
	250.81	Diabetes with other specified manifestations, type I (juvenile type), not stated as uncontrolled
	250.82	Diabetes with other specified manifestations, type II or unspecified type, uncontrolled
	250.83	Diabetes with other specified manifestations, type I (juvenile type), uncontrolled
	250.9	Diabetes with unspecified complication
	250.91	Diabetes with unspecified complication, type I (juvenile type), not stated as uncontrolled
	250.92	Diabetes with unspecified complication, type II or unspecified type, uncontrolled
	250.93	Diabetes with unspecified complication, type I (juvenile type), uncontrolled
Chronic obstructive pulmonary disease	491.1	Mucopurulent chronic bronchitis
	491.2	Obstructive chronic bronchitis
	491.21	Obstructive chronic bronchitis with (acute) exacerbation
	491.22	Obstructive chronic bronchitis with acute bronchitis
	491.8	Other chronic bronchitis
	491.9	Unspecified chronic bronchitis
	492	Emphysema
	492.0	Emphysematous bleb
	492.8	Other emphysema
	493.2	Chronic obstructive asthma
	493.20	Chronic obstructive asthma, unspecified
	493.21	Chronic obstructive asthma with status asthmaticus
	493.22	Chronic obstructive asthma with (acute) exacerbation
	494	Bronchiectasis
	494.0	Bronchiectasis without acute exacerbation

Appendix B. (continued)
Diagnosis Codes for Comorbid Conditions

Event	ICD-9 ^a Code	Description
Chronic liver disease/disorders	494.1	Bronchiectasis with acute exacerbation
	496	Chronic airway obstruction, not elsewhere classified
	571.x	Chronic liver disease and cirrhosis
	571.4x	Chronic hepatitis
	572.x	Liver abscess and sequelae of chronic liver disease
Hypertension	573.x	Other disorders of liver
	401	Essential hypertension
	401.0	Malignant essential hypertension
	401.1	Benign essential hypertension
	401.9	Unspecified essential hypertension
	405	Secondary hypertension
	405.0	Malignant secondary hypertension
	405.01	Malignant renovascular hypertension
	405.09	Other malignant secondary hypertension
	405.1	Benign secondary hypertension
	405.11	Benign renovascular hypertension
	405.19	Other benign secondary hypertension
	405.9	Unspecified secondary hypertension
	405.91	Unspecified renovascular hypertension
	405.99	Other unspecified secondary hypertension
	Ischemic heart disease, including myocardial infarction	410
410.0		Acute myocardial infarction of anterolateral wall
410.01		Acute myocardial infarction of anterolateral wall, initial episode of care
410.02		Acute myocardial infarction of anterolateral wall, subsequent episode of care
410.1		Acute myocardial infarction of other anterior wall
410.10		Acute myocardial infarction of other anterior wall, episode of care unspecified
410.11		Acute myocardial infarction of other anterior wall, initial episode of care
410.12		Acute myocardial infarction of other anterior wall, subsequent episode of care
410.2		Acute myocardial infarction of inferolateral wall
410.20		Acute myocardial infarction of inferolateral wall, episode of care unspecified
410.21		Acute myocardial infarction of inferolateral wall, initial episode of care
410.22		Acute myocardial infarction of inferolateral wall, subsequent episode of care
410.3		Acute myocardial infarction of inferoposterior wall
410.30		Acute myocardial infarction of inferoposterior wall, episode of care unspecified
410.31		Acute myocardial infarction of inferoposterior wall, initial episode of care
410.32		Acute myocardial infarction of inferoposterior wall, subsequent episode of care
410.4	Acute myocardial infarction of other inferior wall	
410.40	Acute myocardial infarction of other inferior wall, episode of care unspecified	

Appendix B. (continued)
Diagnosis Codes for Comorbid Conditions

Event	ICD-9 ^a Code	Description
	410.41	Acute myocardial infarction of other inferior wall, initial episode of care
	410.42	Acute myocardial infarction of other inferior wall, subsequent episode of care
	410.5	Acute myocardial infarction of other lateral wall
	410.50	Acute myocardial infarction of other lateral wall, episode of care unspecified
	410.51	Acute myocardial infarction of other lateral wall, initial episode of care
	410.52	Acute myocardial infarction of other lateral wall, subsequent episode of care
	410.6	Acute myocardial infarction of posterior wall infarction
	410.61	Acute posterior wall infarction, initial episode of care
	410.62	Acute posterior wall infarction, subsequent episode of care
	410.7	Subendocardial infarction
	410.70	Subendocardial infarction, episode of care unspecified
	410.71	Subendocardial infarction, initial episode of care
	410.72	Subendocardial infarction, subsequent episode of care
	410.8	Acute myocardial infarction of other specified sites
	410.80	Acute myocardial infarction of other specified sites, episode of care unspecified
	410.81	Acute myocardial infarction of other specified sites, initial episode of care
	410.82	Acute myocardial infarction of other specified sites, subsequent episode of care
	410.9	Acute myocardial infarction of unspecified site
	410.90	Acute myocardial infarction of unspecified site, episode of care unspecified
	410.91	Acute myocardial infarction of unspecified site, initial episode of care
	410.92	Acute myocardial infarction of unspecified site, subsequent episode of care
	411	Other acute and subacute forms of ischemic heart disease
	411.0	Postmyocardial infarction syndrome
	411.1	Intermediate coronary syndrome
	411.8	Other acute and subacute forms of ischemic heart disease
	411.81	Acute coronary occlusion without myocardial infarction
	411.89	Other acute and subacute forms of ischemic heart disease, other
	412	Old myocardial infarction
	413	Angina pectoris
	413.0	Angina decubitus
	413.1	Prinzmetal angina
	413.9	Other and unspecified angina pectoris
	414	Other forms of chronic ischemic heart disease
	414.0	Coronary atherosclerosis
	414.00	Coronary atherosclerosis of unspecified type of vessel, native or graft
	414.01	Coronary atherosclerosis of native coronary artery
	414.02	Coronary atherosclerosis of autologous vein bypass graft
	414.03	Coronary atherosclerosis of nonautologous biological bypass graft

Appendix B. (continued)

Diagnosis Codes for Comorbid Conditions

Event	ICD-9 ^a Code	Description
	414.04	Coronary atherosclerosis of artery bypass graft
	414.05	Coronary atherosclerosis of unspecified bypass graft
	414.06	Coronary atherosclerosis of native coronary artery of transplanted heart
	414.07	Coronary atherosclerosis of bypass graft transplanted heart
	414.1	Aneurysm and dissection of heart
	414.10	Aneurysm of heart (wall)
	414.11	Aneurysm of coronary vessels
	414.12	Dissection of coronary artery
	414.19	Other aneurysm of heart
	414.2	Chronic total occlusion of coronary artery
	414.3	Coronary atherosclerosis due to lipid rich plaque
	414.8	Other specified forms of chronic ischemic heart disease
	414.9	Chronic ischemic heart disease, unspecified
Heart failure	398.91	Rheumatic heart failure (congestive)
	402.01	Benign hypertensive heart disease without heart failure
	402.11	Benign hypertensive heart disease with heart failure
	402.91	Unspecified hypertensive heart disease with heart failure
	404.01	Hypertensive heart and chronic kidney disease, malignant, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified
	404.03	Hypertensive heart and chronic kidney disease, malignant, with heart failure and with chronic kidney disease stage V or end stage renal disease
	404.11	Hypertensive heart and chronic kidney disease, benign, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified
	404.13	Hypertensive heart and chronic kidney disease, benign, with heart failure and chronic kidney disease stage V or end stage renal disease
	404.91	Hypertensive heart and chronic kidney disease, unspecified, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified
	404.93	Hypertensive heart and chronic kidney disease, unspecified, with heart failure and chronic kidney disease stage V or end stage renal disease
	428	Heart failure
	428.0	Congestive heart failure, unspecified
	428.1	Left heart failure
	428.2	Systolic heart failure
	428.21	Acute systolic heart failure
	428.22	Chronic systolic heart failure
	428.23	Acute on chronic systolic heart failure
	428.3	Diastolic heart failure
	428.31	Acute diastolic heart failure
	428.32	Chronic diastolic heart failure
	428.33	Acute on chronic diastolic heart failure
	428.4	Combined systolic and diastolic heart failure
	428.41	Acute combined systolic and diastolic heart failure

Appendix B. (continued)
 Diagnosis Codes for Comorbid Conditions

Event	ICD-9 ^a Code	Description
Cardiomyopathy	428.42	Chronic combined systolic and diastolic heart failure
	428.43	Acute on chronic combined systolic and diastolic heart failure
	428.9	Heart failure, unspecified
	425	Cardiomyopathy
	425.0	Endomyocardial fibrosis
	425.1	Hypertrophic cardiomyopathy
	425.2	Obscure cardiomyopathy of Africa
	425.3	Endocardial fibroelastosis
	425.4	Other primary cardiomyopathies
	425.5	Alcoholic cardiomyopathy
	425.7	Nutritional and metabolic cardiomyopathy
	425.8	Cardiomyopathy in other diseases classified elsewhere
	425.9	Secondary cardiomyopathy, unspecified
Hypertensive heart disease without heart failure	402	Hypertensive heart disease
	402.0	Malignant hypertensive heart disease
	402.1	Benign hypertensive heart disease
	402.10	Benign hypertensive heart disease without heart failure
	402.9	Unspecified hypertensive heart disease
	404	Hypertensive heart and chronic kidney disease
	404.02	Hypertensive heart and chronic kidney disease, malignant, without heart failure and with chronic kidney disease stage V or end stage renal disease
	404.1	Benign hypertensive heart and renal disease
	404.12	Hypertensive heart and chronic kidney disease, benign, without heart failure and with chronic kidney disease stage V or end stage renal disease
	404.9	Unspecified hypertensive heart and renal disease
	404.90	Hypertensive heart and chronic kidney disease, unspecified, without heart failure and with chronic kidney disease stage I through stage IV, or unspecified
404.92	Hypertensive heart and chronic kidney disease, unspecified, without heart failure and with chronic kidney disease stage V or end stage renal disease	

^aICD-9= *International Classification of Diseases, Ninth Revision.*

Appendix C.
Diagnosis Codes for Adverse Events

Event	ICD-9 ^a Code	Description
Transient ischemic attack	435.8	Other specified transient cerebral ischemia
	435.9	Unspecified transient cerebral ischemia
Cerebrovascular accident	430	Subarachnoid hemorrhage
	431	Intracerebral hemorrhage
	432.0	Nontraumatic extradural hemorrhage
	432.1	Subdural hemorrhage
	432.9	Unspecified intracranial hemorrhage
	433.01	Occlusion and stenosis, basilar artery, with cerebral infarction
	433.11	Occlusion and stenosis, carotid artery, with cerebral infarction
	433.21	Occlusion and stenosis, vertebral artery, with cerebral infarction
	433.31	Occlusion and stenosis, multiple and bilateral precerebral arteries, with cerebral infarction
	433.81	Occlusion and stenosis, other specified precerebral artery, with cerebral infarction
	433.91	Occlusion and stenosis, unspecified precerebral artery, with cerebral infarction
	434.01	Cerebral thrombosis, with cerebral infarction
	434.11	Cerebral embolism, with cerebral infarction
434.91	Cerebral artery occlusion, unspecified, with cerebral infarction	
997.02	Iatrogenic cerebrovascular infarction or hemorrhage	
Acute myocardial infarction	410.01	Acute myocardial infarction, anterolateral wall
	410.11	Acute myocardial infarction, other anterior wall
	410.21	Acute myocardial infarction, inferolateral wall
	410.31	Acute myocardial infarction, inferoposterior wall
	410.41	Acute myocardial infarction, other inferior wall
	410.51	Acute myocardial infarction, other lateral wall
	410.61	Acute myocardial infarction, true posterior wall
	410.71	Acute myocardial infarction, subendocardial (NSTEMI ^b)
	410.81	Acute myocardial infarction, other sites
410.91	Acute myocardial infarction, unspecified site	
Pneumothorax	512.0	Spontaneous tension pneumothorax
	512.1	Iatrogenic pneumothorax
	512.8	Other spontaneous pneumothorax
Pulmonary embolism	415.1	Pulmonary embolism and infarction
	415.11	Iatrogenic pulmonary embolism and infarction
	415.12	Septic pulmonary embolism
	415.19	Other pulmonary embolism and infarction
Other embolism	453.4	Acute venous embolism and thrombosis of deep vessels of lower extremity
	453.41	Acute venous embolism and thrombosis of deep vessels of proximal lower extremity
	453.42	Acute venous embolism and thrombosis of deep vessels of distal lower extremity

Appendix C. (continued)
 Diagnosis Codes for Adverse Events

Event	ICD-9 ^a Code	Description
Operative complication	453.8	Acute venous embolism and thrombosis of other specified veins
	453.9	Other venous embolism and thrombosis of unspecified site
	997.1	Cardiac complications
	997.2	Peripheral vascular complications
	997.3	Respiratory complications
	997.31	Ventilator associated pneumonia
	997.39	Other respiratory complications
	997.4	Digestive system
	997.5	Urinary tract
	997.7	Vascular complications of other vessels
Other adverse events	998	Other complications of procedures
	998.x	Other complications of procedures
	998.xx	Other complications of procedures
	997.4	Digestive system complications
	789.4x	Abdominal rigidity/tenderness
	789.6x	Abdominal rigidity/tenderness
	536.2	Nausea and vomiting nausea
	564.3	Nausea and vomiting nausea
	787.0x	Nausea and vomiting nausea
	536.3	Gastroparesis paralytic ileus
	560.1	Gastroparesis paralytic ileus
	567.9	Peritonitis not specified
	567.8x	Peritonitis not specified
	576.2	Bile duct obstruction
576.3	Bile duct perforation	
576.4	Bile duct fistula	

^aICD-9= *International Classification of Diseases, Ninth Revision*; NSTEMI=non-ST-segment elevation myocardial infarction.