Cost Differences Between Open and Minimally Invasive Surgery

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ABSTRACT

Purpose: To analyze the cost difference between minimally invasive surgery (MIS) and open surgery from a commercial payer perspective for colectomy, ventral hernia repair, thoracic resection (resection of the lung), and hysterectomy.

Design: A retrospective claims data analysis was conducted using the 2011 and 2012 Truven Health Analytics MarketScan Commercial Claims and Encounter Database. Study eligibility criteria included age 18–64 years, pharmacy coverage, ≥1 month of eligibility in 2012, and a claim coded with 1 of the 4 surgical procedures of interest; the index year was 2012.

Methodology: Average allowed facility and professional costs were calculated during inpatient stay (or day of surgery for outpatient hysterectomy) and the 30 days after discharge for MIS vs open surgery. Cost difference was compared after adjusting for presence of cancer, geographic region, and risk profile (age, gender, and comorbidities).

Results: In total, 46,386 cases in the 2012 MarketScan database represented one of the surgeries of interest. The difference in average allowed surgical procedure cost (facility and professional) between open surgery vs adjusted MIS was $10,204 for colectomy; $3,721, ventral hernia repair; $12,989, thoracic resection; and $1,174, noncancer hysterectomy ($P < .001$ for all comparisons). The difference in average allowed cost in the 30 days after surgery between open surgery vs adjusted MIS was $1,494 for colectomy, $1,320 for ventral hernia repair, negative $711 for thoracic resection, and negative $425 for noncancer hysterectomy ($P < .001$ for all comparisons, except $P = .487$ for thoracic resection).

Conclusion: MIS was associated with statistically significantly lower costs than open surgery for all 4 analyzed surgeries.

INTRODUCTION

The performance of minimally invasive surgery (MIS) using laparoscopic, endoscopic, or catheter-based techniques has become an increasingly common alternative to traditional open surgery (Fullum 2010, Epstein 2013). Numerous studies comparing the safety and efficacy of the two approaches for routine procedures have reported that MIS vs open surgery is associated with shorter intensive care and hospital stays and lower rates of transfusion, readmission, surgical site infections, pain, mortality, and time taken to return to normal activities or work (Alexander 2013, Beldi 2006, Colavita 2012, Davies 2012, Delaney 2008, Eisenberg 2010, Kiran 2010, Eker 2013, Forbes 2009, Roumm 2005, Swanson 2012, Tiwari 2011, Howington 2012, Park 2012, Sajid 2009).

Despite evidence supporting the benefits of MIS, its use varies widely by region and hospital (Cooper 2014). High utilization of MIS has been correlated with urban location, large hospital size, teaching hospitals, and specific US regions (Cooper 2014). Surgeon preference, reimbursement considerations, and resident training convention have been shown to be factors in the choice of surgical approach (Fullum 2010, Roumm 2005). Market forces (eg, regional penetration of health maintenance organizations) may also play a role in the adoption of MIS (Dor 2012).

Several studies have compared total hospital costs or total operative costs associated with MIS vs open surgery (Beldi 2006, Delaney 2008, Eisenberg 2010, Howington 2012, Gopaldas 2010, Agarwal 2014), but data are lacking on the cost of MIS from the payer or employer perspective. The purpose of the current study was to analyze the difference in payer costs between MIS and open surgery in a commercial population for four commonly performed elective surgical procedures: colectomy, ventral hernia repair, thoracic resection, and hysterectomy.

METHODS

Data Source

We performed a retrospective claims data analysis using the 2011 and 2012 Truven Health Analytics MarketScan Commercial Claims and Encounter Database (MarketScan), a large dataset containing the inpatient, outpatient, and prescription drug healthcare service use of individuals nationwide who are covered by the benefit plans

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of large employers, health plans, and governmental and public organizations. MarketScan includes the annual enrollment and paid health care claims generated by approximately 50 million commercially insured lives from approximately 100 private sector payers. All MarketScan data used in our analysis were de-identified and comply with Health Insurance Portability and Accountability Act confidentiality requirements.

Study Population Identification

We used 2012 MarketScan data to identify the study population; our index year was 2012. Study eligibility criteria for the study population included age 18-64 years, pharmacy coverage, ≥1 month of eligibility in 2012, and a claim coded with 1 of the 4 procedures of interest (ie, colectomy, ventral hernia repair, thoracic resection (resection of the lung), or hysterectomy). Individuals enrolled in capitated plans were not eligible because of the potential for incomplete claims.

MIS and open surgical procedure cases were identified using International Classification of Diseases Ninth Edition (ICD-9) and/or Current Procedural Terminology/Healthcare Common Procedure Coding System (CPT) codes (Table 1). The ICD-9 procedure code was required to be in the primary position of the claim. In cases that converted to open from MIS, we assigned the case and all costs to the MIS cohort. Robotics cases in which a claim included certain add-on codes (ICD-9 procedure codes

KEY POINTS

- Minimally invasive surgery using laparoscopic, endoscopic, or catheter-based techniques has become an increasingly common alternative to traditional open surgery.
- Studies comparing minimally invasive to open surgery have shown that minimally invasive surgery is associated with shorter stays in intensive care and in the hospital overall; lower rates of transfusion, readmission, surgical site infections, pain, and mortality; and less time taken off before returning to normal activities or work.
- This study made cost comparisons between a minimally invasive approach and an open approach for four procedures: colectomy, ventral hernia repair, thoracic resection, and hysterectomy.
- Cost per episode (inclusive of professional, facility, and costs incurred 30 days after the surgery) was lower for the minimally invasive approach for all four types of surgery.

	Open	Minimally invasive	Difference
Colectomy	$48,382	$36,685	$11,698
Ventral hernia repair	$26,928	$21,886	$5,041
Thoracic resection	$56,780	$44,502	$12,278
Hysterectomy (noncancer)	$15,251	$14,502	$749

- In contrast to other costs and other surgeries, the costs in the 30 days after surgery were higher for minimally invasive thoracic resection ($711) and hysterectomy ($425).
- Using the baseline distribution of open and minimally invasive cases and 2012 costs, the per-member, per-month (PMPM) cost of the four surgeries was calculated to be $3.58. If 50% of the cases were shifted from the open to the minimally invasive technique, the PMPM cost would drop to $3.42.

TABLE 1
Codes used for procedure identification and IP case inclusion

Procedure	Open ICD-9 procedure codes	MIS ICD-9 procedure codes	Open CPT codes	MIS CPT codes	DRGs for IP Cases
Ventral hernia repair	53.61, 53.69, 53.51, 53.59	53.62, 53.63	49560, 49561, 49565, 49566	49652, 49653, 49654, 49655, 49656, 49657	353, 354, 355
Colectomy	45.71, 45.72, 45.73, 45.74, 45.75, 45.76, 45.79, 45.82, 45.83	17.31, 17.32, 17.33, 17.34, 17.35, 17.36, 17.39, 45.81	44157, 44158, 45121, 44150, 44151, 44155, 44156	44204, 44205, 44206, 44207, 44208, 44210, 44211, 44212	329, 330, 331
Thoracic resection	32.29, 32.49, 32.39	32.20, 32.41, 32.30	N/A	N/A	163, 164, 165
Hysterectomy	68.49, 68.39, 68.69	68.41, 68.31, 68.61	58150, 58152, 58180, 58200, 58210, 58285	58570, 58571, 58572, 58573, 58548	735, 738, 741, 743

Source: Authors' analysis of 2012 Truven MarketScan database.
CPT=current procedural terminology. DRG=Diagnosis Related Group. ICD-9=International classification of diseases ninth edition. IP=inpatient. MIS=minimally invasive surgery. ICD-9 procedure codes were required to be in the primary position of the claim.
IP cases were required to be coded with specified DRGs.

17.41-17.45, and 17.49 and the CPT code S2900) in any position of the claim were excluded. Ventral hernia repair cases with a diagnosis of umbilical hernia identified by 1 or more of 3 ICD-9 diagnosis codes (551.1, 552.1, and 553.1) in any position of the index surgery claim were excluded, as these were lower severity cases. Only surgery cases performed in an inpatient hospital setting were included for all cohorts, except MIS hysterectomy cases, for which only outpatient cases were included. Inpatient and outpatient cases were identified using place of service codes: 21 for inpatient cases; and 11 (office), 22 (outpatient hospital), and 24 (ambulatory surgical center) for outpatient cases. Index cases with other place of service codes were excluded.

Our interest was to identify cases that were most directly comparable to each other (ie, where either open or MIS would have been a feasible clinical option). To reflect such cases, we selected only those cases with Diagnosis-Related Group (DRG) codes specified in Table 1. To limit inpatient open hysterectomy cases to those that could potentially shift to outpatient MIS, only inpatient hysterectomy DRG cases without major complications and comorbidities (MCCs) and without complications or comorbidities (CCs) were included, and all cases coded with uterine or cervical cancer were excluded from both the open inpatient and MIS outpatient cases. Cancer cases were identified based on the following ICD-9 codes appearing in any position of the index surgery claim: 179, 180.x, 182.x, 233.1, 233.2, and 236.0.

Eight cohorts meeting the aforementioned criteria were analyzed: inpatient open colectomy, inpatient MIS colectomy, inpatient open ventral hernia repair, inpatient MIS ventral hernia repair, inpatient open thoracic resection, inpatient MIS thoracic resection, inpatient open hysterectomy without MCCs/CCs, and outpatient MIS hysterectomy. The MIS and open surgery cases remaining after meeting all specified criteria were used to calculate the incidence and cost of these procedures in a commercial population. The denominator population for calculating the incidence rates was also required to have pharmacy coverage, ≥1 month of eligibility in 2012, and not be enrolled in capitated plans.

We split cases within the colectomy and thoracic resection cohorts into cancer and noncancer cases based on the following ICD-9 codes appearing in any position of the index surgery claim: colon cancer codes 153.x, 197.5, 209.10, 209.13-209.16, 230.3, 235.2, and 197.5; and lung cancer codes 162.2-162.9, 197.0, 231.2, 235.7, and 197.0.

Cost Analysis

We calculated the average allowed facility and professional costs during the inpatient stay (or day of surgery for outpatient hysterectomy procedures) and all costs in the 30 days after discharge (or 30 days after the outpatient hysterectomy procedure date), including those for inpatient, outpatient, and professional services and prescription drugs. We identified readmissions that initiated within 30 days of discharge for each case and calculated a rate of readmissions per surgical cohort and the cost contribution of readmissions per case. To adjust for outlier costs, we capped each 30-day readmission allowed amount at $100 000.

To compare the cost between open and MIS cohorts by surgery, we adjusted for potential explanatory variables, including age, gender, comorbidities, presence of cancer (colectomy and thoracic surgery only), and US census region. To account for differences in the contribution of cancer cases when comparing the cost of MIS to open surgery, the MIS cancer case contribution in the thoracic surgery and colectomy cohorts was adjusted to reflect the same contribution as the open surgery cancer case contribution. An adjustment was also made to account for regional reimbursement differences when comparing MIS and open surgery costs. The adjustment, which was made for both procedure costs (inpatient stay or outpatient surgery day) and postprocedure 30-day costs, was based on member residence by major geographic census region. A specific region was not identified for 2% of cases, so we also included an "Unidentified" category region. MIS costs were adjusted to reflect the same contribution of cases per region as open surgery cases.

We used a publicly available, federally certified risk adjustment methodology developed by the US Department of Health and Human Services (HHS) to account for differences in age, gender, and comorbidity when comparing the cost of MIS to open surgery. The methodology uses a hierarchical condition category (HCC) system to categorize diagnosis codes by severity for calculating "metal-level" risk scores (ie, platinum, gold, silver, bronze, and catastrophic) (CDC 2013). The risk scores are intended to predict cost in the subsequent year. Using 2011 MarketScan data, we calculated a HHS-HCC gold metal level risk score for each individual using 12 months of claims data prior to the surgery admission date or outpatient procedure date. The gold metal level was chosen to best reflect the risk score for an average commercially insured population. Using individual risk scores, we calculated the mean risk score for each surgery cohort. Using linear regression, we modeled the relationship between post-procedure 30-day costs (after applying a $100 000 outlier cap to readmissions) and the risk score for each surgery cohort. For each surgery cohort, we calculated the ratio between the open surgery and MIS postprocedure 30-day costs predicted by the regression analysis. We adjusted the MIS postprocedure 30-day costs by multiplying this ratio by the MIS costs that already included the adjustments for regional and cancer differences and readmission outliers. We did not make an adjustment to the inpatient costs, as the type of procedure (open vs MIS) impacts the DRG assignment.

Cost Difference of Shifting Open Surgery to MIS

Based on the total cost of all 2012 cases in each of the 8 surgical cohorts, along with the denominator population's total 2012 annual costs and member months of eligibility, we calculated the cost per member per month (PMPM) contribution of each cohort to the total population. We modeled the difference in cost from the starting baseline PMPM if 25%, 50%, and 75% of open cases were shifted to MIS for each surgery cohort, assuming the mean cost of the open cases would be replaced with that of the MIS cases.

RESULTS

We identified 46 386 cases in the 2012 MarketScan database meeting the inclusion criteria for the eight surgical cohorts of interest in the 2012 index year (Table 2). Of these, 3113 cases were thoracic resection (open, n = 1040; MIS, n = 2073); 28 953 cases, noncancer hysterectomy (open, n = 11 136; MIS, n = 17 817); 11 542 cases, colectomy (open, n = 6056; MIS, n = 5 486); and 2778 cases, ventral hernia repair (open, n = 2073; MIS, n = 705). We excluded 23 525 cases that did not meet the inclusion criteria, including 10 260 hysterectomy cases (inpatient open non-cancer with MCCs/CCs, n = 3759; inpatient open cancer, n = 1161; outpatient open, n = 583; inpatient MIS, n = 3497; outpatient MIS cancer, n = 1260) and 13 265 ventral hernia repair cases (outpatient open, n = 9216; outpatient MIS, n = 4049). Outpatient colectomy and thoracic resection cases were not identified in the data.

More patients were identified with open surgery than MIS for colectomy (52.5% vs 47.5%, respectively) and ventral hernia repair (74.6% vs 25.4%, respectively), whereas fewer patients were identified with open surgery than MIS for thoracic resection (33.4% vs 66.6%, respectively) and noncancer hysterectomy (38.5% vs 61.5%, respectively).

The average length of stay for inpatient cases was found to be statistically significantly lower with MIS than open surgery in patients undergoing thoracic resection (4.7 vs 6.6 days, respectively; $P < .001$), colectomy (4.9 vs 7.4 days, respectively; $P < .001$), and ventral hernia repair (2.7 vs 3.6 days, respectively; $P < .001$); the comparison could not be made with noncancer hysterectomy, as MIS was performed on an outpatient basis.

The mean age of patients was significantly different when comparing thoracic resection and hysterectomy open and MIS cohorts ($P < .001$), but not when comparing colectomy and ventral hernia repair open and MIS cohorts ($P = .107$ and $P = .386$, respectively). The gender distribution was significantly different when comparing thoracic resection open and MIS cohorts ($P < .001$), but not when comparing colectomy and ventral hernia repair open and MIS cohorts ($P = .169$ and $P = .434$, respectively). The difference in the distribution of cases from the 10 geographic regions was statistically significant when comparing the open and MIS colectomy, thoracic resection, and hysterectomy cases ($P < .001$) but not the ventral hernia repair cases ($P = .665$). The cancer distribution was significantly different when comparing the thoracic resection open and MIS cohorts ($P < .001$) but not when comparing the colectomy open and MIS cohorts ($P = .032$).

After adjusting for age, sex, comorbidities, geographic region, and cancer, average allowed surgical procedure costs (facility and professional costs) were statistically significantly lower for all MIS cohorts vs open cohorts (Table 3). The difference in average allowed surgical procedure costs (facility and professional) between open surgery vs adjusted MIS was $10 204 for colectomy; $3721, ventral hernia repair; $12 989, thoracic resection; and $1174, noncancer hysterectomy ($P < .001$ for all comparisons).The difference in average allowed cost between open surgery vs adjusted MIS in the 30 days after surgery was $1494 for colectomy; $1320, ventral hernia repair; negative $711, thoracic resection; and negative $425, noncancer hysterectomy ($P < .001$ for all comparisons, except $P = .487$ for thoracic resection). Readmission per 100 cases was lower with MIS than open surgery for colectomy, ventral hernia repair, and thoracic resection, but higher for MIS noncancer hysterectomy than inpatient hysterectomy ($P < .001$ for colectomy and ventral hernia repair; $P = .091$, thoracic resection; $P = .004$, noncancer hysterectomy). The adjusted readmission average allowed cost was lower with MIS vs open surgery for colectomy and ventral hernia repair but higher with MIS vs open surgery for thoracic resection and noncancer hysterectomy ($P < .001$ for ventral hernia repair, $P = .041$, colectomy; $P = .496$, thoracic resection; and $P = .226$, noncancer hysterectomy).

We provided the cost difference if the costs for a portion of the open cases in each surgical cohort were shifted to the costs of the MIS cases. We used the baseline distribution of open and MIS cases and baseline 2012 costs. The contribution of the 4 surgeries was $3.58 to the total population PMPM of $404.46. A shift of 25%, 50%, and 75% of open surgery to MIS resulted in allowed PMPM

TABLE 2
Patient characteristics for surgery cohorts

	Colectomy			Ventral hernia repair		
Characteristic	**Open IP (n = 6,056)**	**MIS IP (n = 5,486)**	***P* value**	**Open IP (n = 2,073)**	**MIS IP (n = 705)**	***P* value**
Case distribution	52.5%	47.5%		74.6%	25.4%	
Incidence	18/100,000	16/100,000		6/100,000	2/100,000	
Average length of stay	7.4	4.9	< .001*	3.6	2.7	< .001*
Age						
Mean	49.4	49.7	.11*	50.0	49.7	.39*
Median	52	51		51	51	
Range	18–64	18–64		19–64	21–64	
Distribution						
18–24	3.4%	2.5%	< .001**	0.6%	0.7%	.88**
25–34	7.0%	6.7%		5.6%	6.0%	
35–44	17.1%	16.4%		20.9%	22.1%	
45–54	35.3%	38.1%		35.3%	35.2%	
55–64	37.2%	36.4%		37.6%	36.0%	
Gender distribution						
Male	51.6%	50.7%	.17**	39.0%	37.6%	.43**
Female	48.4%	49.3%		61.0%	62.4%	
Regional distribution (Census regions)						
East North Central	21.1%	19.7%	< .001**	22.7%	22.4%	.66**
East South Central	9.3%	6.4%		8.0%	8.4%	
Middle Atlantic	8.5%	9.0%		8.8%	7.4%	
Mountain	6.0%	5.8%		5.4%	4.8%	
New England	5.1%	5.0%		4.4%	3.5%	
Pacific	9.3%	11.3%		10.1%	11.1%	
South Atlantic	18.1%	19.6%		16.7%	17.6%	
West North Central	5.4%	5.3%		5.1%	6.2%	
West South Central	15.6%	16.3%		17.6%	17.6%	
Unidentified	1.8%	1.6%		1.3%	1.0%	
DRG distribution for IP cases						
329: Major small & large bowel procedures w MCC	25.5%	10.4%		N/A	N/A	
330: Major small & large bowel procedures w CC	56.1%	51.5%		N/A	N/A	
331: Major small & large bowel procedures w/o CC/MCC	18.4%	38.1%		N/A	N/A	
353: Hernia procedures except inguinal & femoral w MCC	N/A	N/A		8.5%	5.1%	
354: Hernia procedures except inguinal & femoral w CC	N/A	N/A		42.3%	40.7%	
355: Hernia procedures except inguinal & femoral w/o CC/MCC	N/A	N/A		49.2%	54.2%	
Cancer distribution						
Yes	27.9%	29.2%	.03**	0.0%	0.0%	
No	72.1%	70.8%		100.0%	100.0%	

Source: Authors' analysis of 2012 Truven MarketScan database.
* T-Test. ** Chi-Square Test. ***Hysterectomy MIS cases were OP only.
CC, complication or comorbidity; MCC, major complication or comorbidity; MIS,minimally invasive surgery; IP, inpatient; OP: outpatient.

TABLE 2
Patient characteristics for surgery cohorts (cont.)

	Thoracic resection			Hysterectomy non-cancer		
Characteristic	**Open IP (n = 1040)**	**MIS IP (n = 2073)**	***P* value**	**Open IP (n = 11,136)**	**MIS OP*** (n = 17,817)**	***P* value**
Case distribution	33.4%	66.6%		38.5%	61.5%	
Incidence	3/100 000	6/100,000		32/100,000	52/100,000	
Average length of stay	6.6	4.7	<.001*	2.2	N/A	
Age						
Mean	52.4	48.8	<.001*	44.7	43.8	<.001*
Median	55	53		45	44	
Range	18–64	18–64		21–64	18–64	
Distribution						
18–24	2.8%	8.4%	<.001**	0.1%	0.2%	<.001**
25–34	4.4%	7.3%		7.3%	10.5%	
35–44	9.1%	12.0%		40.3%	43.5%	
45–54	29.9%	29.2%		45.2%	38.3%	
55–64	53.8%	43.1%		7.1%	7.5%	
Gender distribution						
Male	45.8%	50.5%	<.001**	0.0%	0.0%	
Female	54.2%	49.5%		100.0%	100.0%	
Regional distribution (Census regions)						
East North Central	23.2%	20.7%	<.001**	17.4%	17.2%	<.001**
East South Central	8.7%	6.8%		9.7%	12.9%	
Middle Atlantic	9.4%	11.8%		7.5%	4.0%	
Mountain	4.3%	6.1%		5.2%	6.9%	
New England	4.8%	7.0%		2.5%	2.0%	
Pacific	8.6%	11.8%		10.9%	6.4%	
South Atlantic	16.4%	18.1%		20.5%	22.6%	
West North Central	6.4%	4.7%		3.9%	6.4%	
West South Central	16.0%	10.9%		21.1%	20.0%	
Unidentified	2.2%	2.1%		1.3%	1.6%	
DRG distribution for IP cases						
163: Major chest procedures w MCC	28.2%	22.8%		N/A	N/A	
164: Major chest procedures w CC	67.0%	58.0%		N/A	N/A	
165: Major chest procedures w/o CC/MCC	4.8%	19.2%		N/A	N/A	
735: Pelvic evisceration, rad hysterectomy & rad vulvectomy w/o CC/MCC	N/A	N/A		0.4%	N/A	
738: Uterine & adnexa proc for ovarian or adnexal malignancy w/o CC/MCC	N/A	N/A		1.2%	N/A	
741: Uterine, adnexa proc for non ovarian/ adnexal malig w/o CC/MCC	N/A	N/A		0.1%	N/A	
743: Uterine & adnexa proc for non-malignancy w/o CC/MCC	N/A	N/A		98.4%	N/A	
Cancer distribution						
Yes	77.1%	45.3%	<.001**	0.0%	0.0%	
No	22.9%	54.7%		100.0%	100.0%	

Source: Authors' analysis of 2012 Truven MarketScan database.
* T-Test. ** Chi-Square Test. ***Hysterectomy MIS cases were OP only.
CC, complication or comorbidity; MCC, major complication or comorbidity; MIS: minimally invasive surgery. IP: inpatient. OP: outpatient.

TABLE 3
Comparison of MIS and open average allowed costs

		MIS IP		Open IP vs adjusted MIS IP	
Surgery	**Open IP**	**Unadjusted**	**Adjusted[4]**	**Difference**	***P* Value**
Colectomy average allowed episode cost per case[1]	**$48,382**	**$36,348**	**$36,685**	**$11,698**	**<.001**
Anchor Average Allowed Cost	$42,132	$32,374	$31,928	$10,204	<.001
Facility	$36,043	$27,064	$26,653	$9,390	<.001
Professional	$6,089	$5,309	$5,275	$814	<.001
30 Day Post-Anchor Average Allowed Cost	$6,250	$3,975	$4,757	$1,494	<.001
Readmissions per 100 Anchor Cases	11.6	7.7	7.7	3.9	<.001
Readmission Average Allowed Cost/Case[2]	$2,751	$1,884	$2,297	$454	.041
Ventral hernia repair average allowed episode cost per case[1]	**$26,928**	**$21,599**	**$21,886**	**$5,041**	**<.001**
Anchor Average Allowed Cost	$23,720	$20,067	$19,998	$3,721	<.001
Facility	$19,623	$16,970	$16,882	$2,741	<.001
Professional	$4,097	$3,097	$3,116	$980	<.001
30 Day Post-Anchor Average Allowed Cost	$3,208	$1,532	$1,888	$1,320	<.001
Readmissions per 100 Anchor Cases	7.7	4.3	4.3	3.4	<.001
Readmission Average Allowed Cost/Case[2]	$1,751	$592	$751	$1,000	<.001
Thoracic resection average allowed episode cost per case[1]	**$56,780**	**$44,979**	**$44,502**	**$12,278**	**<.001**
Anchor Average Allowed Cost	$50,970	$38,742	$37,981	$12,989	<.001
Facility	$42,566	$32,505	$31,625	$10,941	<.001
Professional	$8,404	$6,237	$6,356	$2,048	<.001
30 Day Post-Anchor Average Allowed Cost	$5,810	$6,237	$6,521	($711)	.487
Readmissions per 100 Anchor Cases	10.1	8.2	8.2	1.9	.091
Readmission Average Allowed Cost/Case[2]	$2,435	$2,491	$2,756	($321)	.496
Hysterectomy noncancer[3] average allowed episode cost per case[1]	**$15,251**	**$14,324**	**$14,502**	**$749**	**<.001**
Anchor Average Allowed Cost	$14,321	$12,972	$13,147	$1,174	<.001
Facility	$11,162	$9,687	$9,829	$1,333	<.001
Professional	$3,159	$3,286	$3,318	($159)	<.001
30 Day Post-Anchor Average Allowed Cost	$930	$1,351	$1,355	($425)	<.001
Readmissions per 100 Anchor Cases	2.5	3.1	3.1	(0.6)	.004
Readmission Average Allowed Cost/Case[2]	$424	$482	$483	($59)	.226

Source: Authors' analysis of 2012 Truven MarketScan database.
[1] Total allowed episode cost includes all claims for the initiating "anchor" surgery case and the 30 days after anchor discharge.
[2] Readmission average allowed cost/case reflects the cost of all readmissions spread across all cases – not the average cost of a readmission.
[3] For Open cases, this cohort only includes IP surgeries that are coded with DRGs without CCs or MCCs. For MIS, this cohort includes OP surgeries only.
[4] MIS average cost calculation for each cohort assumes the same regional contribution as Open cases and for thoracic resection and colectomy, MIS assumes the same cancer contribution as Open cases and MIS average cost reflects an adjustment for the difference in 2011 HHS-HCC gold risk score between Open and MIS patients.
MIS: minimally invasive surgery. IP: inpatient. OP: outpatient.

costs moving from a starting $3.58 to $3.50, $3.42, and $3.34, respectively (Table 4).

DISCUSSION

The results of our study, which identified cost difference between MIS vs open surgery for colectomy, ventral hernia repair, thoracic resection, and hysterectomy, provide further support for the use of MIS and are directly relevant for health care payers and employers. Our calculations showed that MIS vs open surgery is associated with lower facility and professional costs for the initiating procedure for all 4 analyzed surgeries and that readmission rates are lower with MIS than open surgery for colectomy, ventral hernia repair, and thoracic resection. Furthermore, the statistically significant cost differences between MIS vs open surgery persisted after adjustments were made.

Our findings pertaining to the cost of MIS vs open surgery are in general agreement with those in the published literature (Fullum 2010, Swanson 2012, Dor 2012, Warren 2009). For example, in one study based on claims

TABLE 4
Total allowed PMPM difference with open to MIS shift scenarios

		Baseline Distribution		PMPM after % Shift From Open to MIS		
Surgery	**PMPM***	**Open**	**MIS**	**25%**	**50%**	**75%**
Colectomy	$1.55	52.5%	47.5%	$1.49	$1.43	$1.38
Ventral Hernia Repair	$0.22	74.6%	25.4%	$0.21	$0.21	$0.20
Thoracic Resection	$0.47	33.4%	66.6%	$0.46	$0.45	$0.44
Hysterectomy Non-Cancer	$1.34	38.5%	61.5%	$1.33	$1.33	$1.32
Total	**$3.58**			**$3.50**	**$3.42**	**$3.34**

Source: Authors' analysis of 2012 Truven MarketScan database. Costs have not been trended
*PMPM is the contribution of each surgery episode's costs to total population PMPM.
Total population PMPM = $406.46.

data from a single large US care plan, the unadjusted cost of laparoscopic surgery was found to be lower than that for open hysterectomy ($10 868 vs $12 086, respectively), and there was no statistically significant cost difference between the 2 procedures after adjustment was made for differences in patient case mix (Warren 2009). Another study reported that hospital costs in patients undergoing lobectomy were higher with open surgery than video-assisted thoracoscopic surgery ($21 016 vs $20 316, respectively) (Swanson 2012).

The data we reported on length of stay and readmission rates in patients receiving MIS vs open surgery are also consistent with those in the published literature (Delaney 2008, Eisenberg 2010, Swanson 2012, Howington 2012, Juo 2014, Paul 2013). For example, we found that the average length of stay in patients who received colectomy with MIS was 2.5 days shorter ($P < .001$) than in those who received open surgery, which is similar to published reports showing a median difference of 2.0 days (Juo 2014) and a mean difference of 1.7 days (Eisenberg 2010). Our analysis showed that postprocedure 30-day readmission for colectomy with MIS and open surgery was 7.7 vs 11.6 per 100 surgeries, respectively ($P < .001$), which is consistent with a large study (N = 32 733) that reported rates of 7.9% and 9.6%, respectively (Delaney 2008). In our analysis, the postprocedure 30-day readmission rate for thoracic resection with MIS and open surgery was 8.2 vs 10.1 per 100 surgery cases, respectively ($P = .091$). Of interest, in a recent study in which 69% of patients underwent MIS and 31% of patients underwent open thoracotomy for pulmonary lobectomy, readmission was found to be independent of surgical approach (Assi 2015).

We found that the utilization of MIS vs open surgery varied widely by procedure. In our study, <50% of patients undergoing colectomy and ventral hernia repair received MIS (47.5% and 25.4%, respectively), whereas 66.6% and 61.5% of patients undergoing thoracic resection and non-cancer hysterectomy, respectively, received MIS. Recently, Cooper and colleagues retrospectively reviewed the hospital-level utilization of MIS vs open surgery for several commonly performed procedures, including colectomy, hysterectomy, and lung lobectomy (Cooper 2014). In the study, hospitals were stratified into low, medium, and high categories to depict MIS utilization. The average portion of MIS cases in low, medium, and high hospitals for colectomy was found to be 6.7%, 29.0%, and 49.8%, respectively; hysterectomy, 0.0%, 6.2%, and 33.6%, respectively; and lung lobectomy, 3.6%, 26.7%, and 65.7%, respectively. Our findings for colectomy and thoracic resection are close to those reported by Cooper and colleagues in the high hospital category; however, our finding that 61.5% of noncancer hysterectomies were performed by MIS is inconsistent with their data.

We did not analyze lost work time or disability data associated with MIS and open surgery; however, a meta-analysis reported that the number of days to return to work was 26 days less for colectomy, 15 days less for hysterectomy (laparoscopic vs abdominal hysterectomy), and 22 days less for ventral hernia repair with MIS vs open surgery (Roumm 2005). The cost associated with lost work time is an additional consideration for employers when examining MIS vs open surgery outcomes.

We acknowledge several study limitations. First, coding inaccuracies may have biased the results. Second, we were unable to examine clinical outcomes. Third, hospital prices may have been susceptible to managed care penetration and competing hospital dynamics. Fourth, our results remained susceptible to bias despite adjustments. For example, (1) although we adjusted for the regional contribution of cases, outlier hospital or professional reimbursement rates could have biased the results; (2) although we adjusted for cancer vs noncancer cases, the impact of different disease diagnoses for which the procedures were performed could have biased the results; and (3) although we adjusted for comorbidities, age, and gender, the clinical severity in patients receiving MIS vs open surgery may have been different. Additionally, confounding variables beyond those for which adjustments were made (eg, socioeconomic or racial differences, type of hospital, skill of the surgeon) could also have biased the results. Finally, our findings may not have been representative of all hospitals, other surgery types, and other payers (eg, Medicare and Medicaid). In addition, we did not distinguish between emergency vs elective surgery.

CONCLUSION

MIS has become an increasingly common alternative to open surgery for routine procedures, and its use has been linked to numerous patient benefits. Data comparing total hospital costs or total operative costs associated with MIS vs open surgery have generally placed MIS in a favorable light. Despite these benefits, however, MIS remains underutilized in many US regions and hospitals. Our study provides real-world outcomes showing that MIS has statistically significant lower costs than open surgery for the 4 analyzed surgeries.

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