Pelvic Floor Consequences of Cesarean Delivery on Maternal Request in Women with a Single Birth: A Cost-effectiveness Analysis

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Abstract

Background: The potential benefit in preventing pelvic floor disorders (PFDs) is a frequently cited reason for requesting or performing cesarean delivery on maternal request (CDMR). However, for primigravid women without medical/obstetric indications, the lifetime cost-effectiveness of CDMR remains unknown, particularly with regard to lifelong pelvic floor consequences. Our objective was to assess the cost-effectiveness of CDMR in comparison to trial of labor (TOL) for primigravid women without medical/obstetric indications with a single childbirth over their lifetime, while explicitly accounting for the management of PFD throughout the lifetime.

Methods: We used Monte Carlo simulation of a decision model containing 249 chance events and 101 parameters depicting lifelong maternal and neonatal outcomes in the following domains: actual mode of delivery, emergency hysterectomy, transient maternal morbidity and mortality, perinatal morbidity and mortality, and the lifelong management of PFDs. Parameter estimates were obtained from published literature. The analysis was conducted from a societal perspective. All costs and quality-adjusted life-years (QALYs) were discounted to the present value at childbirth.

Results: The estimated mean cost and QALYs were $14,259 (95% confidence interval [CI] $8,964-$24,002) and 58.21 (95% CI 57.43-58.67) for CDMR and $13,283 (95% CI $7,861-$23,829) and 57.87 (95% CI 56.97-58.46) for TOL over the combined lifetime of the mother and the child. Parameters related to PFDs play an important role in determining cost and quality of life.

Conclusions: When a woman without medical/obstetric indications has only one childbirth in her lifetime, cost-effectiveness analysis does not reveal a clearly preferable mode of delivery.

Introduction

CESAREAN DELIVERY is the most commonly performed operating room procedure in the United States.[1] In addition to being major abdominal surgery, cesarean delivery is associated with increased risk of neonatal respiratory morbidity and can cause complications in subsequent pregnancies, such as uterine rupture, placenta previa, and placenta accreta.[2] Cesarean delivery on maternal request (CDMR), defined as cesarean delivery for a singleton pregnancy on maternal request at term in the absence of any medical or obstetric indications,[3] has generated nationwide debate as the cesarean delivery rate reaches its highest level (31.1% of all births in 2006).[4] The widespread concern that some of this increase may be attributable to an increase in CDMR[5,6] provided impetus for the National Institutes of Health (NIH) 2006 State-of-the-Science Conference on CDMR.[3]

Patients and healthcare providers frequently report prevention of pelvic floor disorders (PFDs) as the primary reason for choosing cesarean delivery.[6,7] PFDs include several clinical conditions, such as urinary incontinence (UI), fecal incontinence (FI), and pelvic organ prolapse (POP). Among women 20 and older in the United States, the prevalences of UI, FI, and POP are 15.7%, 9.0%, and 2.9%, respectively.[8] These debilitating conditions significantly impact women's quality of life (QOL) and increase healthcare costs. Each year

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in the United States, UI costs \$19.5 billion,[9] and over 200,000 women undergo inpatient surgery for POP.[10,11]

Although there is evidence supporting an association between vaginal birth and the development of PFDs,[3] only two cost-effectiveness studies[12,13] comparing modes of delivery have incorporated PFDs as a maternal outcome. One examined vaginal birth after a previous cesarean delivery,[12] and the other compared planned cesarean delivery with trial of labor (TOL) for primigravid women with macrosomic infants.[13] For primigravid women without medical or obstetric indications, however, the lifetime cost-effectiveness of CDMR vs. TOL remains unknown, particularly with regard to lifelong pelvic floor consequences. This subgroup of pregnant women is at the center of the CDMR debate.

The choice between CDMR and TOL is complex, involving both maternal and neonatal factors with short-term and long-term implications. Drawing on the advantage of decision analysis, which allows for multiple, often conflicting, factors to be analyzed in a single model, this study makes an important first step toward addressing this complex question by investigating the lifelong cost-effectiveness of CDMR vs. TOL for primigravid women without medical or obstetric indications having only one childbirth in their lifetime. A single birth model provides important insights for future studies of two or more childbirths.

Materials and Methods

Decision tree model

Cost-effectiveness analysis is a method designed to assess the comparative impacts (i.e., cost and effectiveness) of different health interventions.[14] It involves estimating the incremental costs and effects of an intervention compared with some alternatives.[14] The method has been widely applied to inform difficult clinical and public health decisions and has been used to assess the relative cost and benefit trade-offs of alternative healthcare interventions in gynecologic oncology, gynecologic surgery, maternal-fetal medicine, infertility treatment, and other subspecialties in the field of obstetrics and gynecology.[15–17]

A decision tree is a visual tool to illustrate how each compared intervention relates to the possible outcomes.[18] In this study, a decision tree model containing 249 chance events and 101 parameters was constructed mapping the sequence of most relevant clinical outcomes after each delivery management scheme (CDMR or TOL) throughout the mother and the newborn's lifetime (Fig. 1).

The patient in this analysis was defined as a 25-year-old (i.e., the mean age of American women at first childbirth[19]), primigravid woman with a term singleton birth without medical or obstetric indications (e.g., known fetal or maternal risk factors) favoring either management strategy. The woman has no history of PFD before delivery. We assumed that women who opt for CDMR undergo a cesarean delivery before onset of labor and that women undergoing TOL could not have a cesarean delivery without medical reasons. The analysis was conducted from a societal perspective, including all costs to the healthcare system and the patient.

Our analysis focused on women who actually have only one birth over their lifetime, who account for 21.6% of parous women in the United States.[20] We limited our analysis to a single birth because of lack of data on the differential risk of PFD consequences in women with different delivery modes at successive childbirths (e.g., an instrumental vaginal delivery followed by a CDMR vs. a CDMR followed by a spontaneous vaginal delivery). Single birth is also the scenario most favorable to CDMR and often is discussed as a specific situation in which it might be appropriate.

Our model incorporated the following PFDs: stress UI (SUI), FI, and POP. SUI is believed to be primarily a result of the childbirth experience, which can cause injury to muscles, connective tissues, and nerves.[16] In contrast, the etiology of urge UI, the other main type of UI in women, is less well characterized and, therefore, was not included in our model.[21] The definition of FI varies in the literature, with some studies including flatus incontinence whereas others consider involuntary loss of stool only.[22] Because prior studies show that flatal incontinence has less impact on QOL and there is confusion in women reporting voluntary vs. involuntary passing of flatus,[23] we defined FI as involuntary leakage of liquid/solid stool in our analysis. We did not include female sexual dysfunction (FSD)[5] because the published data on FSD do not provide sufficient detail to suit our analysis.

Our selection of other maternal and perinatal morbidities was guided by the 2006 Visco et al.[24] systematic review of research comparing outcomes of CDMR and TOL and supplemented by our review of more recent studies. Visco et al.[24] indicated moderate quality or some limited evidence for differential incidence of infection, hemorrhage/blood transfusion, and surgical complications between CDMR and TOL, as well as differences in the rate of neonatal respiratory morbidity. More recent studies also suggested evidence of differential rates of peripartum hysterectomy between CDMR and TOL.[25–27]

Data sources

Estimates of the base value and plausible ranges for the probability, cost, and utility parameters associated with each health state were obtained from the published literature (Tables 1, 2, 3, and 4). A utility value, ranging from 0 (death) to 1 (perfect health), quantifies an individual's perception and preference for a health state. All parameter estimates were reviewed by an expert panel, including two obstetricians and the two clinical authors with considerable clinical and research experience (D.F. and J.O.L.D). Because this study analyzed published data, it was not human subject research and, hence, did not require Institutional Review Board oversight.

We accounted for the major cost items during and after childbirth over the course of the woman's and newborn's lifetimes, including delivery, maternal and neonatal mortality and morbidity, management and treatment of PFDs, and productivity loss (Table 3). Hospital facility costs and physicians' professional fees associated with the delivery were estimated using the Medicare fee schedules,[98] which are developed to measure the costs of providing medical services to Medicare patients and widely used in economic evaluations to represent the societal cost of healthcare.[109] Because the medically recommended period of recovery for cesarean delivery is usually 2 weeks longer than that for vaginal delivery, we incorporated a 2-week difference in productivity loss between these delivery modes.[123,124] (A sensitivity analysis was conducted varying the difference in this recovery period between vaginal and cesarean delivery. There was no
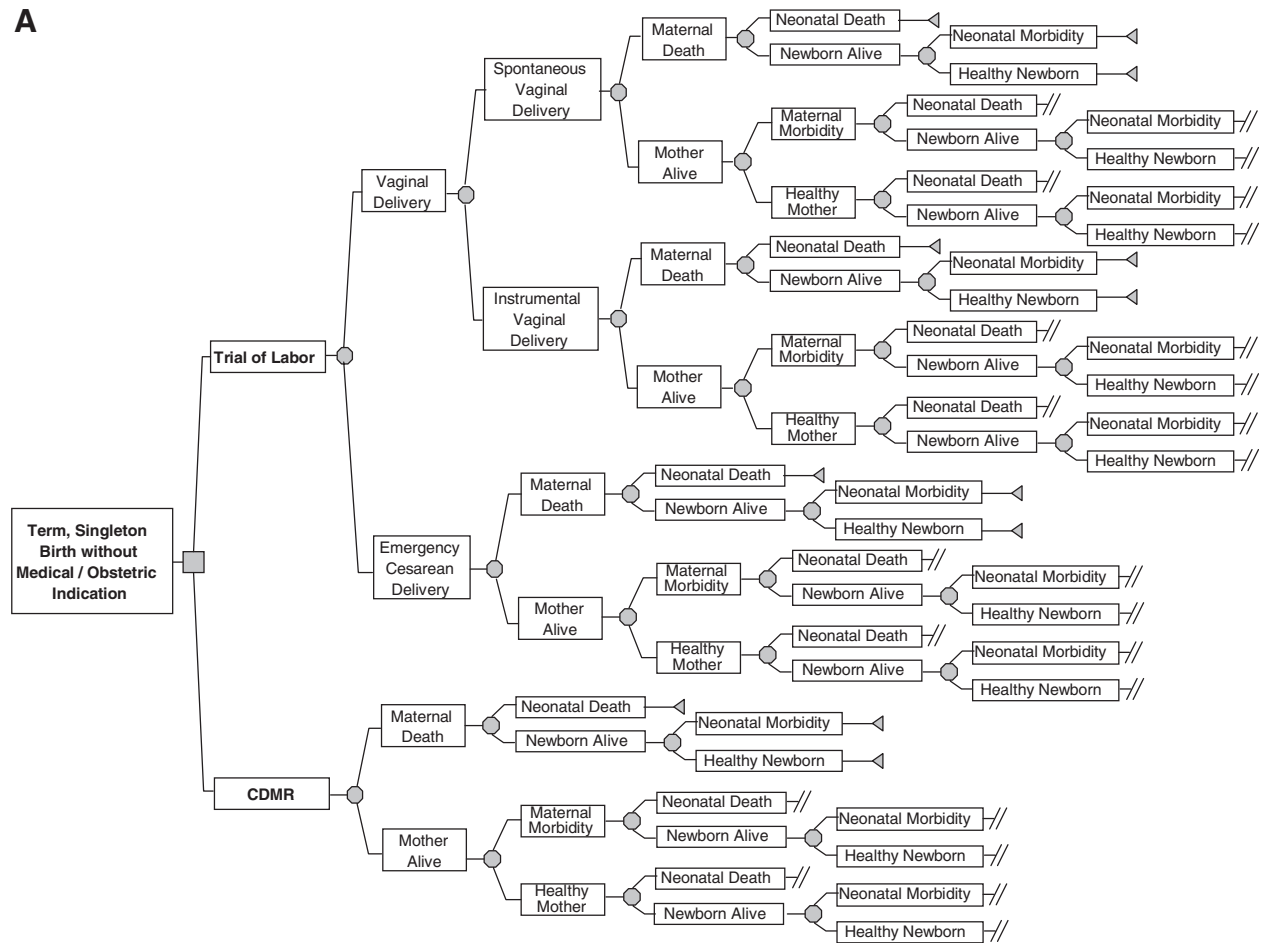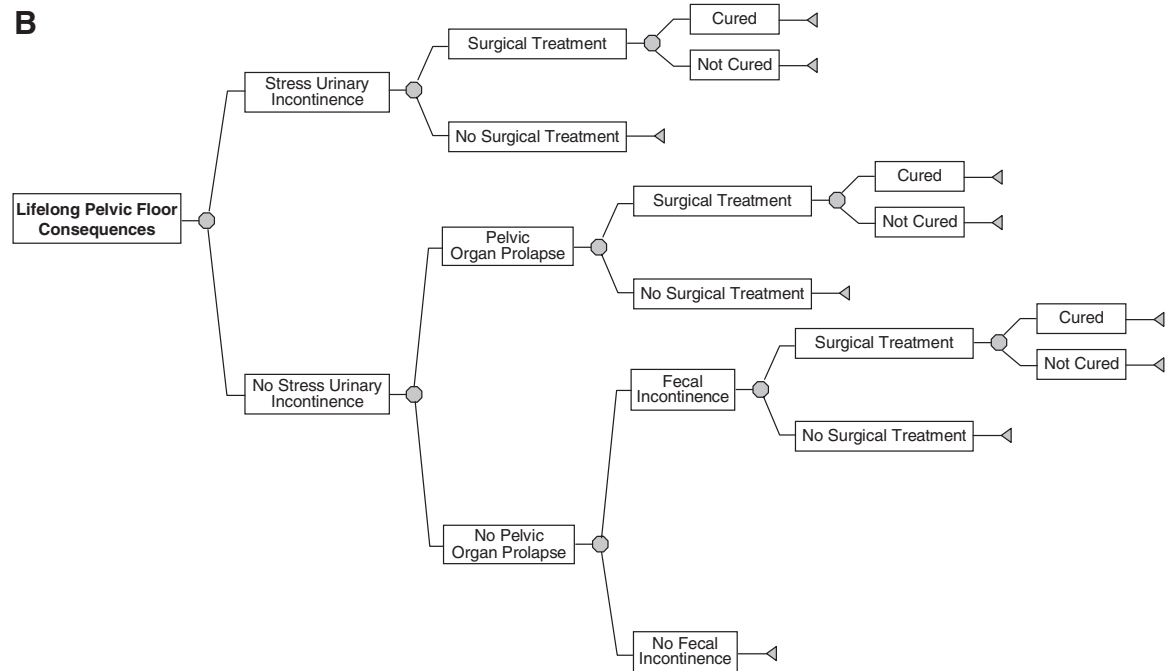
FIG. 1. Decision tree model for one term singleton birth without medical or obstetric indications. Part A of the figure illustrates the portion of the decision tree related to short-term maternal and neonatal outcomes. Part B of the figure depicts the portion of the decision tree related to the long-term pelvic floor consequences. Square, decision node; circle, chance node; triangle, end node; double slash, branch continues with the Lifelong Pelvic Floor Consequences subtree.

TABLE 1. ESTIMATES OF PROBABILITY PARAMETERS IN MODEL

Parameter	Base value	Range[a]	References
Trial of labor			
Probability of having a vaginal delivery	90%	84.4%–97.0%	25, 28–30
If vaginal delivery			
Probability of spontaneous vaginal delivery	90%	85.0%–95.0%	25, 31, 32
If spontaneous vaginal delivery			
Probability of maternal death	0.0%	0.0%–0.0020%	33, 34[b]
Probability of neonatal death	0.02%	0.018%–0.063%	35–38
If spontaneous vaginal delivery and mother alive			
Probability of composite maternal morbidity[c]	1.22%	0.94%–1.35%	31, 39–44
Probability of having stress urinary incontinence (SUI)	19.90%	14.93%–40.80%	45–49
Probability of having pelvic organ prolapse (POP)	8.9%	7%–9.79%	47, 50
Probability of having fecal incontinence (FI)	2.65%	2.13%–6.9%	47, 48, 51–53
If spontaneous vaginal delivery and baby alive			
Probability of neonatal morbidity[d]	1.0%	0.75%–1.25%	54
If instrumental vaginal delivery			
Probability of maternal death	0.0028%	0.0024%–0.0028%	29, 33, 34[b]
Probability of neonatal death	0.0352%	0.030%–0.063%	35–38
If instrumental vaginal delivery and mother alive			
Probability of composite maternal morbidity[c]	3.81%	2.58%–4.19%	29, 31, 39–44
Probability of having SUI	21.80%	16.35%–43.50%	45–47, 49
Probability of having POP	12.0%	7%–13.2%	47, 50
Probability of having FI	8.0%	3.9%–18.8%	47, 51–53, 55, 56
If instrumental vaginal delivery and baby alive			
Probability of neonatal morbidity[d]	0.9%	0.68%–1.13%	54
If emergency cesarean delivery			
Probability of maternal death	0.0097%	0.0097%–0.0250%	25, 33, 34, 57
Probability of neonatal death	0.08%	0.06%–0.169%	36, 38
If emergency cesarean delivery and mother alive			
Probability of composite maternal morbidity[c]	13.69%	10.04%–17.01%	31, 39–42, 44, 58–61
Probability of having SUI	11.50%	7.00%–33.00%	45, 47, 49, 50, 62
Probability of having POP	7%	0.00%–11.0%	47, 50
Probability of having FI	5%	4.0%–8.47%	47, 52, 55, 56, 63
If emergency cesarean delivery and baby alive			
Probability of neonatal morbidity[d]	4.5%	3.55%–4.95%	64, 65
Cesarean delivery on maternal request (CDMR)			
Probability of maternal death	0.0059%	0.0%–0.0148%	26, 33, 34, 57
Probability of neonatal death	0.047%	0.0%–0.173%	36, 38, 66–69
If CDMR and mother alive			
Probability of composite maternal morbidity[c]	5.01%	2.47%–9.39%	25, 26, 31, 39–44, 59, 61, 70
Probability of having SUI	10.00%	0.0%–33.00%	45–47, 49, 50, 62
Probability of having POP	1%	0.0%–6%	47, 50
Probability of having FI	1.78%	0.0%–7.7%	47, 52, 55, 56, 63, 71
If CDMR and baby alive:			
Probability of neonatal morbidity[d]	3.3%	2.9%–3.63%	54, 64, 65, 72
Treatment of pelvic floor disorders			
SUI			
Proportion of SUI symptomatic women seeking healthcare for SUI	61%	45.75%–76.25%	73

(Continued)

TABLE 1. (CONTINUED)

Parameter	Base value	Range[a]	References
Proportion of women seeking healthcare for SUI who receive surgical treatment	29.8%	22.35%–37.25%	74
Success rate of SUI surgeries	81.3%	63%–93%	75–82
POP			
Proportion of POP symptomatic women seeking healthcare for POP	73%	54.75%–91.25%	73
Proportion of women seeking healthcare for POP who receive surgical treatment	75%	56.25%–93.75%	Authors' assumption
Success rate of surgical treatment for POP	71%	58%–100%	83–89
FI			
Proportion of FI symptomatic women seeking healthcare for FI	33.8%	20.5%–43%	73, 90, 91
Proportion of women seeking healthcare for FI who receive surgical treatment	17.46%	13.10%–34.50%	92[e]
Success rate of FI surgeries	25%	10%–54%	93–97

[a]Plausible ranges of the parameters were determined based on data from the literature or ±25% of the base value if no range was available from the literature.
[b]Supplemented by authors' analysis of the 2004 National Hospital Discharge Survey data.
[c]Including any blood transfusion, wound infection and endometritis, peripartum hysterectomy, and surgical injury of the uterine, bladder, or bowel (see Table 2 for more details).
[d]Including respiratory distress syndrome (RDS) and transient tachypnea (TTN).
[e]Supplemented by unpublished research data from the Michigan Bowel Control Program.

TABLE 2. PROBABILITY PARAMETERS ASSOCIATED WITH COMPOSITE MATERNAL MORBIDITY

Parameter	Base value	Range[a]	References
Trial of labor			
Spontaneous vaginal delivery			
Maternal: Any blood transfusion	0.3%	0.11%–0.33%	31, 39, 40, 44
Maternal: Infection (including wound infection and endometritis)	0.8%	0.72%–0.88%	39–41
Maternal: Peripartum hysterectomy	0.023%	0.0207%–0.03%	27, 42, 43
Maternal: Surgical injury (including uterine, bladder, or bowel injuries)	0.1%	0.09%–0.11%	39, 40
Instrumental vaginal delivery			
Maternal: Any blood transfusion	1.0%	0.12%–1.1%	31, 39, 40, 44
Maternal: Infection (including wound infection and endometritis)	2.6%	2.34%–2.86%	39–41
Maternal: Peripartum hysterectomy	0.05%	0.03%–0.055%	29, 42, 43
Maternal: Surgical injury (including uterine, bladder, or bowel injuries)	0.2%	0.1%–0.22%	39, 40
Emergency cesarean delivery			
Maternal: Any blood transfusion	0.6%	0.37%–1.1%	31, 39, 40, 44, 58, 59
Maternal: Infection (including wound infection and endometritis)	11.2%	9.45%–13.14%	39–41, 58, 61
Maternal: Peripartum hysterectomy	0.12%	0.108%–0.38%	42, 58, 59
Maternal: Surgical injury (including uterine, bladder, or bowel injuries)	2.1%	0.17%–3.02%	39, 40, 58, 60
Cesarean delivery on maternal request			
Maternal: Any blood transfusion	0.3%	0.07%–4.455%	26, 31, 39, 40, 44, 59, 70
Maternal: Infection (including wound infection and endometritis)	4.53%	2.3%–8.261%	26, 39–41, 61
Maternal: Peripartum hysterectomy	0.06%	0.0%–0.715%	25–27, 39, 42, 43, 59
Maternal: Surgical injury (including uterine, bladder, or bowel injuries)	0.14%	0.1%–0.17%	26, 39, 40

[a]Plausible ranges of the parameters were determined based on data from the literature or ±25% of the base value if no range was available from the literature.

TABLE 3. ESTIMATES OF COST-RELATED PARAMETERS, IN 2007 U.S. DOLLARS

Parameter	Base value	Range[a]	References
Obstetric care (including delivery and postpartum care)			
Spontaneous vaginal delivery	$3,520	$2,640–$4,400	98–100
Instrumental vaginal delivery	$3,569	$2,677–$4,461	98–101
Emergency cesarean delivery	$6,513	$4,885–$8,141	98–100, 102
Cesarean delivery on maternal request	$4,735	$3,666–$6,110	30, 98, 102
Maternal outcomes			
Composite maternal morbidity after spontaneous vaginal delivery[b]	$1,308	$981–$1,635	12
Composite maternal morbidity after instrumental vaginal delivery[b]	$1,283	$962–$1,604	12
Composite maternal morbidity after emergency cesarean delivery[b]	$313	$235–$391	12
Composite maternal morbidity after planned cesarean delivery[b]	$219	$164–$274	12
Maternal death	$2,589	$1,942–$3,236	12
Neonatal outcomes			
Neonatal morbidity (postbirth respiratory problem)	$62,843	$24,082–$180,611	12
Neonatal death	$48,662	$24,082–$72,245	12
National mean age of women at first childbirth	25.2 years	–	19
Additional productivity loss of cesarean delivery compared with vaginal delivery	2 weeks	–	Authors' assumption
National median wage rate/week for women aged ≥25	$654	$491–$818	103
National median wage rate/week for workers (regardless of gender and age)	$695	$521–$869	103
Female life expectancy at age of first childbirth (i.e., 25.2 years of age)	56 years	–	104
Life expectancy at birth (regardless of gender)	77.5 years	–	104
Pelvic floor disorders (PFDs)			
Time of PFD onset (measured as number of years after delivery)	10 years	0–20 years	Authors' assumption
Stress urinary incontinence (SUI)			
Annual cost of routine care for SUI (for community dwelling adult, mainly absorbent materials and cleaning)	$595	$129–$2,185	105, 106
Annual productivity loss associated with SUI when age <65 years	104 hours	52–192.4 hours	9
Age at which women undergo SUI surgeries	54 years	49–59 years	107, 108
Cost of diagnosis evaluation of SUI	$239	$120–$479	105
Cost of SUI surgery	$9,849	$5,396–$19,296	105
Pelvic organ prolapse (POP)			
Annual cost of routine care for POP	$0	–	Authors' assumption
Annual productivity loss associated with POP when age <65 years	0 hours	–	Authors' assumption
Age at which women undergo POP surgeries	59 years	49–60 years	108–110
Cost of diagnosis evaluation of POP	$230	$173–$288	98
Cost of POP surgery	$5,787	$4,340–$7,234	109
Fecal incontinence (FI)			
Annual cost of routine care (primarily absorbent materials and cleaning)	$241	$24–$1,009	111, 112
Annual productivity loss associated with FI when age <65 years	37.44 hours	28.08–46.8 hours	113
Age at which women undergo FI surgeries	55 years	49–62 years	114, 115
Cost of diagnosis evaluation of FI	$659	$494–$824	111
Cost of FI surgery	$7,868	$5,901–$9,835	116

[a]Plausible ranges of the parameters were determined based on data from the literature or ±25% of the base value if no range was available from the literature.

[b]The cost of the composite maternal morbidity was derived based on the following cost estimates (adjusted to 2007 U.S. dollars) from Chung et al.[12] weighted by the distribution of the probability of each individual morbidity subsequent to different modes of delivery: peripartum hysterectomy after vaginal delivery ($5,710), infection after vaginal delivery ($1,562), blood transfusion after vaginal delivery ($395), surgical injury ($997), emergency hysterectomy after cesarean delivery ($1,547), infection after cesarean delivery ($171), and blood transfusion after cesarean delivery ($321).

TABLE 4. ESTIMATES OF UTILITY-RELATED PARAMETERS

Parameter	Base value	Range[a]	References
Obstetric events			
Spontaneous vaginal delivery	0.92	0.69–1.00	117, 118
Instrumental vaginal delivery	0.76	0.57–0.95	117, 118
Emergency cesarean delivery	0.59	0.44–0.74	117, 118
Cesarean delivery on maternal request	0.91	0.50–0.99	117, 118
Maternal outcomes			
Peripartum hysterectomy[b] (regardless of mode of delivery)	0.605	0.3–0.81	13, 119
Infection[c] (regardless of mode of delivery) (first year after delivery)	0.995	0.972–0.999	12
Blood transfusion[c] (regardless of mode of delivery) (first year after delivery)	0.995	0.972–0.999	12
Surgical injury after cesarean delivery[c] (first year after delivery)	0.972	0.945–0.995	12
Maternal death	0	–	Authors' assumption
Neonatal outcomes			
Postbirth respiratory problem[d]	0.99	0.70–0.99	120
Neonatal death	0.01	0–0.02	117, 120
Pelvic floor disorders[e]			
Stress urinary incontinence (SUI)	0.81	0.60–1	106
After successful surgical treatment for SUI	0.870	0.689–1	121
Pelvic organ prolapse (POP)	0.7067	0.4677–0.9457	122
After successful surgical treatment for POP	0.949	0.782–1	121
Fecal incontinence (FI)	0.50	0.40–0.65	13
After successful surgical treatment for FI	0.943	0.821–1	121

[a]Plausible ranges of the parameters were determined based on data from the literature or ±25% of the base value if no range was available from the literature.

[b]We assumed that the disutility of hysterectomy lasts for the woman's entire lifetime.

[c]Chung et al.[12] estimated the per diem disutility of infection to be 0.48 and a duration of disutility for 4 days. We assumed the same per diem disutility value (i.e., 0.48) for infection, blood transfusion, and surgical injury. For infection and blood transfusion, we varied the event duration from 1 to 21 days and use 4 days as base case. For surgical injury, we varied the duration of disutility from 4 to 42 days and use 21 days as base case.

[d]We used the disutility of admission to neonatal nursery as a proxy measure for the disutility associated with postbirth respiratory problem.

[e]When data on the Pelvic Floor Impact Questionnaire (PFIQ) were used, we assumed linear relationship between the FPIQ score and utility score.

statistically meaningful difference in our findings.) Lost productivity in the event of maternal and neonatal death was estimated based on a work life from age 25 to 65 and 18 to 65 for the mother and the child, respectively. For PFDs, we only modeled the routine care cost, diagnostic evaluation and surgery costs, and productivity loss for the subset of women who actively seek healthcare for the condition (used as an indicator for having bothersome symptoms) because some women may not have symptoms bothersome enough to entail such costs. Behavioral and pharmacological therapies of PFDs were not included in the model because of their relatively lower cost compared with surgical treatment and the limited availability of such data for FI and POP. Moreover, costs associated with reoperations for PFDs were not considered because of a lack of quality data on the timing of such reoperations. All cost estimates were adjusted to 2007 U.S. dollars.[125] Future costs were discounted to the time at childbirth using a 3% discount rate.

Effectiveness was measured by quality-adjusted life-years (QALYs) over the combined lifetime of the mother and the newborn. QALYs were computed by multiplying the number of expected life-years in each health state by the utility associated with that health state. Our model assumed the utility for maternal outcomes was independent from the utility for neonatal outcomes and the QALYs were additive. For example, we assumed the utility of maternal death and the utility of a healthy neonate after cesarean delivery were independent, such that each future year in the woman's and the newborn's life was counted as 0 and 1 QALY, respectively, with the overall QALYs being the sum of the numbers. For concurrent maternal outcomes (e.g., maternal infection and surgical injury), we assumed the utilities were independent and multiplicative. Only women actively seeking healthcare for a PFD condition were assumed to incur disutility. QALY estimates later in life were discounted to the time at childbirth using a 3% discount rate.

Data analysis

We used Monte Carlo simulation ($n = 5000$ iterations) to determine the expected cost and expected QALY throughout the lifetime of the woman and newborn for CDMR and TOL, respectively. Monte Carlo simulation is a method of using repeated random sampling to compute the results. Possible values of each input parameter were defined by a prespecified distribution. In each iteration, a random set of values for all input parameters was drawn from such prespecified distributions, entered in the model, and used to calculate the outcome measures. By doing so, the simulation accounted for the variability of parameter values and identified important factors influencing the cost-effectiveness outcome.

We simultaneously varied the value of 79 parameters from five domains: actual mode of delivery, transient maternal morbidity and mortality, paripartum hysterectomy,

perinatal morbidity and mortality, and the lifelong management of PFDs (i.e., all parameters with a specified range in Tables 1, 2, 3, and 4). We assumed a RiskPert distribution for the probability and utility parameters (a special form of beta distribution).[126] The base value identified for each parameter (Tables 1 and 4) corresponded to the mode of the RiskPert distribution. We also assumed that the lower and upper bounds of the parameters covered 95% of the values for the underlying distribution. For cost parameters, we drew on the desirable property of lognormal distributions (e.g., skewed distribution, positive and unbounded range).[127] The parameter base value (Table 3) corresponded to the mode of the lognormal distribution, and the natural logs of the lower and upper bounds of the parameter were assumed to cover 95% of the values for the underlying normal distribution. We applied truncated lognormal distributions to age parameters in a similar manner except they were subject to certain minimum and maximum values, such as minimum age of 25 (i.e., age at delivery) and maximum age of 81 (i.e., 25 plus the life expectancy of American women at age 25) for onset of PFDs.

With 5000 iterations of data, the mean and 95% confidence intervals (CIs) for the expected cost and QALY associated with CDMR and TOL, respectively, were calculated. We also estimated the mean and 95% CIs for the expected incremental cost (i.e., CDMR cost − TOL cost), incremental QALY (i.e., CDMR QALY − TOL QALY), the average cost-effectiveness ratios (i.e., CDMR cost/CDMR QALY, TOL cost/TOL QALY), and the incremental cost-effectiveness ratio (ICER) (i.e., incremental cost divided by incremental QALY). An incremental cost-effectiveness plane and cost-effectiveness acceptability curve also were constructed to assess the probability distribution of the ICER. Because cost and ICER mea-

sures are typically not normally distributed and our results also suggested skewed distribution of QALY data, we estimated the 95% CIs based on a nonparametric method using the 2.5th and 97.5th percentiles.[128] DecisionTools Suite® software (Palisade Corporation, Ithaca, NY) and SAS 9.1 (SAS Institute Inc., Cary, NC) were used for data analysis.

Results

For a primigravid woman without medical or obstetric indications having only one childbirth in her lifetime, Monte Carlo simulation suggested that, on average, CDMR would cost $14,259 (95% CI $8,964-$24,002) over the combined lifetime of the mother and newborn, whereas TOL would cost $13,283 (95% CI $7,861-$23,829) (Table 5). The estimated mean incremental cost of CDMR (compared with TOL) was $976 (95% CI −$7,863-$7,935). In terms of QALY, undergoing CDMR would result in 58.21 QALYs (95% CI 57.43-58.67) over the lifetime of the mother and the newborn, and TOL was expected to generate 57.87 QALYs (95% CI 56.97-58.46). The estimated mean incremental QALY of CDMR (compared with TOL) was 0.35 (95% CI −0.24-1.10). Because the confidence intervals of both the estimated mean incremental cost and incremental QALY contain zero, there was no statistically significant difference in the expected cost or expected QALY between CDMR and TOL at the 0.05 level.

Figure 2 shows the incremental cost-effectiveness plane, which plots the joint distribution of the incremental cost and incremental QALY. Each dot on the plane corresponds to one incremental cost and QALY pair resulting from one iteration of the simulation. The incremental cost and QALY pairs were largely distributed across each quadrant of the incremental cost-effectiveness plane, primarily in the first,

TABLE 5. SUMMARY OF RESULTS FROM MONTE CARLO SIMULATION

Monte Carlo simulation	Trial of labor	Cesarean delivery on maternal request (CDMR)[a]
Cost, mean (95% CI[a])	$13,283 ($7,861-$23,829)	$14,259 ($8,964-$24,002)
Quality-adjusted life-years (QALY), mean (95% CI)	57.87 (56.97-58.46)	58.21 (57.43-58.67)
Average cost-effectiveness ratio, mean (95% CI)	$230/QALY ($135/QALY-$414/QALY)	$245/QALY ($153/QALY-$417/QALY)
ΔCost,[b] mean (95% CI)	$976 (−$7,863-$7,935)	
ΔQALY,[c] mean (95% CI)	0.35 (−0.24-1.10)	

Most significant parameters[d]	Effect of 1 SD[e] increase in parameter on ΔCost[b]	Effect of 1 SD[e] increase in parameter on ΔQALY[c]
Probability of stress urinary incontinence (SUI) after CDMR (SD[e] = 0.09)	$2,509	−0.17
Probability of SUI after spontaneous vaginal delivery (SD[e] = 0.07)	−$1,711	0.10
Cost of neonatal morbidity (SD[e] = 47,589)	$924	n/a
Cost of CDMR (SD[e] = 625)	$625	n/a
Annual routine care cost for SUI (SD[e] = 1,009)	−$1,080	n/a
Age of pelvic floor disorder onset (SD[e] = 5.20)	$817	−0.11
Utility of CDMR (SD[e] = 0.13)	n/a	0.13
Utility of pelvic organ prolapse (SD[e] = 0.13)	n/a	−0.09
Utility of SUI (SD[e] = 0.10)	n/a	−0.10

[a]CI, confidence interval.
[b]ΔCost, cost of CDMR − cost of trial of labor.
[c]ΔQALY, QALY of CDMR − QALY of trial of labor.
[d]All these parameters are statistically significant at 0.05 level.
[e]SD, standard deviation. These are estimated SDs of the parameters based on the simulation (n = 5000 iterations).
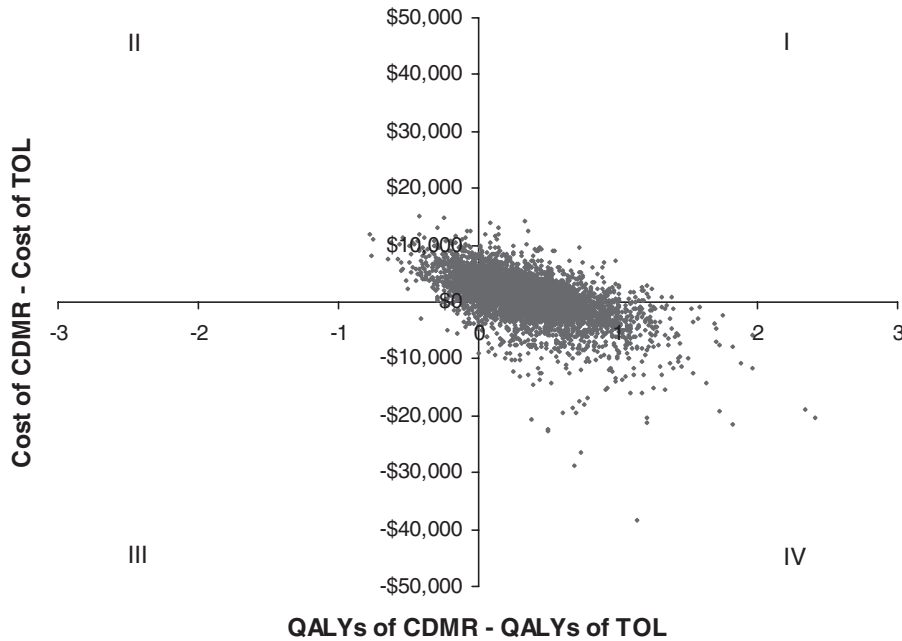
FIG. 2. Incremental cost-effectiveness plane. The horizontal axis represents the difference in quality-adjusted life-years (QALYs) between cesarean delivery on maternal request (CDMR) and trial of labor (TOL) (i.e., incremental QALY). The vertical axis represents the difference in the costs between CDMR and TOL (i.e., incremental cost). Each dot in the figure corresponds to one incremental cost and incremental QALY pair resulting from one iteration of the Monte Carlo simulation.

second, and fourth quadrants. In 12.14% of the iterations, CDMR was dominated by TOL (i.e., CDMR was more costly and less effective than TOL), whereas in 33.32% of the iterations, CDMR was the dominant strategy, with higher QALY and lower cost. In the other 54.54% of the iterations, one delivery scheme was less costly and the other generated higher QALY, with significant variability in the magnitude of the ICER (95% CI $352/QALY-$220,496/QALY).

Figure 3 illustrates the probability that CDMR is cost-effective compared with TOL for a given cutoff cost-effectiveness ratio that a society is willing to pay. For example, if a society is willing to pay $50,000 for one QALY, there is an 82% chance that undergoing CDMR is cost-effective compared with TOL (i.e., there is an 82% chance that the additional cost of CDMR is < $50,000 for each additional QALY gained). The null hypothesis that there is no net benefit of CDMR is rejected only when the cost-effectiveness
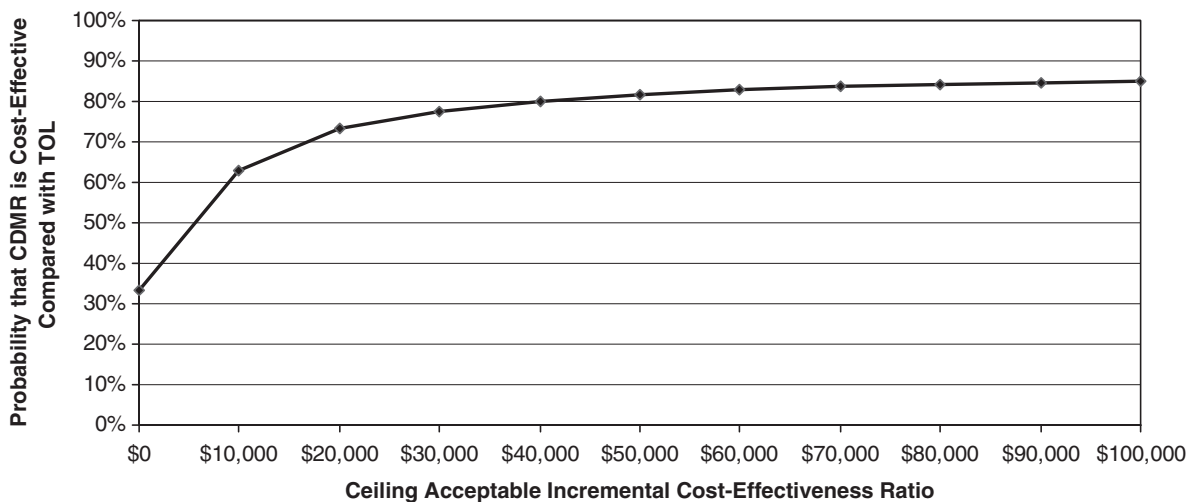

FIG. 3. Cost-effectiveness acceptability curve. This figure illustrates the probability that cesarean delivery on maternal request (CDMR) is cost-effective compared with trial of labor (TOL) for a given cutoff cost-effectiveness ratio that a society is willing to pay. For example, if a society is willing to pay $50,000 for one QALY, there is an 82% chance that undergoing CDMR is cost-effective (i.e., there is an 82% chance that the additional cost of CDMR is < $50,000 for each additional QALY gained).

acceptability curve is above 95%.[129] In our simulation, the probability of CDMR being cost-effective never exceeded 88% for any cutoff cost-effectiveness ratio. Therefore, we could not reject the null hypothesis that there was no net benefit of CDMR in comparison to TOL.

Table 5 reports the factors identified as most influential in the simulation and their estimated effects on the incremental cost and QALY. The cost of CDMR and neonatal morbidity significantly affected the incremental cost between CDMR and TOL. PFD-related parameters also were found important. For example, based on the simulation data, a 1 standard deviation (SD) increase in the probability of developing SUI after CDMR was associated with a $2,509 increase in the incremental cost and a 0.17 reduction in incremental QALY. In contrast, a 1 SD increase in the probability of developing SUI after spontaneous vaginal delivery resulted in a $1,711 reduction in the incremental cost and a 0.10 increase in incremental QALY. In addition, the age of PFD onset, women's perceived quality of life when having POP or SUI, and the annual routine care cost for SUI all influenced the expected incremental cost and QALY between CDMR and TOL.

Discussion

There has been a growing debate surrounding the appropriateness of CDMR, especially in view of the recent substantial increase in cesarean delivery rate in the United States. Using currently available evidence, we assessed the lifetime cost-effectiveness of CDMR compared with TOL from a societal perspective. Our results showed that for primigravid women without medical or obstetric indications and with only one childbirth over their lifetime, CDMR and TOL are associated with comparable costs and QALYs. Moreover, PFD-related parameters were found to be important factors in the cost-effectiveness assessment.

By modeling the impact of delivery mode on lifelong PFD outcomes, this study provides a more comprehensive view of the long-term cost and quality of life consequences of CDMR among primigravid women who have no medical or obstetric indications and do not go on to have future deliveries. The model structure developed in this analysis can be used as a basis for future cost-effectiveness analyses of CDMR that include multiple deliveries.

Although prevention of PFDs is a frequently cited reason for requesting or performing CDMR, our analyses suggest that even after considering the long-term pelvic floor consequences, CDMR is not superior to TOL in terms of lifelong cost and quality of life for a primigravid woman without medical or obstetric indications having only one childbirth over her lifetime. However, our findings also imply that CDMR is not worse than TOL in this subpopulation of women. This is consistent with the NIH State-of-the-Science statement that there are "relatively similar degrees of risk from both pathways in women intending to limit their childbearing to one or two children."[3]

Our finding, however, should not be generalized to women with multiple childbirths. Women with a primary cesarean delivery face increased risk for complications in subsequent pregnancies.[2] This could substantially increase the cost while reducing QOL for women undergoing CDMR. Similarly, women with more than one vaginal delivery are at higher risk for PFDs, which could increase the lifetime cost while re-

ducing the QALY for TOL patients. The overall impact of additional childbirths on the cost-effectiveness of CDMR will require further investigation as more data become available about maternal and neonatal outcomes associated with different modes of delivery at successive childbirths. Further, the cost-effectiveness of CDMR will likely differ for women with medical indications or in certain high-risk situations. For example, a planned cesarean delivery may prove beneficial for preterm or postterm births by preventing serious morbidity and mortality during labor. Further research analyzing this issue for subsets of women with certain indications would inform whether there are specific subpopulations who may benefit from CDMR.

The framework of cost-effectiveness analysis offers a unique opportunity to identify gaps in the current literature about CDMR and its relationship with PFDs. For example, we located only two studies examining women's utility related to their delivery experience and outcomes.[117,118] This makes it difficult to evaluate the implications of CDMR for women's quality of life. In addition, the PFD-related parameters were found to be significant factors in our model; yet there is a fair amount of uncertainty surrounding these parameters. Future research providing better estimates of these parameters would facilitate more elaborated comparisons between CDMR and TOL.

Several additional factors must be kept in mind when interpreting our findings. First, to streamline the analytical model, we did not consider coexisting PFDs. Consequently, we might have overestimated the cost related to the care of PFDs, biasing our results in favor of CDMR. This could also cause underestimation of disutility associated with PFDs, however, biasing the QALY estimates in favor of TOL. Second, although there is evidence that forceps delivery may be more likely than vacuum delivery to cause PFDs,[130] our analysis could not stratify on these two types of instrumental vaginal delivery because of a lack of detailed data.

Conclusions

This study makes an important first step toward addressing a complicated question: Is cesarean delivery on maternal request more cost-effective than trial of labor when lifelong pelvic floor consequences are considered? Our results suggest that in the absence of medical and obstetric indications, CDMR and TOL are not significantly different from each other in terms of lifelong cost and QALY for primigravid women having only one childbirth over their lifetime. Women's QOL related to delivery experience and the PFD-related factors should be studied more closely and incorporated in future decision analyses. This will help advance the understanding of the complex relationship between childbirth and long-term maternal outcomes and allow for more informed clinical and policy recommendations.

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Disclosure Statement

The authors have no conflicts of interest to report.

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