Examining Labor in the Upright Positioning with a Low-Dose Epidural: A Cost-Effectiveness Analysis

Michael Phillipi

michael.phillipi@md.cusm.edu

California University of Science and Medicine School of Medicine

Claire Packer
Sarina R Chaiken
Alyss R Hersh
Aaron B Caughey

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Tables 1 to 2 are available in the Supplementary Files section

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Short Title: Cost-Effectiveness of Laboring Upright

Authors:
Michael A. Phillipi, BA[1]
Claire Packer, MD, MPH[2]
Sarina R. Chaiken, MD, MPH[3]
Alyssa R. Hersh, MD, MPH[4]
Aaron B. Caughey, MD, MPH, PhD[4]

Author affiliations:
1 School of Medicine, California University of Science and Medicine, Colton, CA.
2 Department of Obstetrics & Gynecology, Brigham and Women's Hospital, Boston, MA.
3 Department of Obstetrics & Gynecology, The Warren Alpert Medical School at Brown University, Providence, RI.
4 Department of Obstetrics & Gynecology, Oregon Health & Science University, Portland, OR.

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Corresponding Author:
Michael A. Phillipi, BA
c/o Department of Obstetrics & Gynecology
3181 SW Sam Jackson Park Road
Portland, OR 97239
503-494-2999
michael.phillipi@md.cusm.edu

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What does this study add to the clinical work: This study shows laboring in the recumbent compared to the upright position with a low-dose epidural is cost-saving and leads to improved maternal outcomes. We present further evidence providers should encourage patients given a low-dose epidural to labor in the recumbent position rather than in the upright position.

Abstract:

Purpose:

To estimate the outcomes, costs, and cost-effectiveness associated with birthing in the upright position compared to the recumbent position in patients with a low-dose epidural.

Methods:

We designed a decision-analytic model using TreeAge Pro software to compare the outcomes and cost-effectiveness of employing the upright versus recumbent position during the first delivery with a low-dose epidural, incorporating the impact of mode of delivery on a subsequent delivery. We used a theoretical cohort of 756,000 patients, representing the approximate number of nulliparous individuals who have a term birth in the United States annually and are given an epidural. Probabilities and costs were derived from the literature.

Results:

In our theoretical cohort of 756,000 nulliparous individuals with a low-dose epidural, the recumbent positioning strategy was associated with 18,652 fewer cesarean deliveries in the first pregnancy (66,210 vs 84,862), which would lead to 11,228 fewer cesarean deliveries in the second pregnancy (135,787 vs 147,015), 4 fewer uterine ruptures (15 vs 19) and 1 fewer hysterectomy (4 vs 5) in the second pregnancy, 2 fewer maternal deaths (23 vs 25) in the first delivery, and 1 fewer maternal death in the second delivery (26 vs 27). Laboring in the recumbent position saved $157 million ($15.526 billion vs $15.683 billion) and increased QALYs by 2,141 QALYs (19.846 million vs 19.844 million).

Conclusion:

Our results show that in a theoretical cohort of 756,000 patients, laboring in the recumbent position may save $157 million annually and improve maternal outcomes.

Key Words: cost-effectiveness, epidural, upright, recumbent, labor

Introduction

Epidural anesthesia is used in the majority of vaginal deliveries in the United States, with 61% of individuals electing to receive this intervention [1]. A recent Cochrane Review of 40 randomized controlled trials with over 11,000 patients shows that epidurals did not affect the rate of cesarean sections [2]. While the review demonstrated that epidurals increased rates of assisted vaginal birth before 2005, this was likely due to a higher concentration of local anesthetic used. Recent studies using epidurals with lower doses of local anesthetic have not seen this effect. The traditional epidural analgesia uses 0.25%-0.5% bupivacaine, while low-dose epidurals use a lower concentration of local anesthetic (e.g. 0.125% bupivacaine, 0.1% or 0.2% ropivacaine) in addition to an opiate [3].

In patients without an epidural, laboring in the upright position has been shown to result in shorter labors and a lower rate of episiotomies and instrumental deliveries as compared to laboring in the recumbent position [4]. Currently, the WHO recommends that patients undergoing epidural anesthesia may choose their positioning including either recumbent or upright positioning [5]. The low-dose epidural allows more mobility during labor and gives patients a greater ability to reposition [6]. However, recent literature suggests the benefits of the upright position are not present when an epidural is administered. A Cochrane Review of eight randomized controlled trials involving 4,464 patients did not show any clear impact of positioning on maternal outcomes in patients with an epidural [6]. When only the high-quality evidence was included, 2 trials including 3,502 patients showed that among individuals with a low-dose epidural, recumbent positioning was associated with a higher rate of spontaneous vaginal deliveries as compared with those who deliver upright. The Birth in the Upright Maternal Position with Epidural in Second stage (BUMPES) trial, a high-quality trial included in the Cochrane Review, demonstrated a decreased time in the second stage of labor with recumbent positioning, with no adverse effects on the short or long-term outcomes of either the mother or baby [7].

Given that repositioning in labor is a free and straightforward intervention to reduce cesarean deliveries, it is important for both patients and providers to understand the benefits of utilizing each position. This study aimed to

estimate the outcomes, costs, and cost-effectiveness associated with laboring in the upright versus recumbent position after receiving a low-dose epidural.

Methods

We constructed a decision-analytical model using TreeAge Pro software (2023 version; TreeAge Software, LLC, Williamstown, MA) to assess the cost-effectiveness of laboring in the upright versus recumbent position during the first delivery and the impact on the subsequent pregnancy. We used a theoretical cohort of 756,000 patients, the approximate number of term, nulliparous individuals who receive an epidural in labor annually. We derived this value from the 3.3 million term births that occur annually in the United States, assuming 37.8% of these births are to nulliparous individuals, and 61% of these nulliparous mothers receive an epidural [1, 8, 9]. Model inputs were derived from the literature. As no human subjects were included in this study, it was deemed exempt from Institutional Review Board approval.

In our model, the primary decision node divided nulliparous individuals at term with an epidural into either the recumbent or upright positioning strategies. Individuals could then experience either a cesarean or vaginal delivery. Those who underwent a vaginal delivery were divided into those who experienced spontaneous or instrumental deliveries. 87% of individuals were assumed to have a second delivery [10]. Those with a cesarean delivery in the first pregnancy were stratified into two groups: trial of labor after cesarean (TOLAC) or a planned cesarean in the second delivery. Those with a TOLAC were then divided into a successful or an unsuccessful vaginal delivery after cesarean (VBAC). Those with an unsuccessful VBAC could experience a uterine rupture, and subsequently a hysterectomy. Those with a vaginal delivery in the first pregnancy, including both spontaneous and instrumental, were stratified based on a vaginal or cesarean delivery for their subsequent pregnancy. Subsequent to mode of delivery and birth complications for both pregnancies and deliveries was maternal death.

The probabilities modeled were derived from the literature (Table 1). The probabilities of cesarean and operative vaginal delivery in each birthing position during the first delivery were estimated from evidence in the

Cochrane Review that was deemed high-quality [6]. The review showed the upright position had a statistically significantly higher rate of cesarean delivery (11.23% vs 8.76%, relative risk of 1.28) than the recumbent position. The probability of an instrumental vaginal delivery was set at 2.96% in both positions, equal to the rate of instrumental deliveries in United States births in 2021 [8]. A study on the trends in attempted and successful TOLAC in the US found a 21.70% probability of TOLAC, and a 25.31% probability of an unsuccessful TOLAC which results in a cesarean [11]. A study on vaginal birth after a cesarean in California was used to establish the probability of a cesarean after a vaginal delivery (14.59%) [12]. It demonstrated 25.11% of these cesareans after prior vaginal delivery are planned, while the remaining 74.89% are due to failed labor [12]. The probabilities of uterine rupture after failed TOLAC (0.47%) and maternal death after failed TOLAC leading to repeat cesarean (0.004%) were derived from a systematic review on VBAC [13]. Research on outcomes associated with TOLAC presented probabilities of peripartum hysterectomy following uterine rupture after failed TOLAC (26.32%) [14]. A study on maternal outcomes after uterine rupture showed a maternal death rate of 0.29% after failed TOLAC leading to uterine rupture [15]. We assumed this mortality rate was not impacted by the performance of a hysterectomy. A study on maternal death in the 21st century provided probabilities of maternal death in all other nodes, including a 0.016% probability after the first cesarean and a 0.0068% probability after planned repeat cesarean [16]. We assumed the maternal death rate after successful VBAC and first and second vaginal delivery in both positions was equal (0.0017%) [16].

The costs incorporated in the model were also derived from the literature (Table 1). Costs were adjusted to 2023 U.S. dollars using the medical component of the consumer price index and discounted at an annual rate of 3% [17]. Costs related to the second delivery were discounted for 2.4 years, the mean time between first and second births in the United States [18]. Costs were considered from a societal perspective, and it was assumed there was no marginal cost of repositioning as it would be patient and nursing time that would already be accounted for. The cost of a vaginal delivery in a multiparous patient in the recumbent position was estimated at $10,472 [19]. A cesarean delivery cost $15,325 in all patients [19]. The additional cost of labor in nulliparous patients was $113.71, derived from the additional time in the active second stage of labor and the hourly cost of patient care in the labor and delivery ward [19, 20]. To determine the additional cost of labor time in patients utilizing the upright position, we

first found the mean length of second stage labor in patients in the upright and recumbent position [20]. Using the cost of additional hours in the labor unit and the difference in the mean length of time in labor in patients in both positions, we found the additional cost of labor time in the upright position to be $18.64 [7, 19]. The cost of TOLAC was assumed to be equal to $1,896, the cost of the additional hours in the labor unit [19]. The cost of maternal death was determined by the lost wages over a patient's lifespan, derived from the median wages ($50,279 annually) and the assumption of a first delivery at the mean age of 26.3, the second at 28.7 and retirement at the mean age of 62 [18, 21, 22].

Maternal quality-adjusted life-years (QALYs) were included in our analysis, calculated by applying utilities to an amount of time in a health state (Table 1). Utility values ranged from 0 to 1, with 0 representing maternal death and 1 representing optimal health. QALYs were discounted at a rate of 3%. Here, we considered vaginal delivery to be a utility of 1. The utility of a cesarean was valued at 0.996 based on a study regarding the preference for modes of delivery [23]. We used a utility of 0.963 for a peripartum hysterectomy until the mean age of menopause, with a subsequent utility of 1 until the mean age of death, accounting for the loss of fertility [19]. The life expectancies of patients and the mean ages at first and second delivery were also used to calculate QALYs [18, 24, 25]. We then determined the incremental cost-effectiveness ratio (ICER) to compare the cost and QALYs of laboring in the recumbent and upright positions. We considered a willingness-to-pay (WTP) threshold of $100,000 or less to be cost-effective, and an intervention that is both higher in effectiveness and lower in cost to be dominant [26].

To evaluate the robustness of our results we conducted univariable sensitivity analyses on the probabilities, costs, and utilities. Probabilities, costs, and utilities were varied by ±3 standard deviations. We constructed a tornado diagram to analyze which model inputs had the largest impact on the outcomes. Additionally, a Monte Carlo multivariable probabilistic sensitivity analysis was run 10,000 times to test our conclusions through uncertainty throughout all inputs concurrently. For the Monte Carlo simulation, a beta distribution was used for the probabilities and utilities, while a gamma distribution was used for the costs and life expectancies.

Results

In our theoretical cohort of 756,000 nulliparous, term individuals undergoing a low-dose epidural during labor, the recumbent positioning strategy was associated with 18,652 fewer cesarean deliveries in the first pregnancy (66,210 vs 84,862), which would lead to 11,228 fewer cesarean deliveries in the second pregnancy (135,787 vs 147,015), 4 fewer uterine ruptures (15 vs 19) and 1 fewer hysterectomy (4 vs 5) in the second pregnancy, 2 fewer maternal deaths (23 vs 25) in the first delivery, and 1 fewer maternal death in the second delivery (26 vs 27). The recumbent strategy saved $157 million ($15.526 billion vs $15.683 billion) and resulted in 2,141 increased QALYs (19.846 million vs 19.844 million) across the cohort's first and second pregnancies. Given that the recumbent positioning strategy was associated with reduced costs and increased QALYs as compared with the upright positioning strategy, it was the dominant strategy in our model.

We constructed a tornado diagram, varying all the inputs and parameters in Table 1. No variables within their reasonable ranges resulted in the upright strategy being favored or cost-effective. The most sensitive inputs were the utility of a cesarean delivery, the probability of a cesarean in each strategy, the additional cost of labor time in the upright position, and the cost of a cesarean and vaginal delivery. Given these results, we performed univariable sensitivity analyses on these probabilities and costs. We modeled a 28% greater likelihood of a cesarean delivery in the upright compared to the recumbent position (relative risk = 1.28) The recumbent position was found to be cost-effective with a relative risk of a cesarean delivery in the upright compared to the recumbent position of 0.99 to 1.00, including when the risk of a cesarean in both positions was equal (relative risk = 1.00). The recumbent position led to cost-savings and greater effectiveness with any greater likelihood of a cesarean delivery in the upright compared to the recumbent position (relative risk >1.00). The literature showed mothers positioned upright spend more time in the active second stage of labor compared to mothers in the recumbent position, leading to a $18.64 (0.18%) increase in the cost of a vaginal delivery. We found the recumbent strategy resulted in greater effectiveness and cost-savings with equal costs of labor in both positions, and for any additional cost of labor in the upright position. The recumbent strategy also led to greater effectiveness and cost-savings for any additional cost of labor in the recumbent compared to the upright strategy <$208 (up to a 1.99% increase in total delivery costs). For any additional cost of laboring recumbent >$208 but <$492 (up to a 4.70% increase), the recumbent strategy was cost-

effective. The cost of a cesarean delivery in our model ($15,325) was 1.46 times greater than the cost of a vaginal delivery ($10,472). Assuming a cesarean was always 1.46 times more expensive than a vaginal delivery, the recumbent strategy was cost-saving and more effective for any price of a vaginal delivery. Additionally, the recumbent strategy always resulted in lower costs and greater effectiveness with every variation of the relative price of a cesarean compared to a vaginal delivery, assuming a cesarean was always more expensive than a vaginal delivery.

On 10,000 simulations, the Monte Carlo multivariable probabilistic sensitivity analysis of the probabilities, costs, and utilities in the model demonstrated the recumbent strategy was cost-effective in 97.9% of simulations and cost-saving in 93.9% of simulations.

Discussion

We found that among nulliparous individuals with a low-dose epidural in labor, the recumbent positioning strategy led to fewer cesarean deliveries, uterine ruptures, hysterectomies, and maternal deaths and was not just cost-effective, but was cost-saving as well. The model's results were resistant to variation on both univariable and multivariable sensitivity analyses.

Existing literature has highlighted the benefits of laboring in the recumbent position in patients with epidural anesthesia. Although the Cochrane Review of eight randomized controlled trials identified no clear impact of the two positions on maternal outcomes, the review rates the data used to calculate these outcomes as very-low quality [6]. When only the high-quality studies were included, the upright position led to a significant increase in the rate of cesareans. The BUMPES trial was the most recent, largest study included in the Cochrane Review and was one of the two trials considered to provide high-quality evidence on cesarean and instrumental delivery rates with a low-dose epidural [6, 7]. It found that recumbent positioning increased the probability of a spontaneous vaginal delivery, and had no disadvantages on either maternal or fetal outcomes when compared to the upright position [7].

Our study expands on this trial to outline the cost-effectiveness of the recumbent strategy and provides further evidence of the improved maternal outcomes associated with this laboring position.

Our study suggests that nulliparous individuals who elect to receive low-dose epidurals should utilize the recumbent birthing position. The lower rates of adverse outcomes should be incentives to avoid birthing upright. Our findings also suggest that providers should prioritize the recumbent position after a low-dose epidural is administered due to its cost-effectiveness.

The robustness of the results of this study is dependent on the reliability of model inputs. Different populations and locations may experience varying costs or probabilities than those derived from the literature. For example, the cost of an uncomplicated vaginal and cesarean delivery varies widely between US hospitals [27]. The data from the Cochrane Review used to derive the probability of a cesarean in each position primarily studied white patients [7]. The generalizability of the study to other, more diverse populations needs additional research. Another limitation of the model is the assumption that all patients will have either one or two pregnancies. We did not model the outcomes associated with patients who have more than two children. However, given that additional downstream births would have more complications in those with a prior cesarean delivery, the differences would only be greater than in our current model. A separate limitation is our inability to incorporate other factors for choosing the upright birthing position into our model. An upright birthing position may allow patients to feel more in control and can result in greater satisfaction associated with birth [28] Patients with this sentiment may receive a greater utility from laboring upright instead of recumbent.

This study expands on current literature to suggest that laboring in the recumbent position with a low-dose epidural leads to fewer cesarean deliveries, and in turn, fewer uterine ruptures, hysterectomies, and maternal deaths in subsequent births. Further, this approach is cost-saving. While current guidelines recommend either a recumbent or upright position per the patient's choice after receiving a low-dose epidural, it is important for patients to be counseled regarding the potential outcomes.

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Figure 1. Tree schematic
The branches that terminate in a circle are concealed to simplify the schematic. The concealed portions of the branches are identical to the comparable branches that terminate in a triangle.

Figure 2. Univariate sensitivity analysis of the additional cost of labor time with an epidural in the recumbent position
The vertical axis displays the incremental cost-effectiveness ratio (ICER) while the horizontal displays the additional cost of labor time with an epidural in the recumbent position. The literature showed laboring in the upright strategy resulted in additional costs compared to the recumbent position due to a longer active second stage of labor. However, the recumbent position resulted in cost-savings and greater effectiveness for any additional cost of labor in the upright position. This figure shows that the recumbent strategy also results in greater effectiveness and cost-savings with additional costs of labor in the recumbent compared to the upright position, up to $208. With an additional cost of labor in the recumbent position between $208 to $492, the recumbent position is cost-effective with a WTP of $100,000. A $492 additional cost of labor in the recumbent position would result in a 4.70% increase in the total cost of a vaginal delivery as compared to delivering in the upright position.

Figure 3. Multivariate sensitivity analysis
This figure displays a Monte Carlo simulation of 10,000 scenarios. The ellipse represents the 95% confidence interval of cost and effectiveness outcomes. The samples that are cost-effective run below the dashed line representing the willingness-to-pay (WTP) threshold of $100,000 per quality-adjusted life year. This line runs above 97.9% of simulations, indicating the recumbent strategy is cost-effective in those simulations.

Figures

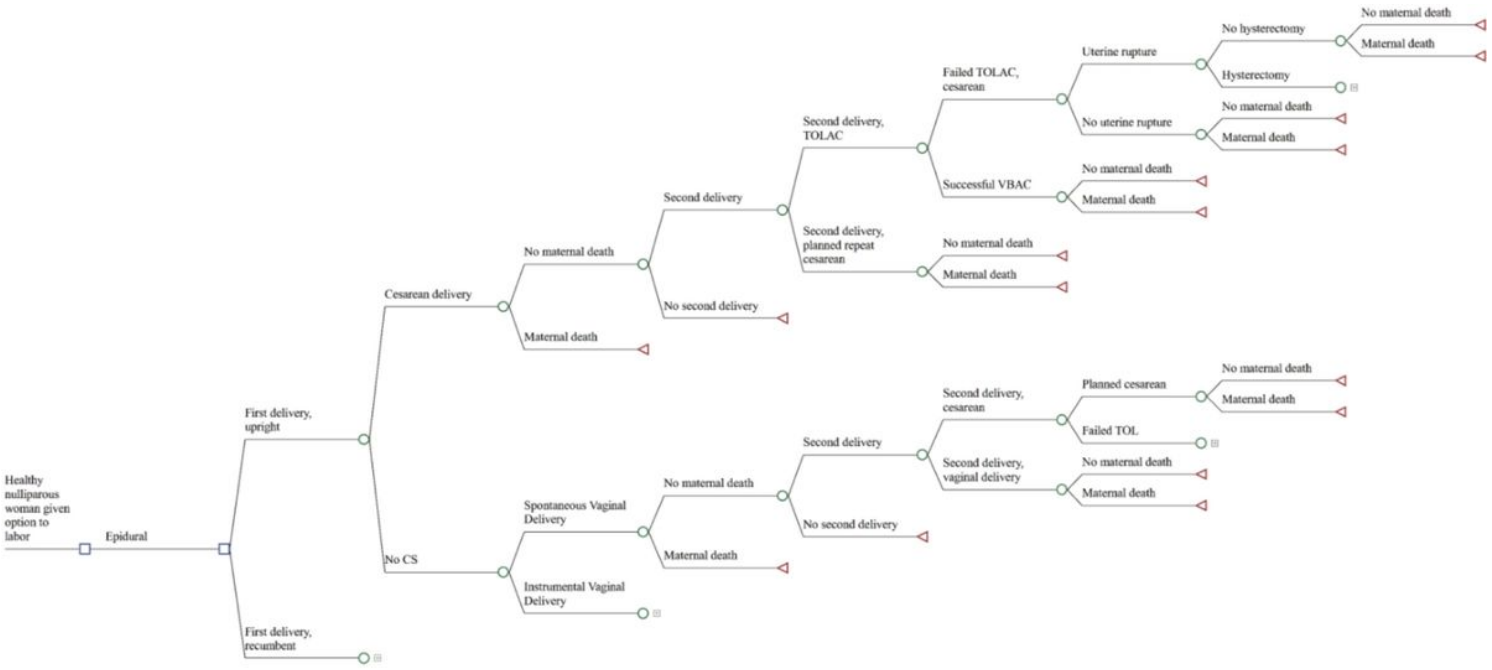

Figure 1

Tree schematic

The branches that terminate in a circle are concealed to simplify the schematic. The concealed portions of the branches are identical to the comparable branches that terminate in a triangle.

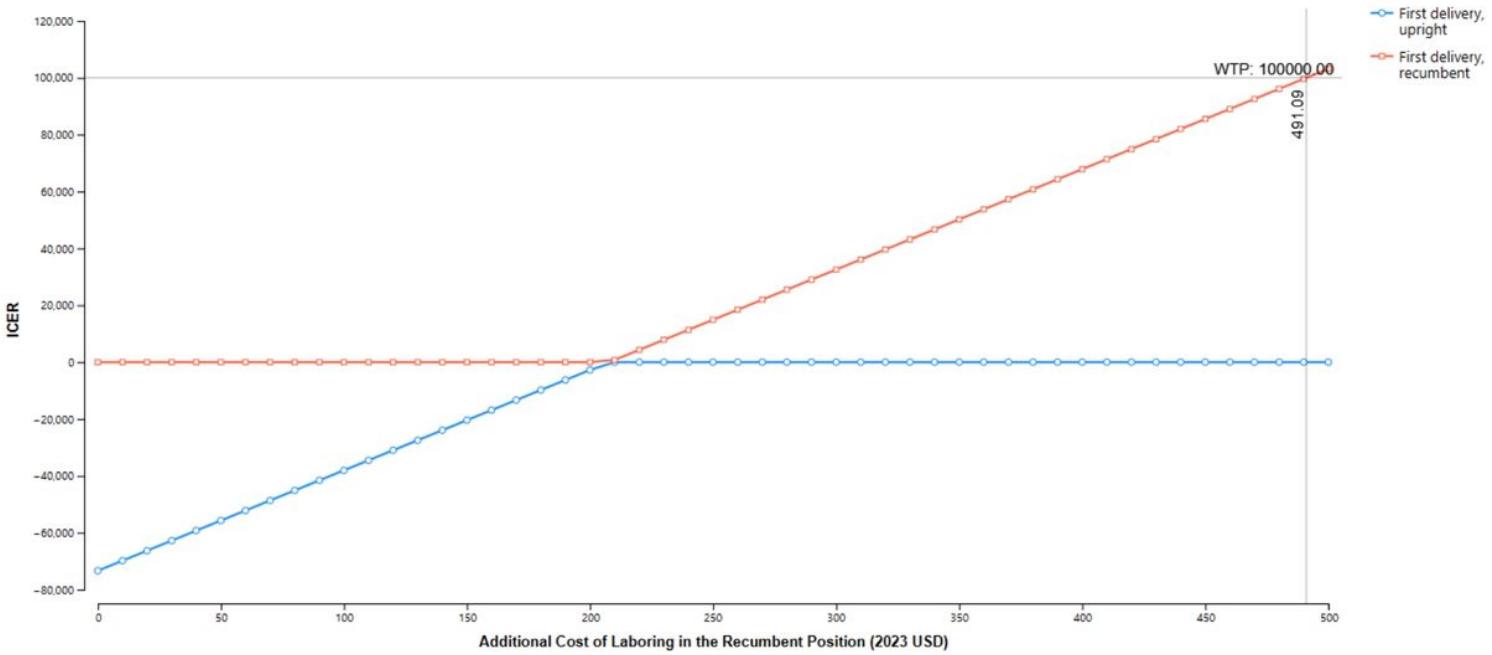

Figure 2

Univariate sensitivity analysis of the additional cost of labor time with an epidural in the recumbent position The vertical axis displays the incremental cost-effectiveness ratio (ICER) while the horizontal displays the additional cost of labor time with an epidural in the recumbent position. The literature showed laboring in the upright strategy resulted in additional costs compared to the recumbent position due to a longer active second stage of labor. However, the recumbent position resulted in cost-savings and greater effectiveness for any additional cost of labor in the upright position. This figure shows that the recumbent strategy also results in greater effectiveness and cost-savings with additional costs of labor in the recumbent compared to the upright position, up to $208. With an additional cost of labor in the recumbent position between $208 to $492, the recumbent position is cost-effective with a WTP of $100,000. A $492 additional cost of labor in the recumbent position would result in a 4.70% increase in the total cost of a vaginal delivery as compared to delivering in the upright position.

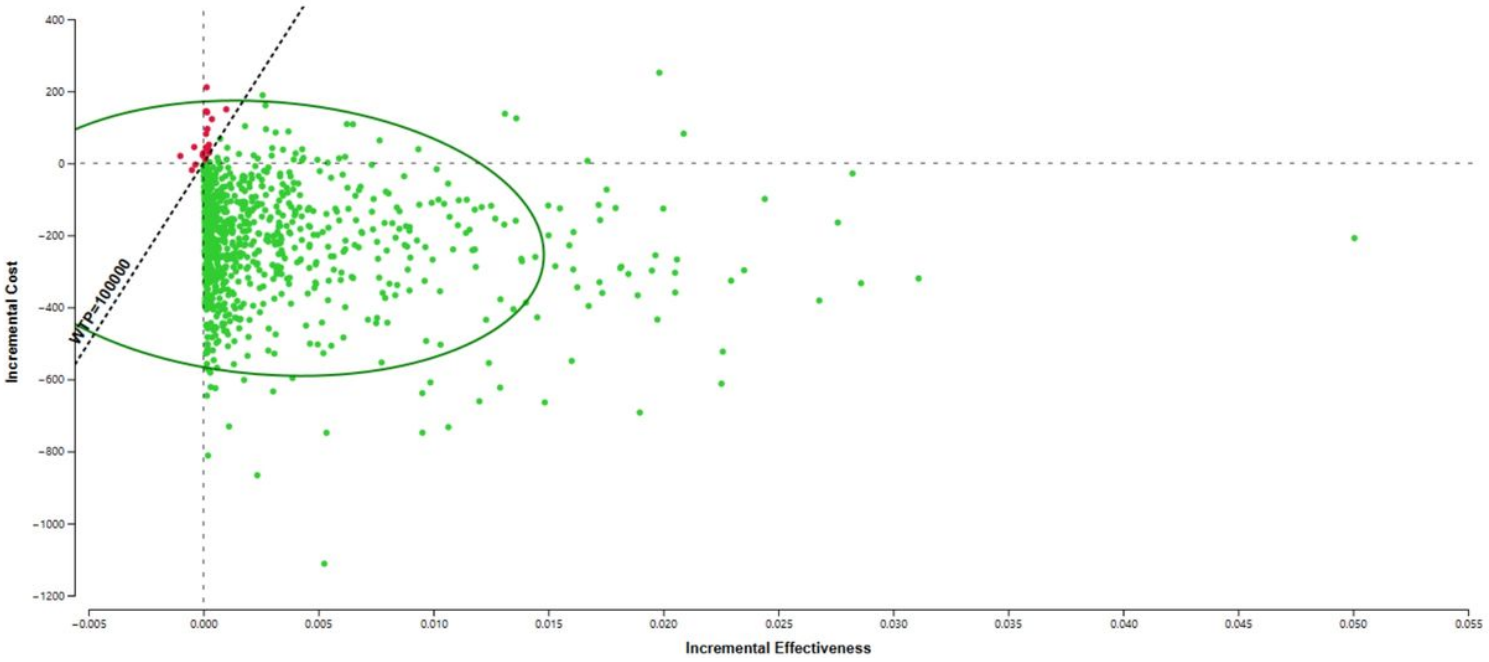

Figure 3

Multivariate sensitivity analysis This figure displays a Monte Carlo simulation of 10,000 scenarios. The ellipse represents the 95% confidence interval of cost and effectiveness outcomes. The samples that are cost-effective run below the dashed line representing the willingness-to-pay (WTP) threshold of $100,000 per quality-adjusted life year. This line runs above 97.9% of simulations, indicating the recumbent strategy is cost-effective in those simulations.

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