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Clinical and economic impact of adhesiolysis during repeat cesarean delivery

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Conflict of interest
Vanja Sikirica was an employee of Ethicon, Inc. and stockholder at the time this research was conducted. Michael Broder and Eunice Chang are employees of PHAR, LLC, which was paid by Ethicon, Inc. for its involvement in this research. Piet Hinoul is an employee of Ethicon, Inc. and a stockholder. Malcolm Wilson received a consultant fee from Ethicon, Inc. for his involvement in the research described in this manuscript. David Robinson is Medical Director, WorldWide Neuro-Modulation Solutions, WW Franchise Development, Ethicon Endo-Surgery.

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Abstract

Objective. To estimate adhesiolysis rates at cesarean delivery (CD) and to estimate costs and clinical implications of performing adhesiolysis at repeat CD. *Design.* Retrospective cohort using secondary data. *Setting.* Over 500 acute care hospitals in the USA. *Population.* Women ≥15 years old with a medical claim for CD between 1 January 2007 and 31 December 2008 who were treated in a hospital that contributed data to the Premier Perspective™ database. *Methods.* Using data from hospital discharge records, rates of adhesiolysis at the time of CD were calculated. Among patients with repeat CD, a propensity score was used to create matched cohorts with and without adhesiolysis. Unadjusted rates and means were compared between these cohorts. *Main outcome measures.* Cost, length of stay and selected clinical complications between repeat CD patients with and without adhesiolysis. *Results.* Adhesiolysis was performed in 0.5% of primary and 6.1% of repeat CD patients. Using propensity scores, 10 261 women who experienced repeat CD with adhesiolysis were matched to 10 261 control women. Hospital cost ($5739 vs. $5448), length of stay (2.97 vs. 2.88 days) and operative time (84.0 vs. 74.2 min) were significantly greater in the adhesiolysis than in the non-adhesiolysis group ($p < 0.01$ for all comparisons), as was the overall complication rate (6.3 vs. 3.5%). *Conclusions.* Adhesiolysis rates were higher in repeat compared with primary CD. Among repeat CD patients, costs and complications were higher in the adhesiolysis group. Reducing adhesion formation after primary CD could reduce cost and complications at the time of repeat CD.

Abbreviations: APR-DRG, All Patient Refined–Diagnosis-Related Groups; CD, cesarean delivery; CI, confidence interval; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; LOS, length of stay.

Introduction

Adhesions occur in most women who have gynecological surgery (1). Adhesions may lead to potentially serious problems, including pain, infertility and small bowel obstruction. Cesarean delivery is the most common operation done on women in the USA, with 1.37 million cesarean deliveries performed in 2007 (2–4). After a cesarean, 35–50% of women develop adhesions (5,6). Patients with adhesions who undergo subsequent cesarean deliveries are at risk for injury (7). Strategies for prevention of adhesions include advanced microsurgical techniques, administration of nonsteroidal anti-inflammatory drugs before surgery, and the use of adhesion barriers at the surgical site (8–10).

The purpose of our study was to calculate the proportion of women who had surgical adhesiolysis at the time of either primary or repeat cesarean and, in a matched cohort study, to estimate the economic and clinical impact of adhesiolysis at the time of repeat cesarean.

Material and methods

This study used the Premier Perspective™ database, which includes data on 25 million hospital discharges from over 500 hospitals. These data primarily derive from coded discharge forms, but operative time and actual cost are also reported. The cost data are reported directly by Premier member hospitals. Information on preadmission conditions, prior surgery and postoperative outpatient care is not available. Data are verified, reconciled and validated to be certain values were within acceptable ranges. The data are de-identified and compliant with the Health Insurance Portability and Accountability Act, making this study exempt from review by a human subject protection committee. The database does not contain a description of surgical procedures, such as operative reports, but does contain coded information on procedures and complications.

Patients were included if they had a medical claim with an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure code (74.1) for cesarean delivery, were ≥15 years old at discharge and were discharged between 1 January 2007 and 31 December 2008. If a patient had more than one cesarean within the study period, the initial event was chosen. Women who had a length of stay (LOS) >30 days, who delivered twins or higher-order multiples or who had a diagnosis of adhesions (ICD-9-CM codes 560.81, 568.0, 614.6 and 621.5) but who had no evidence of adhesiolysis were excluded from the study.

To ascertain baseline adhesiolysis rates, the first part of this study was a descriptive comparison of unadjusted adhesiolysis rates between patients with primary and repeat cesareans. Adhesiolysis was defined by the presence of an ICD-9-CM procedure code for adhesiolysis (54.5x, 59.11 or 65.8x). The second part was a matched cohort study; women with the ICD-9-CM diagnosis code for previous cesarean (654.2x) who had adhesiolysis at the time of repeat cesarean were compared with women who did not have adhesiolysis at the time of repeat cesarean. The only information contained in the database regarding adhesiolysis was the presence or absence of the ICD-9-CM codes mentioned above. There were no descriptions of the surgical procedure, the extent of adhesions, the indication for adhesiolysis, the location of adhesions or the surgical techniques necessary to lyse the adhesions. The decision to report the code for adhesiolysis was solely at the discretion of the surgeon or hospital staff.

For the matched cohort study, the primary outcome of interest was the cost of the index hospitalization. Secondary outcomes of interest included postoperative LOS, discharge disposition, operating room time and intensive care unit days. Clinical outcomes included damage to pelvic organs or blood vessels, hysterectomy and wound complications. These outcomes were identified using a list of ICD-9-CM diagnosis and procedure codes modified from published studies of maternal morbidity (11,12).

Baseline measures included patient, hospital and procedure characteristics. Patient information included demographics and clinical conditions. Pregnancy-related comorbidities were defined by modifying published lists (11,12) to encompass those conditions that might impact the outcomes of interest (ICD-9-CM code list available on request). These conditions included hypertensive disorders of pregnancy (such as chronic hypertension and pre-eclampsia); disorders of glucose tolerance; anemia; antepartum hemorrhage (including placenta previa); and infections during labor (amnionitis and chorioamnionitis).

Additional comorbidities included cardiovascular conditions, asthma and thyroid conditions. Hospital characteristics included region, teaching status and urban vs. rural location. Physician characteristics were limited to specialty. Admission and procedure characteristics included Medicaid/charity or commercial insurance as the payer, elective or urgent admission, and hospital day of cesarean (day 1 was the day of admission). For each patient, the indication for cesarean was classified into one of five categories using a previously validated system (13). Overall acuity of illness was measured using the All Patient Refined–Diagnosis-Related Groups (APR-DRG) disease severity system. This variable evaluates the interactions of multiple factors to predict LOS and resource use. It has four subclasses: minor, moderate, major and extreme (APR-DRG, version 12.0; 3M Health Information Systems, Wallingford, CT, USA).

Statistical analysis

For the descriptive study of primary and repeat cesareans, the proportion of patients with evidence of adhesiolysis was tabulated. For the matched study of repeat cesareans, descriptive statistics were calculated. To control for baseline differences between groups, propensity scores were used to create matched cohorts (14).

Patients without adhesiolysis were matched to patients with adhesiolysis in a 1:1 ratio using a combination of propensity score and exact matching. Propensity scores were estimated by a logistic regression model incorporating baseline measures as independent variables and adhesiolysis as the dependent variable. The APR-DRG was not a matching variable because it may reflect outcomes of surgery. All patients without adhesiolysis who had an exact match on hospital region and indication for cesarean and who were within a quarter of a standard deviation of the logit of the propensity score were

selected as potential matches for each adhesiolysis patient. The control patient with the smallest Mahalanobis distance (based on age, race and payment source) was chosen as the final match. Unmatched patients were excluded.

Unadjusted rates and means were compared via chi-squared tests for categorical variables and Student's unpaired *t*-tests for continuous variables. For continuous variables, means, standard deviation and 95% confidence interval (CI) were reported. For dichotomous variables, rates and relative risk with 95% CI were reported. All statistical tests were two-sided using a 0.05 significance level. All data extraction and statistical analyses were done using SAS® version 9.2 (SAS Institute, Cary, NC, USA).

Results

There were 234 664 hospitalizations for primary cesarean and 174 354 for repeat cesarean for calendar years 2007 and 2008. After eliminating admissions for subsequent repeat cesarean, those with adhesions but no adhesiolysis, multiple gestations, and those with LOS >30 days, there were 223 129 primary and 166 980 repeat cesareans remaining (Figure 1). Among primary cesarean patients, 0.5% (1056) had adhesiolysis; among those who had repeat cesarean, 6.1% (10 262) had adhesiolysis. The remainder of the study examined the 166 980 women who had repeat cesarean.

Before matching, repeat cesarean patients with adhesiolysis differed from those without adhesiolysis. Race, various comorbidities, hospital region, teaching status, urban vs. rural location and physician specialty differed between groups. There was a significant difference between the groups with regard to the proportion with charity care, proportion with elective admissions, hospital day of cesarean, indication for cesarean and APR-DRG disease severity.

Propensity matching was possible for all but one of the 10 262 adhesiolysis patients, leaving 10 261 patients each in the adhesiolysis and control groups. The groups were statistically indistinguishable with regard to all but a few characteristics. Significant differences remained for the proportion with asthma and mental health conditions (Table 1). With regard to admission and procedure characteristics, in the adhesiolysis group, 91.9% of cesareans were completed on hospital day 1 compared with 93.2% in the control group ($p < 0.01$). There was a significant difference in APR-DRG disease severity after matching, although most patients were in the minor category (88.3 vs. 90.2% in adhesiolysis and control groups, respectively; $p < 0.01$). Indications for surgery were exactly matched between groups, and elective repeat ce-

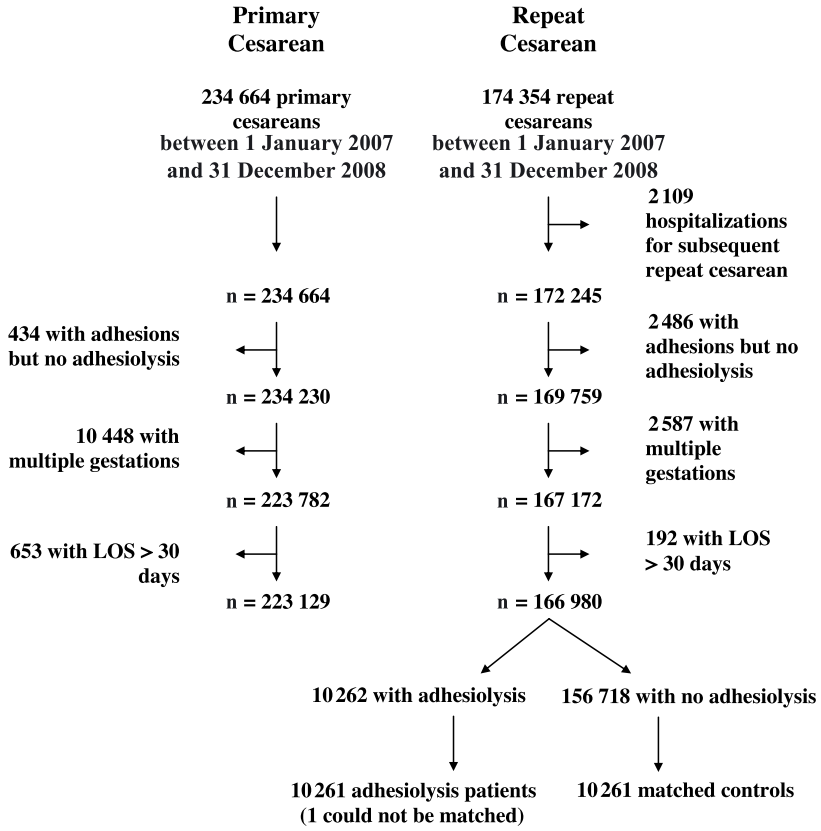

Figure 1. Selection of adhesiolysis patients and matched control women. The figure shows the effect of the various exclusion criteria on the sample size. Abbreviation: LOS, length of stay.

Table 1. Patient, hospital and physician characteristics of matched patients with repeat cesarean.

Variable	Adhesiolysis	Control	*p*-Value
	$n = 10\,261$	$n = 10\,261$	
Age (years)	Mean (SD)	Mean (SD)	
	29.9 (5.6)	29.9 (5.6)	0.52
Race	*n* (%)	*n* (%)	
White	4030 (39.3)	4105 (39.1)	0.96
Black	2167 (21.1)	2159 (21.0)	
Hispanic	1414 (13.8)	1403 (13.7)	
Other	2650 (25.8)	2684 (26.2)	
Pregnancy-related comorbidities			
Hypertensive disorders of pregnancy	891 (8.7)	858 (8.4)	0.41
Disorders of glucose tolerance	1104 (10.8)	1119 (10.9)	0.74
Anemia	1643 (16.0)	1559 (15.2)	0.11
Retained placenta without hemorrhage	24 (0.2)	20 (0.2)	0.55
Antepartum hemorrhage	154 (1.5)	134 (1.3)	0.24
Obstructed or long labor	232 (2.3)	241 (2.3)	0.68
Infections during labor	53 (0.5)	50 (0.5)	0.77
Uterine rupture	43 (0.4)	35 (0.3)	0.36
Other comorbidities			
Cardiovascular conditions	125 (1.2)	97 (0.9)	0.06
Asthma	460 (4.5)	362 (3.5)	<0.01
Thyroid disorders	300 (2.9)	260 (2.5)	0.09
Renal disease	29 (0.3)	24 (0.2)	0.49
Mental health conditions	427 (4.2)	369 (3.6)	0.04
Obesity	789 (7.7)	718 (7.0)	0.06
Hospital region			
Northeast	1755 (17.1)	1755 (17.1)	n/a
Midwest	1544 (15.0)	1544 (15.0)	
West	1975 (19.2)	1975 (19.2)	
South	4987 (48.6)	4987 (48.6)	
Teaching hospital			
Yes	3823 (37.3)	3795 (37.0)	0.69
Location of hospital			
Urban	9562 (93.2)	9589 (93.5)	0.45
Surgeon specialty			
Obstetrician or gynecologist	9454 (92.1)	9502 (92.6)	0.21

Table 2. Admission and procedure characteristics of matched patients with repeat cesarean.

Characteristic	Adhesiolysis $n = 10\,261$		Control $n = 10\,261$		*p*-Value
Payment source					
Medicaid/charity	4071	(39.7)	4082	(39.8)	0.88
Other	6190	(60.3)	6179	(60.2)	
Admission type					
Elective	7013	(68.3)	7131	(69.5)	0.08
Urgent/emergency	3248	(31.7)	3130	(30.5)	
Hospital day of cesarean					
Day 1	9430	(91.9)	9562	(93.2)	<0.01
Day 2	601	(5.9)	515	(5.0)	
Day 3 or later	230	(2.2)	184	(1.8)	
Indication for cesarean section					
Breech	282	(2.8)	282	(2.8)	n/a
Dystocia	578	(5.6)	578	(5.6)	
Fetal distress	17	(0.2)	17	(0.2)	
Other	2402	(23.4)	2402	(23.4)	
Elective repeat cesarean	6982	(68.0)	6982	(68.0)	
APR-DRG[a]					
Minor	9062	(88.3)	9252	(90.2)	<0.01
Moderate	935	(9.1)	785	(7.7)	
Major	245	(2.4)	209	(2.0)	
Extreme	20	(0.2)	15	(0.1)	

[a] APR-DRG, All Patient Refined–Diagnosis-Related Groups; this is not a matching variable, because it may be affected by postoperative outcomes.

sarean was the most common indication for surgery (68.0%; Table 2).

The mean total cost for the index hospitalization was $5739 (95% CI 5 674–5804) for the adhesiolysis group compared with $5448 (95% CI 5 390–5507) for the control group, a difference of $291 ($p < 0.01$). The mean postoperative LOS in the adhesiolysis group was 2.97 days (95% CI 2.96–2.99) compared with 2.8 days (95% CI 2.86–2.89) in the control group ($p < 0.01$). Operating room time was available for approximately half the sample. Mean operating room time was 84.0 min in the adhesiolysis group (95% CI 82.8–85.3) compared with 74.2 min in the control group (95% CI 73.4–75.0; $p < 0.01$; Table 3).

The relative risk of each measured complication was significantly higher in the adhesiolysis group, with the exception of thrombophlebitis and embolism. Twenty-seven women (0.3%) who had adhesiolysis also had a hysterectomy at or after cesarean, compared with 10 control women (0.1%), for a relative risk of 2.70 ($p < 0.01$). In the adhesiolysis group, 1.7% of women had postpartum hemorrhage and 1.9% received a transfusion, compared with 1.2 and 1.1% of controls, respectively ($p < 0.01$ for both comparisons). Pelvic organs or vessels were damaged in 1% of adhesiolysis patients and 0.1% of control women, a relative risk of 10.20 (95% CI 5.33–19.52). Wound complications occurred in 1.4% of women with adhesiolysis and 0.7% of control women ($p < 0.01$), and other infections occurred in 1.1% of women with adhesiolysis and 0.7% of control women ($p = 0.003$). The relative risk of any of the measured adverse events was 1.82 (95% CI 1.61–2.07) for adhesiolysis vs. control women (6.3% of adhesiolysis patients

Table 3. Resource use outcomes in matched patients with repeat cesarean.

Outcome	Adhesiolysis $n = 10\,261$ Mean (SD) (95% CI)	Control $n = 10\,261$ Mean (SD) (95% CI)	*p*-Value
Total hospitalization cost ($)	5739 (3368) (5674–5804)	5448 (3031) (5390–5507)	<0.01
Postoperative LOS (days)[a]	2.97 (0.92) (2.96–2.99)	2.88 (0.82) (2.86–2.89)	<0.01
Intensive care unit (days)	0.01 (0.22) (0.006–0.014) $n = 6432$	0.01 (0.17) (0.007–0.013) $n = 6100$	0.12
Operative room time (min)[b]	84.0 (52.2) (82.8–85.3)	74.2 (31.3) (73.4–75.0)	<0.01

Abbreviations: CI, confidence interval; and LOS, length of stay.
[a] Excludes preoperative hospital days.
[b] Not all discharged patients had records of operating room time.

vs. 3.5% of control women; Table 4). There was one death in each group ($p = 0.99$).

In a sensitivity analysis, we used multivariate regression to adjust for residual differences between groups. The between-group differences in outcomes were quite similar to the main analysis. For example, adjusted total costs were within $30 of unadjusted means for both groups ($5713 vs. $5474) and LOS was unchanged (2.88 vs. 2.97 days) for women with adhesiolysis compared with those without adhesiolysis.

Discussion

In this study, adhesiolysis was 12 times more common at repeat than at primary cesarean. Women who had adhesiolysis at the time of repeat cesarean had higher costs, longer operating room times and hospital stays, and more complications than matched control women. Total cost was almost $300 higher, operating room time was 10 min longer, and LOS was extended by several hours. Cesarean hysterectomy occurred twice as often in women with adhesiolysis. Adhesiolysis patients were also more likely to have other serious complications, including damage to pelvic organs or vessels, wound complications, infections, postpartum hemorrhage and transfusions.

Our findings are consistent with clinical experience; repeat cesarean is a more difficult operation to perform than primary cesarean, and adhesions are an important cause of this difficulty (5–7). The results are also internally consistent. Lysing adhesions increases the length and difficulty of surgery, and the resultant intraoperative and postoperative complications increase both LOS and cost.

Comparisons with prior literature are difficult because we measured adhesiolysis, whereas most other studies focused on the presence of adhesions and not their surgical treatment. In those studies, adhesions were reported at 16–75% of repeat cesareans (6,15–17). Tulandi et al. found adhesions increased operative time by 5–12 min for repeat cesarean, which is consistent with our results (16). Phipps and colleagues found adhesions in 60% of women who had bladder injury at cesarean compared with 10% of those without such

Table 4. Rates and relative risks of clinical outcomes in matched patients with repeat cesarean.

Clinical outcome	Adhesiolysis (95% CI)		Control (95% CI)		Relative risk, adhesiolysis vs. control	*p*-Value
Damage to pelvic organs/vessels	102 (0.82–1.22%)	(1.0)	10 (0.05–0.18%)	(0.1)	10.20 (5.33–19.52)	<0.01
Hysterectomy	27 (0.17–0.38%)	(0.3)	10 (0.05–0.18%)	(0.1)	2.70 (1.31–5.57)	<0.01
Wound complications	143 (1.19–1.66%)	(1.4)	75 (0.58–0.92%)	(0.7)	1.91 (1.44–2.52)	<0.01
Other infectious complications	117 (0.95–1.38%)	(1.1)	76 (0.59–0.93%)	(0.7)	1.54 (1.15–2.05)	0.003
Thrombophlebitis and embolism	18 (0.10–0.27%)	(0.2)	9 (0.04–0.17%)	(0.1)	2.00 (0.90–4.45)	0.08
Postpartum hemorrhage	178 (1.52–2.04%)	(1.7)	121 (0.99–1.42%)	(1.2)	1.47 (1.17–1.85)	<0.01
Transfusion	194 (1.67–2.21%)	(1.9)	108 (0.87–1.28%)	(1.1)	1.80 (1.42–2.27)	<0.01
Any complication[a]	647 (6.23–7.25%)	(6.3)	355 (3.23–3.97%)	(3.5)	1.82 (1.61–2.07)	<0.01

[a] These values include damage to pelvic organs/vessels, hysterectomy, wound complications, other infectious complications, thrombophlebitis and embolism, postpartum hemorrhage and transfusion. In the adhesiolysis group, 100 patients had two or more complications (1.0% of 10 261; 15.5% of 647); in the control group, 46 patients had two or more complications (0.4% of 10 261; 13.0% of 355).

injury (7). We found that women with adhesions at repeat cesarean are at increased risk of damage to pelvic organs and vessels, although the organ or vessels involved could not be identified using the available data.

Using our results, we estimated the nationwide hospital cost of adhesiolysis at repeat cesarean. There were approximately 550 000 repeat cesareans in 2008 (4,18,19). Using our estimate that 6% of women undergoing repeat cesarean have adhesiolysis gives 33 000 such cases nationwide. At approximately $290 for each cesarean at which adhesiolysis was performed, we estimate the additional cost of adhesiolysis at repeat cesarean to be $9.6 million annually. A similar calculation suggests 2970 excess hospital days per year result from complications of adhesiolysis. A previous study estimated 5255 excess days of hospitalization and $24 million in cost in 1994 dollars (20), so our estimate may be conservative.

Our study database included no information on prior surgery, but previous cesarean was a likely contributor to adhesions, because it is one of the most commonly performed operations on US women (21). Adhesion prevention measures taken at the time of primary cesarean may therefore reduce the frequency of adhesions. Use of meticulous surgical technique may be the best such measure (22,23), but many additional methods have been studied (8–10). Of these, Interceed™ and Gore-Tex®, two barrier methods, have been the best studied, reducing the odds of adhesions to 20–30% of the untreated odds (9). Other methods (such as intraperitoneal or systemic steroids, nonsteroidal anti-inflammatory drugs or peritoneal closure) either appear ineffective or have limited evidence to support their use (10,15).

This study had limitations. The scope of this retrospective database research based on billing information is on a large scale; hence, the value of such research is its sample size, representativness of national practices and generalizeablity at the expense of clinical detail. Thus, the most important limitation was that the database used was created from records used primarily for billing purposes, and much clinically relevant information was not available. There were no data available describing the surgical procedure, or the location, density or character of the adhesions. Likewise, there were no data on the surgical technique or procedures used to perform adhesiolysis. The decision to record that adhesiolysis was done was left to the discretion of the surgeon and/or hospital staff. Some surgeons or hospitals may have been more diligent about coding for adhesiolysis than others, and there is no way, given privacy regulations, of reviewing medical records or operative reports to obtain more detailed clinical information on the procedures. Data on maternal and fetal outcomes could not be linked, nor could we study events that occurred after discharge. Data may have been missing, and there may have been coding errors. This study excluded women coded as having adhesions but not adhesiolysis, because they might have had less severe adhesions, and thus including them might have introduced bias.

In addition, the data source represented hospitals associated with one large group purchasing organization and might not be representative of the entire country. However, the study population's age distribution was similar to the national distribution of women having repeat cesarean; 57% were between 25 and 34 years old nationally, compared with 58% in our sample. Black and Hispanic women were overrepresented in our sample compared with the nation as a whole, as were births to women with Medicaid or charity care (19). The LOS in our sample was comparable to the national average (22). The overall maternal death rate in the US was 17 per 100 000 in 2008, consistent with our finding of two deaths in the entire matched sample (24).

The rate of adhesiolysis at repeat cesarean is an order of magnitude higher than at primary cesarean. Pelvic adhesiolysis at the time of repeat cesarean increases hospital cost and the likelihood of adverse clinical consequences, including hysterectomy. Interventions aimed at reducing cesarean delivery rates, use of meticulous surgical technique and the use of adhesion barriers all may reduce the frequency of adhesions requiring surgical treatment and the attendant costs and consequences.

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