

The effects of laparoscopic cholecystectomy, hysterectomy, and appendectomy on nosocomial infection risks

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Abstract

Background Recent reviews of the literature have concluded that additional, well-defined studies are required to clarify the superiority of laparoscopic or open surgery. This paper presents precise estimates of nosocomial infection risks associated with laparoscopic as compared to open surgery in three procedures: cholecystectomy, appendectomy, and hysterectomy.

Methods A retrospective analysis was performed on 11,662 admissions from 22 hospitals that have a nosocomial infection monitoring system. The Nosocomial Infection Marker (NIMTM, patent pending) was used to identify nosocomial infections during hospitalization and post discharge. The dataset was limited to admissions with laparoscopic or open cholecystectomy (32.7%), appendectomy (24.0%), or hysterectomy (43.3%) and was analyzed by source of infection: urinary tract, wounds, respiratory tract, bloodstream, and others. Single- and multivariable logistic regression analyses were performed to control for the following potentially confounding

variables: gender, age, type of insurance, complexity of admission on presentation, admission through the emergency department, and hospital case mix index (CMI).

Results Analyses were based on 399 NIMs in 337 patients. Laparoscopic cholecystectomy and hysterectomy each reduced the overall odds of acquiring nosocomial infections by more than 50% ($p < 0.01$). Laparoscopic cholecystectomy and hysterectomy also resulted in statistically significantly fewer readmissions with nosocomial infections ($p < 0.01$). Excluding appendectomy, the odds ratio for laparoscopic versus open NIM-associated readmission was 0.346 ($p < 0.01$). Laparoscopic appendectomy did not significantly change the odds of acquiring nosocomial infections.

Conclusion As compared to open surgery, laparoscopic cholecystectomy and hysterectomy are associated with statistically significantly lower risks for nosocomial infections. For appendectomy, when comparing open versus laparoscopic approaches, no differences in the rate of nosocomial infections were detected.

Keywords Nosocomial · Laparoscopic · Cholecystectomy · Appendectomy · Hysterectomy

List of abbreviations

NIM nosocomial infection marker
CAH Cardinal Health
CMI case mix index
OR odds ratio

With the realization of smaller incisions, better cosmesis, less postoperative pain, same-day surgery, speedier postoperative recovery, and the potential for reduced

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complications, laparoscopic approaches have all but replaced the traditional laparotomic alternatives for certain commonly performed surgical procedures. However, the widespread adoption of laparoscopic techniques into the overall surgical armamentarium has been slowed by a variety of factors, including the learning curves required to integrate new levels of depth perception and fine dexterity, longer operating times without commensurate economic reward, and the nullification of savings from earlier hospital discharge by the cost of disposable surgical instrumentation. Nevertheless, the laparoscopic approach is now widely accepted as the gold standard for cholecystectomy and the surgical treatment of gastroesophageal reflux [1, 2].

Laparoscopic appendectomy has been controversial since its introduction in the early 1980s, particularly for cases of complicated appendicitis. Although laparoscopic appendectomies now account for almost half of appendectomies in the United States [3], several recent reviews of the literature have concluded that additional, well-defined studies will be required to clarify the superiority of laparoscopic or open approaches [4–6].

Despite the demonstration that abdominal hysterectomy is associated with higher morbidity and worse outcomes when compared to the vaginal or laparoscopic approach, the majority of hysterectomies worldwide are still performed in this fashion. For the remaining cases, laparoscopic hysterectomy is least apt to be performed [7, 8]. Although laparoscopy facilitates vaginal hysterectomy for the larger uterus, allows for the concurrent diagnosis and treatment of benign pelvic conditions such as endometriosis or pelvic adhesions, permits concomitant adnexal surgery, and provides the ability to secure and reaffirm intraperitoneal hemostasis at the end of the procedure [9], a meta-analysis of randomized controlled trials comparing different types of hysterectomy published by the Cochrane Collaboration failed to clearly demonstrate the superiority of laparoscopic hysterectomy over vaginal hysterectomy [10].

Some studies have reported that laparoscopic approaches are associated with lower risks of surgical site infections than their open counterparts [11–13], but the effects of laparoscopic surgery on overall nosocomial (hospital-acquired) infection risks have not been established. Since a significant number of nosocomial infections in surgical patients occur after discharge [14, 15], it is likely that comparisons of laparoscopic and open surgeries have underestimated risks.

Nosocomial infections are a leading cause of death in the United States, affecting two to three million patients annually [16]. Starting in 2009, Centers for Medicare and Medicaid Services (CMS) will stop reimbursing hospitals for certain complications including surgical-site infections,

catheter-associated urinary tract infections, and central-line associated bloodstream infections [17]. Therefore, the establishment of nosocomial infection risks in general is important.

The objective of this study is to obtain more precise estimates of nosocomial infection risks associated with laparoscopic and open approaches for cholecystectomy, appendectomy, and hysterectomy. We hypothesize that laparoscopic surgery will reduce the risk of nosocomial infections for each of these surgical modalities. To test these hypotheses we performed a retrospective analysis of more than 11,000 admissions, each with one of the procedures of interest, from 22 hospitals that have implemented a nosocomial infection monitoring system that can detect nosocomial infections up to 30 days post discharge.

Methods

The Nosocomial Infection Marker (NIM)

The Nosocomial Infection Marker (NIM, patent pending, Cardinal Health) monitors and tracks nosocomial infection rates for hospitals and communities. Cardinal Health extracts data from client facilities on an ongoing basis using a secure, Health Insurance Portability and Accountability Act- (HIPAA) compliant method. Data are cleaned and mapped in real time as they arrive at the Cardinal Health data center by proprietary software systems. Rare exceptions that are not electronically modeled are modeled by technical and clinical experts, processed and loaded. The new models are then used by the systems to process like data in the future.

The Nosocomial Infection Marker is a computer algorithm that identifies the existence of nosocomial infections at the microbiological level. Specifically, the NIM algorithm distinguishes likely pathogens from contaminants, identifies duplicate isolates, and temporally determines hospital versus community-acquired pathogen acquisition [18].

In a multihospital study using comprehensive medical records review and gold-standard infectious disease physician discrepancy resolution, the NIM algorithm identified nosocomial infections with 86% sensitivity and 98.5% specificity hospital-wide, statistically outperforming Centers for Disease Control (CDC) case finding methods [18]. Unlike the NIM, traditional CDC case finding methods are subjectively applied with inconsistent results and are only used for certain types of infections, mostly in ICUs [18, 19]. Like the NIM, the performance characteristics of CDC methods have only been formally evaluated in one study [19].

Data

The Nosocomial Infection Marker (NIM) was used to identify nosocomial infections during hospitalization and post discharge. Data were extracted from the Cardinal Health (CAH) data repository for the period September 1, 2004 through December 31, 2006 from 22 hospitals in 15 states. Hospitals with matching International Statistical Classification of Diseases and Related Health Problems (ICD-9) procedure codes and more than 100 admissions with a primary ICD-9 procedure for cholecystectomy, appendectomy, or hysterectomy were eligible. These hospitals had a median number of beds of 359, with an interquartile range from 191 to 483 beds; one hospital exceeded 1,000 beds and two had fewer than 150. Mean hospital CMI was 1.56 with a standard deviation of 0.22. Admissions with primary Diagnosis Related Group (DRGs) listed in Table 1 comprised more than 95% of eligible admissions. When these admissions were restricted to adults 18 years and older for cholecystectomy and hysterectomy, and patients 2 years and older for appendectomy, 11,662 admissions were available for analysis.

Data elements included NIMs, age, gender, insurance type (Medicaid, Medicare, private, other), hospital case mix index (CMI), primary DRG, whether or not the admission was through emergency department (ED), and ICD-9 procedure codes. The primary ICD-9 procedure code was used to identify both procedure (cholecystectomy, appendectomy, or hysterectomy) and type of approach (open or

laparoscopic) and the primary DRG was used to differentiate simple from complex presentations in an attempt to account for intrinsic infection risks and biases towards open approaches. DRGs indicating malignancy or other complex presentations were assigned a complexity value of 1, as shown in Table 1. Hospital CMI was used to control for differences between and clustering within hospitals.

Statistical Analysis

Single and multiple logistic regression analyses were performed to quantify the associations between NIM rate and procedure, approach, patient age, gender, insurance type, complexity of presentation, ED admission status, and hospital CMI. The first model pooled all three procedures and included binary variables to adjust for the influence of each procedure on the acquisition of NIMs. Then separate models for cholecystectomy, appendectomy, and hysterectomy were constructed. Finally models were constructed for procedure and approach for wound, urinary tract, bloodstream, and respiratory tract NIMs.

Results

Hysterectomies comprised 43.3% of all procedures, cholecystectomies 32.7%, and appendectomies 24.0%. The percentage of cholecystectomies, appendectomies, and hysterectomies that were laparoscopic was 84.7%, 65.6%,

Table 1 DRGs included in the analysis

		% admissions	NIM rate	% laparoscopy
<i>Simple presentations (complexity = 0)</i>				
166	Appendectomy W/O complicated Principal Diag W Cc	3.16	2.71	67.21
167	Appendectomy W/O Complicated Principal Diag W/O Cc	14.53	1.12	71.66
195	Cholecystectomy W C.D.E. W Cc	0.52	14.75	16.39
196	Cholecystectomy W C.D.E. W/O Cc	0.21	0.00	25.00
197	Cholecystectomy Except By Laparoscope W/O C.D.E. W Cc	3.64	9.43	11.79
198	Cholecystectomy Except By Laparoscope W/O C.D.E. W/O Cc	2.01	2.56	40.60
358	Uterine & Adnexa Proc For Non-Malignancy W Cc	11.43	3.30	36.53
359	Uterine & Adnexa Proc For Non-Malignancy W/O Cc	25.72	1.20	47.92
493	Laparoscopic Cholecystectomy W/O C.D.E. W Cc	14.86	4.15	100
494	Laparoscopic Cholecystectomy W/O C.D.E. W/O Cc	11.42	0.68	100
<i>Complex presentations (complexity = 1)</i>				
164	Appendectomy W Complicated Principal Diag W Cc	2.96	9.28	47.25
165	Appendectomy W Complicated Principal Diag W/O Cc	3.39	3.04	54.43
354	Uterine, Adnexa Proc For Non-Ovarian/Adnexal Malig W Cc	2.24	8.05	5.36
355	Uterine, Adnexa Proc For Non-Ovarian/Adnexal Malig W/O Cc	2.04	2.10	19.33
357	Uterine & Adnexa Proc For Ovarian Or Adnexal Malignancy	1.89	10.00	5.00

Diag = Diagnosis; W/O = Without; C.D.E. = Common Duct Exploration; Proc = Procedure; Malig = Malignancy; W = With; Cc = Complication and comorbidities

Table 2 Nosocomial infection rates by approach and procedure

	Admissions	Admissions with ≥ 1 NIM	Rate (%)
	11,662	337	2.89
Approach			
Laparoscopic	7061	149	2.11
Open	4601	188	4.09
Procedure			
Cholecystectomy	3808	136	3.57
Appendectomy	2803	73	2.60
Hysterectomy	5051	128	2.53
Approach by procedure			
Laparoscopic			
Cholecystectomy	3226	84	2.60
Appendectomy	1840	42	2.28
Hysterectomy	1995	23	1.15
Open			
Cholecystectomy	582	52	8.93
Appendectomy	963	31	3.21
Hysterectomy	3056	105	3.44

and 39.5%, respectively. Unsurprisingly, fewer than one-quarter of all patients were male. Approximately 19.3% of admissions were covered by Medicare, 7% by Medicaid, 58.8% by private health insurance, and the remaining 14.8% by other types of insurance.

NIM rates were defined as the number of admissions with at least one NIM divided by the total number of admissions. Of the 11,662 admissions, 337 (2.89%) had at least one NIM (Table 2). Overall, NIM rates were higher for open approaches (4.09%) than laparoscopic ones (2.11%). NIM rates were highest for cholecystectomy (3.57%), followed by appendectomy (2.60%), then hysterectomy (2.53%).

There were 399 NIMs identified in 337 admissions. Of all NIMs identified, 118 (30%) were from surgical wounds, 122 (31%) were from the urinary tract, 37 (9%) were from the blood, 29 (7%) were from the respiratory tract, and 93 (23%) were from other sources.

At least one post-discharge NIM was identified in 136 admissions, accounting for 40% of all admissions with a NIM. Of the 147 post-discharge NIMs, 39% were from surgical wounds, 31% were from the urinary tract, 7% were from blood, and 22% were from other sources. Of the 136 total admissions with at least one post-discharge NIM, 92 patients had NIM-associated readmissions.

Univariate Analyses

Simple logistic regressions examined associations between NIM rates and surgical approaches (laparoscopic or open),

Table 3 Univariate analyses of factors associated with NIM

Variable	Category	NIM rate (%)	OR	95% CI
Gender	Male	3.84	1.50	1.19–1.90
	Female	2.59		
Age	<18 years	2.41	0.82	0.49–1.39
	18–34 years	1.50	0.46	0.32–0.65
	35–49 years	2.20	0.66	0.52–0.84
	50–64 years	3.41	1.25	0.97–1.61
	65–74 years	3.89	1.41	1.02–1.95
	≥ 75 years	7.10	2.96	2.25–3.90
Insurance	Private	2.11	0.51	0.42–0.65
	Medicare	5.24	2.32	1.85–2.92
	Medicaid	3.19	1.12	0.74–1.68
	Other	2.77	0.95	0.70–1.29
Approach	Laparoscopic	2.11	0.32	0.21–0.52
	Open	4.09		
Procedure	Cholecystectomy	3.57	1.41	1.13–1.76
	Appendectomy	2.60	0.87	0.67–1.13
	Hysterectomy	2.53	0.79	0.64–0.97
CMI			2.28	1.59–3.27
Complexity	Complex	6.31	2.74	2.14–3.50
	Not complex	2.40		
Emergency department admission	Emergent	3.03	1.06	0.72–1.55
	Nonemergent	2.88		

CI: confidence interval; NIM: nosocomial infection marker; OR: odds ratio

and the following covariates: gender (male, female), age (<18 y, 18–34 y, 35–49 y, 50–64 y, 65–74 y, ≥ 75 y), surgical procedure (cholecystectomy, appendectomy, hysterectomy), type of insurance (private, Medicare, Medicaid, other), complexity of admission on presentation (0/1), admitted through ED (0/1), and hospital CMI. The results, summarized in Table 3, show significantly higher NIM rates for males, adults aged ≥ 65 years, patients undergoing cholecystectomy, complex admissions, and admissions covered by Medicare; and significantly lower NIM rates for laparoscopic surgery, females, adults 18–49 years old, patients undergoing hysterectomy, and those covered by private insurance. NIM rates were positively correlated with hospital CMI, but were unaffected by ED admission status.

Multivariable analyses

Since ED admission status was insignificant in the univariate analysis, it was excluded from the multivariable analyses. Pairwise correlations of all remaining covariates were performed, and all pairs were reasonably

Table 4 Multivariable logistic regression analyses of factors associated with NIM

Variable	Odds ratio for NIM			
	Pooled (<i>n</i> = 11,662)	Cholecystectomy (<i>n</i> = 3,808)	Appendectomy (<i>n</i> = 2,803)	Hysterectomy (<i>n</i> = 5,051)
Laparoscopy	0.48**	0.34**	0.97	0.48**
Type of procedure				
Cholecystectomy	1.87**	–	–	–
Hysterectomy	1.05	–	–	–
Age				
<18 years	0.83	–	0.90	–
18–34 years	0.64*	0.47	0.84	0.72
50–64 years	1.22	2.13*	1.00	0.96
65–74 years	1.02*	2.21*	0.58	0.51
≥75 years	1.92**	4.04**	3.31	0.61
Male	1.4*	1.11	1.89*	–
Type of insurance				
Medicare	1.42	1.33	1.12	2.09*
Medicaid	1.45	3.47**	1.11	0.79
Others	1.29	1.53	1.22	1.32
CMI	1.63*	1.09	1.31	2.88*
Complexity	2.45**	NS	3.95	2.54**

** Statistically significant at the 1% level

* Statistically significant at the 5% level

uncorrelated. Therefore, all were included in the multivariable analyses.

Results of multiple logistic regression models, which controlled for gender (male, female), age (<18 yr, 18–34 yr, 35–49 yr, 50–64 yr, 65–74 yr, ≥75 yr), type of insurance (private, Medicare, Medicaid, other), complexity of admission on presentation (0/1), and hospital CMI, show that laparoscopic procedures reduced the odds of acquiring a nosocomial infections by half, but that the effect is entirely attributable to reduced infection risks in laparoscopic cholecystectomy and hysterectomy with odds ratios (ORs) of 0.34 ($p < 0.01$) and 0.48 ($p < 0.01$), respectively. No change in nosocomial infection risk was found for laparoscopic appendectomy. Estimates for individual procedures are shown in Table 4.

Consistent with results of the univariate analyses, multivariable regression showed a significantly higher risk of NIMs for males, patients aged ≥65 years, and complexity of presentation at the time of admission. CMI was found to

be significant in both univariate and multivariable analyses [OR = 1.63 (CI₉₅ 1.11–2.40), $p < 0.05$], and this risk was significantly higher for hysterectomy patients, for whom the odds of acquiring a NIM were as high as 2.88 times that of not acquiring NIM.

Analysis of the same dataset by source of infection (urinary tract, wounds, respiratory tract, bloodstream, and others) revealed that the overall infection rates at each of these sites were all statistically significantly lower for laparoscopic approaches, as summarized in Table 5. The odds of acquiring a site-specific infection were statistically significantly lower for all sites in laparoscopic cholecystectomy and for wound sites in hysterectomy.

There were no significant differences between laparoscopic versus open appendectomy for all sources of nosocomial infections (urine, blood, wound, respiratory, and other). However, laparoscopic appendectomy is associated with a statistically significantly higher risk of abscess ($p < 0.05$), a finding consistent with the literature [12].

Table 5 Odds ratios by source

	Urinary tract	Wound	Respiratory tract	Bloodstream	Others
Overall OR (95% CI)	0.61 (0.38–0.96)	0.41 (0.27–0.62)	0.20 (0.08–0.49)	0.31 (0.14–0.65)	0.52 (0.33–0.82)
By procedure					
Cholecystectomy	0.48 (0.24–0.97)	0.20 (0.11–0.39)	0.17 (0.06–0.45)	0.23 (0.10–0.55)	0.34 (0.18–0.64)
Appendectomy	0.83 (NS)	1.06 (NS)	0.27 (NS)	Too few NIMs	0.91 (NS)
Hysterectomy	0.76 (NS)	0.27 (0.09–0.79)	Too few NIMs	0.48 (NS)	0.62 (NS)

OR: odds ratio, CI: confidence interval, NS: not significant

Forty-one percent of patients with a nosocomial infection had at least one post-discharge nosocomial infection, and 58 of 115 (50%) of surgical wound infections were post discharge. There were 118 readmissions associated with at least one post-discharge NIM, and post-discharge NIMs associated with readmission were significantly lower for laparoscopic approaches ($p < 0.001$). Excluding appendectomy, the odds ratio for laparoscopic versus open NIM-associated readmission was 0.346 (CI₉₅ 0.19–0.63).

Discussion

This study demonstrates that laparoscopic cholecystectomy and hysterectomy reduced the overall odds of acquiring nosocomial infections from all sources by more than 50% and reduced the odds of readmission with nosocomial infection by two-thirds. Laparoscopic appendectomy showed no differences in overall nosocomial infection risks compared to open surgery. The findings for wound infections are consistent with results from randomized trials, which have reported statistically significantly lower surgical site infection rates for laparoscopic approaches [10–12, 20].

This study also demonstrates statistically significant differences in source-based infection risks by procedure and approach. Specifically, wound, bloodstream, respiratory tract, urinary tract, and other nosocomial infections were all statistically significantly less likely to occur in association with laparoscopic cholecystectomy. Risks of wound infections in laparoscopic hysterectomy were also significantly lower than in open procedures. However, no differences in infection risks were found between laparoscopic and open appendectomy.

It was important to stratify admission by complexity of presentation to avoid biases associated with complex presentations, higher intrinsic infection risks, and surgical approaches; for example, primary DRGs indicating malignancy or complex presentations (Table 1) were associated with open surgical approaches in 69% of admissions, whereas simple presentations were associated with open approaches in only 35% of admissions. Complex presentations are also commonly believed to be at higher risk of infections, an association that is also demonstrated in this analysis. Therefore, by controlling for presentation complexity, this analysis accounts for some of the intrinsic risk of infection as well as a bias towards open surgical approaches.

The difference in patient severity between hospitals was accounted for by using CMI, and indeed CMI is significant in the univariate and multivariable models, with CMI contributing to nosocomial infection risks. Interestingly, admission through the emergency department was not significant in determining differences in nosocomial infection risks. One possible explanation is that emergency

department use is a crude measure of patient severity because it may also be related to other factors such as time of day of admission and socioeconomic status. However, other variables associated with comorbidity, like age and certain payer types, were significant.

Limitations

While a variety of confounders were controlled for, this study is limited by the absence of certain data; for example, antibiotic use, anesthesia scores, wound class, body mass index, prior hospitalization, and certain comorbidities (i.e., cardiovascular status, diabetes mellitus, and immunodeficiency) were unavailable. These variables could explain additional NIM risk. Although omitted-variable bias is often a concern in multivariable modeling using retrospective databases, the similarity of findings in our univariate and multivariable analyses suggest that these results are robust.

This study documents for the first time that laparoscopic hysterectomy and cholecystectomy are associated with statistically significantly lower overall risks of nosocomial infections ($p < 0.01$). Laparoscopic hysterectomy and cholecystectomy were also associated with statistically significantly fewer readmissions with nosocomial infections ($p < 0.01$). Differences in infection risks between laparoscopic and open appendectomy were not found to be statistically significant, suggesting that these differences are likely small or nonexistent. Where differences in risks have been demonstrated, future studies should be performed to quantify their effects on health care costs and length of stay.

Other important directions for future research include controlling for potentially important confounders to test the robustness of our results and extending the analysis to examine the effect of laparoscopic versus open surgery on the risk of nosocomial infections for additional surgical procedures. Another interesting avenue for future research would be to examine the effect of hospital volume on the rate of nosocomial infections.

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