OBSTETRICS

Cost-effectiveness of elective induction of labor at 41 weeks in nulliparous women

Anjali J. Kaimal, MD, MAS; Sarah E. Little, MD; Anthony O. Odibo, MD, MSCE; David M. Stamilio, MD, MSCE; William A. Grobman, MD, MBA; Elisa F. Long, PhD; Douglas K. Owens, MD; Aaron B. Caughey, MD, PhD

OBJECTIVE: To investigate the cost-effectiveness of elective induction of labor at 41 weeks in nulliparous women.

STUDY DESIGN: A decision analytic model comparing induction of labor at 41 weeks vs expectant management with antenatal testing until 42 weeks in nulliparas was designed. Baseline assumptions were derived from the literature as well as from analysis of the National Birth Cohort dataset and included an intrauterine fetal demise rate of 0.12% in the 41st week and a cesarean rate of 27% in women induced at 41 weeks. One-way and multiway sensitivity analyses were conducted to examine the robustness of the findings.

RESULTS: Compared with expectant management, induction of labor is cost-effective with an incremental cost of $10,945 per quality-adjusted life year gained. Induction of labor at 41 weeks also resulted in a lower rate of adverse obstetric outcomes, including neonatal demise, shoulder dystocia, meconium aspiration syndrome, and severe perineal lacerations.

CONCLUSION: Elective induction of labor at 41 weeks is cost-effective and improves outcomes.

Key words: elective induction, induction of labor, postterm pregnancy

Cite this article as: Kaimal AJ, Little SE, Odibo AO, et al. Cost-effectiveness of elective induction of labor at 41 weeks in nulliparous women. Am J Obstet Gynecol 2011;204:137.e1-9.

Postterm pregnancy, defined as pregnancy that extends to 42 completed weeks (42 weeks and 0 days) and beyond, is associated with significant risks to the fetus, including perinatal death, meconium staining, macrosomia, low umbilical artery pH, and low 5 minute Apgar score.[1-4] Postterm pregnancy carries additional maternal risks as well, such as increased rates of severe perineal laceration, labor dystocia, and cesarean delivery.[3] Thus, 42 weeks has been designated by the American College of Obstetricians and Gynecologists as the threshold at which the balance of benefits and risks of intervention favors induction of labor.[5] However, a recent systematic review[6] and a Cochrane review[7] suggest that induction at 41 weeks results in improved perinatal outcomes without increasing the cesarean delivery rate. Additionally, analysis of practice patterns reveals that many obstetricians induce their patients at 41 weeks.[6,8] Still, induction of labor has associated costs, and for nulliparous women, who are more likely to reach a gestational age of 41 weeks, elective induction of labor may result in an increase in rates of prolonged labor, failed induction, or cesarean delivery.[9,10]

The purpose of the current study was to use decision analysis to investigate the clinical outcomes and cost-effectiveness of elective induction of labor at 41 weeks vs expectant management with antenatal testing until 42 weeks in nulliparous women.

From the Department of Obstetrics and Gynecology (Drs Kaimal and Little), Massachusetts General Hospital, Harvard Medical School, Boston, MA; the Department of Obstetrics and Gynecology (Drs Odibo and Stamilio), Washington University in St Louis, St Louis, MO; the Department of Obstetrics and Gynecology (Dr Grobman), Feinberg School of Medicine, Northwestern University, Chicago, IL; School of Management, Yale University, New Haven, CT (Dr Long); Veterans Affairs Palo Alto Health Care System, Palo Alto, and Stanford Health Policy, Stanford University, Stanford, CA (Dr Owens); and the Department of Obstetrics and Gynecology (Dr Caughey), Oregon Health and Science University, Portland, OR.

Received April 27, 2010; revised July 3, 2010; accepted Aug. 12, 2010.

Reprints not available from the authors.

This study was supported in part by contract 290-02-0017 from the Agency for Healthcare Research and Quality, US Department of Health and Human Services. A.B.C. is supported by the Robert Wood Johnson Foundation as a Physician Faculty Scholar Grant RWJF-61535.

The views expressed herein are those of the authors, who are responsible for the content of the manuscript. Statements in the manuscript should not be construed as endorsement by the Agency for Healthcare Research and Quality or the US Department of Health and Human Services.

0002-9378/$36.00 • • doi: 10.1016/j.ajog.2010.08.012

See Journal Club, page 179

MATERIALS AND METHODS

A decision analytic model was developed with TreeAgePro 2006 software (Treeage Software Inc, Williamstown, MA) to compare elective induction of labor at 41 weeks of gestation with expectant management with antenatal testing until 42 weeks of gestation. The decision analytic model tracks a hypothetical cohort of nulliparous women with low risk, singleton, cephalic gestations, beginning at 41 weeks of pregnancy. The framework allowed us to compare the expected costs and health benefits of 2 alternative strategies (induction of labor at 41 weeks and expectant management until 42 weeks), while accounting for uncertainty in potential adverse outcomes.

We estimated the probabilities of several pregnancy- and delivery-related events as well as the risk of maternal and/or neonatal mortality and monetary costs, based on the published literature. Women undergoing expectant management could go into spontaneous labor, develop preeclampsia requiring induction of labor, or have an intrauterine fetal demise (IUFD). In addition, women undergoing expectant management were subjected to antenatal testing consisting of a nonstress test and measurement of amniotic fluid volume to assess fetal well-being. Nonreassuring antenatal status was considered as an indication for, and resulted in, labor induction. All women who reached a gestational age of 42 weeks underwent induction of labor at that time (Figure 1).

The probability of different obstetric and neonatal outcomes was modeled as a function of both approach to labor (ie, expectant management vs labor induction) and gestational age at delivery. Neonatal outcomes included the following: (1) IUFD, (2) shoulder dystocia with the possibility of brachial plexus injury or neonatal demise, and (3) meconium aspiration with the possibility of neonatal demise. Maternal outcomes included the following: (1) mode of delivery, including spontaneous vaginal delivery, operative vaginal delivery, or cesarean delivery with potential for maternal mortality as a consequence, and (2) severe perineal laceration, defined as a perineal laceration injuring the anal sphincter. The probability estimates were obtained from the published literature as well as the National Birth Cohort dataset. Baseline probabilities are displayed in Table 1.

Information regarding cesarean delivery rates was primarily obtained from the National Birth Cohort, a retrospective cohort of all term, singleton deliveries in the United States in 2003. The association between labor induction and cesarean delivery remains controversial. Whereas earlier studies have indicated that induction of labor is associated with an increased risk of cesarean delivery, more recent studies as well as metaanalyses and systematic reviews[6,7] have not supported this concept, particularly when examining women at 41 weeks' gestation and beyond. Therefore, for the baseline, an equal risk of cesarean delivery in induced patients and expectantly managed patients was assumed, but the impact of this assumption was tested in sensitivity analysis.

Cost and utility estimates were obtained from the literature. All costs were projected to 2007 U.S. dollars by inflation with the consumer price index. Costs were applied for maternal interventions as well as neonatal complications. Health benefits were measured in quality-adjusted life years (QALYs), which capture both maternal and neonatal mortality and morbidity, and were discounted to the present at an annual rate of 3% (Table 2). Maternal and neonatal life expectancy was derived from national birth/death statistics, and the associated morbidity was calculated from quality-of-life adjustments based on possible delivery complications and neonatal outcomes.

A cesarean delivery resulted in a slight decrease in maternal quality of life, which was applied during her reproductive life, assuming an average age at menopause of 50 years. In the case of a neonatal demise or IUFD, maternal utility was decreased to 0.92 per year, an estimate for women who experience a miscarriage. Because the loss is not recovered, the utility decrement was applied across the remainder of the maternal life. The effect of this assumption was examined in sensitivity analysis. There are no data available with regard to the reduction in the quality of life for neonatal complications such as meconium aspiration or shoulder dystocia; therefore, in the calculation of neonatal QALYs, a utility of 1 was applied for survival, and a utility of 0 was applied for demise.

Analysis consisted first of examining the rates of clinical outcomes that would occur in the 2 arms: elective induction of labor at 41 weeks of gestation or expectant management until 42 weeks of gestation. Next, we estimated the total costs and QALYs for each strategy and determined the incremental cost-effectiveness ratio of elective induction of labor at 41 weeks of gestation from a societal perspective. We performed deterministic 1-way and multiway sensitivity analyses to identify key parameters and examine the robustness of the findings. We also performed probabilistic sensitivity analysis (via a Monte Carlo simulation) by simultaneously sampling each model parameter from an appropriate probability distribution to test the model's robustness to simultaneous multivariable changes.

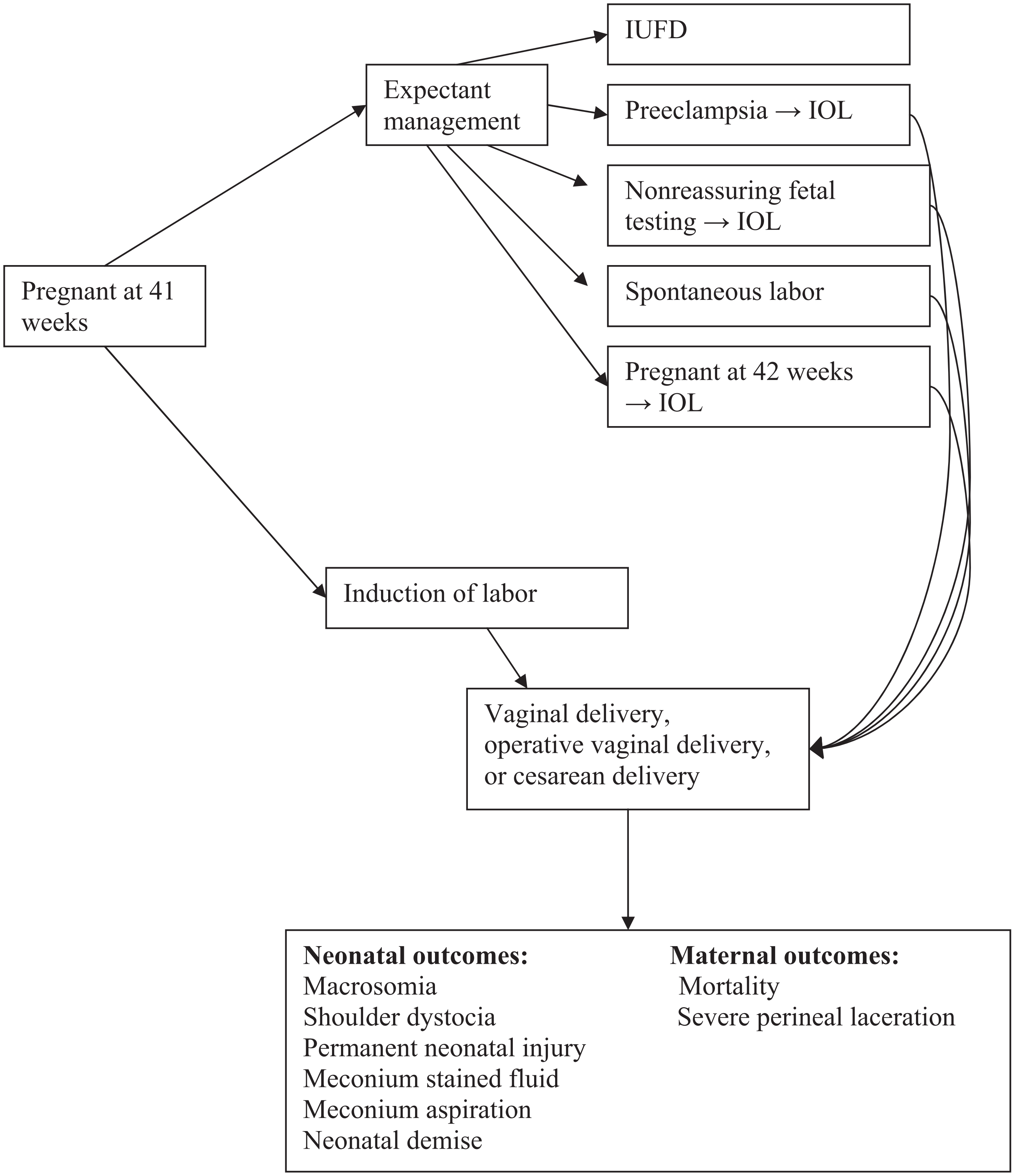
RESULTS

Given the 4.1 million live births in the United States in 2005,[11] we estimated that approximately 200,000 nulliparous women remain undelivered at a gestational age of 41 weeks. Among this cohort, induction of labor at 41 weeks compared with expectant management until 42 weeks results in a lower rate of all adverse obstetric outcomes, including perinatal demise, shoulder dystocia, meconium aspiration syndrome, and severe perineal lacerations (Table 3). In particular, there were 4 perinatal demises in the induction group vs 208 in the expectant management group, 2620 shoulder dystocias in comparison with 3090, and 1598 cases of meconium aspiration in comparison with 3548 in the expectant management group.

With regard to health effectiveness, induction of labor at 41 weeks is superior to expectant management until 42 weeks, with a total of 11,382,025 QALYs for induction of labor at 41 weeks vs 11,375,460 QALYS for expectant management per 200,000 women. This results in an incremental gain of 6565 QALYs for this theoretical cohort of 200,000 women, equivalent to approximately 12.0 additional quality-adjusted days per woman.

Induction of labor at 41 weeks is also more expensive as compared with expectant management: $2,319,260,799 vs $2,247,401,242, an additional cost of $71,859,557. Thus, the incremental cost-effectiveness ratio for induction of labor is $10,945 per QALY. While the optimal threshold for cost-effectiveness in the United States is a matter of debate,[12,13] the range of cost-effectiveness thresholds is commonly set at $50,000-100,000 per QALY.[14] Thus, under baseline assumptions, induction of labor at 41 weeks is a cost-effective intervention.

FIGURE 1
Schematic of decision tree



IOL, induction of labor; *IUFD*, intrauterine fetal demise.

Kaimal. Elective induction of labor at 41 weeks. Am J Obstet Gynecol 2011.

TABLE 1
Probability estimates

Variable	Baseline	Low	High	Reference
Probability of cesarean delivery				
Induction of labor	0.27	0.135	0.405	US Birth Cohort, 2003
Spontaneous labor	0.217	0.108	0.325	US Birth Cohort, 2003
RR for cesarean delivery for expectant management vs IOL at 41 wks	1.0	0.7	1.50	Gulmezoglu et al, 2006[6]
Probability of spontaneous labor at 41 wks	0.52	0.26	0.78	Alexander et al, 2001[21]
Probability of IUFD at 41 wks	0.0012	0.0006	0.0018	Smith, 2001[22]
Probability of operative vaginal delivery				
42 wks	0.174	0.087	0.261	Caughey et al, 2007[23]
41 wks	0.133	0.0665	0.1995	Caughey et al, 2007[23]
Probability of epidural				
Induction of labor	0.8143	0.7198	1.0	UCSF
Spontaneous labor	0.7198	0.6	1.0	UCSF
Probability of macrosomia				
42 wks	0.15	0.075	0.225	Alexander et al, 2000[1]
41 wks	0.12	0.06	0.18	Alexander et al, 2000[1]
RR for cesarean delivery with macrosomia	1.52	0.81	2.43	Boulet et al, 2003[24]; Sanchez-Ramos et al, 2003[25]
Probability of shoulder dystocia				
Without macrosomia	0.0065	0.00325	0.00975	Nesbitt et al, 1998[26]; Rouse et al, 1996[27]
With macrosomia	0.1	0.05	0.15	Nesbitt et al, 1998[26]
RR for shoulder dystocia with operative vaginal delivery	1.74	0.95	2.85	Nesbitt et al, 1998[26]
Probability of shoulder dystocia causing				
Permanent injury	0.067	0.0335	0.1005	Rouse et al, 1996[27]
Neonatal demise	0.001	0.0005	0.0015	Nesbitt et al, 1998[26]
Probability of meconium-stained fluid				
42 wks	0.277	0.1385	0.4155	Sanchez-Ramos et al, 2003[25]
41 wks	0.224	0.112	0.336	Sanchez-Ramos et al, 2003[25]
Probability of meconium aspiration syndrome				
42 wks	0.032	0.016	0.048	Gulmezoglu et al, 2006[6]
41 wks	0.008	0.004	0.012	Gulmezoglu et al, 2006[6]
Probability of meconium aspiration syndrome causing neonatal demise	0.00025	0.000125	0.000375	Dargaville and Copnell, 2006[28]
Probability of positive NST at 41 wks	0.14	0.07	0.21	Bochner, 1988[29]
Probability of severe perineal laceration				
42 wks, vaginal delivery	0.051	0.0255	0.0765	Caughey et al, 2007[23]
42 wks, operative vaginal delivery	0.282	0.141	0.423	Caughey et al, 2007[23]
41 wks, vaginal delivery	0.036	0.018	0.054	Caughey et al, 2007[23]
41 wks, operative vaginal delivery	0.26	0.13	0.39	Caughey et al, 2007[23]

Kaimal. Elective induction of labor at 41 weeks. Am J Obstet Gynecol 2011.

(continued)

TABLE 1
Probability estimates *(continued)*

Variable	Baseline	Low	High	Reference
Probability of preeclampsia				
42 wks	0.012	0.006	0.018	Caughey et al, 2003[30]
41 wks	0.012	0.006	0.018	Caughey et al, 2003[30]
Probability of maternal mortality				
Cesarean delivery	0.00035	0.000175	0.000525	Harper et al, 2003[31]
Vaginal delivery	0.000092	0.000046	0.000138	Harper et al, 2003[31]

IOL, induction of labor; *IUFD*, intrauterine fetal demise; *NST*, nonstress test; *RR*, relative risk; *UCSF*, University of California, San Francisco.

Kaimal. Elective induction of labor at 41 weeks. Am J Obstet Gynecol 2011.

One of the key and potentially controversial assumptions in the model is that induction of labor leads to an equal cesarean delivery rate as compared with expectant management. To fully appreciate the impact of this assumption on model outcomes, we ran the model under 3 separate assumptions: (1) cesarean delivery rates are equal in the induction as compared with expectant management group (our baseline assumption), (2) cesarean delivery rates are 22% less in the induction as compared with the expectant management group,[7] and (3) cesarean delivery rates are 22% more in the induction as compared with the expectant management group. The alternate scenarios utilized a 22% change because that is the difference noted in a recent systematic review of elective induction of labor.[7]

The cesarean delivery rate has only a marginal impact on cost-effectiveness results. In our baseline model, induction of labor leads to an incremental gain of 6565 QALYs. If induction of labor is associated with a 22% decrease in the cesarean delivery rate, this strategy further improves health benefits and results in an incremental gain of 8864 QALYs with induction of labor. Conversely, if patients who undergo induced labor incur a 22% increase in the cesarean delivery rate, then the health benefits associated with labor induction are slightly attenuated; however, this strategy still results in a gain of 4267 QALYs compared with expectant management.

As for cost-effectiveness, under all 3 assumptions, induction of labor at 41 weeks is a cost-effective strategy compared with expectant management, with results ranging from $2932 to $27,612 per QALY gained. In fact, assuming a willingness to pay of $100,000 per QALY gained, induction remains cost effective until the cesarean rate associated with induction reaches 40%, a 47% increase

TABLE 2
Utility and cost estimates

Variable	Baseline	Low	High	Reference
Utility of cesarean delivery	0.99	0.9	1.0	Caughey et al, 2006[32]
Utility of IUFD	0.92	0.6	1.0	Kuppermann et al, 2000[33]
Utility of vaginal delivery	1.00			Assumed
Discount rate	0.03	0	0.06	Assumed
Maternal life expectancy	56	28	84	US Mortality Data 2003
Neonatal life expectancy	77	30	100	US Mortality Data 2003
Cost of antenatal testing	210	105	840	Goeree et al, 1995[34]
Cost of cesarean delivery	11,092	5546	44,368	Bost, 2003[35]
Cost of epidural	788	394	3152	Bost, 2003[35]
Additional cost of induction	1237	618	4948	Bost, 2003[35]
Cost of vaginal delivery	7213	3606	28,852	Bost, 2003[35]
Cost of uncomplicated newborn stay	1440	770	5760	Gilbert et al, 2003[36]
Cost of complicated newborn stay	2213	1106	8852	Phibbs and Schmitt, 2006[37]
Cost of neonatal demise	76,260	38,130	305,040	Phibbs and Schmitt, 2006[37]

IUFD, intrauterine fetal demise.

Kaimal. Elective induction of labor at 41 weeks. Am J Obstet Gynecol 2011.

TABLE 3
Outcomes for 200,000 nulliparous women for induction of labor at 41 weeks vs expectant management until 42 weeks

Outcome	Induction of labor at 41 wks	Expectant management at 41 wks
Cesarean delivery	54,000	54,000
Perinatal demise	4	208
Shoulder dystocia	2620	3090
Meconium aspiration syndrome	1598	3548
Severe perineal lacerations	11,220	12,880
Cost	$2,319,260,799	$2,247,401,242
QALYs	11,382,025	11,375,460
Incremental cost-effectiveness	$10,945/QALY	—

QALYs, quality-adjusted life years.

Kaimal. Elective induction of labor at 41 weeks. Am J Obstet Gynecol 2011.

from the baseline estimate of 27% (Figure 2).

In additional univariate sensitivity analysis, the model remained robust to a wide variety of inputs. If the rate of spontaneous labor between 41 and 42 weeks is 25% or less, induction of labor at 41 weeks is the dominant option, meaning that it both decreases costs and increases QALYs. Induction of labor remains cost-effective as long as the probability of spontaneous labor is less than 99%, a 2-fold increase over our baseline estimate.

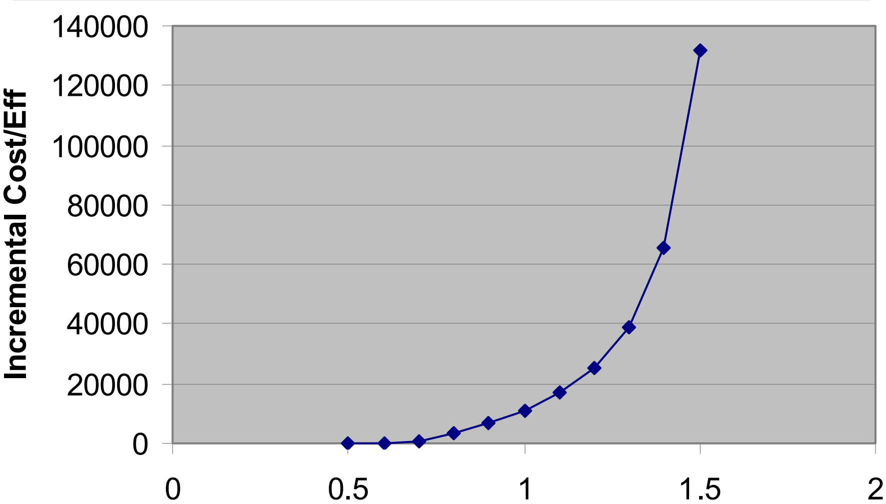
In terms of the utility inputs, even if no decrement in maternal utility was assigned for women who experience IUFD or neonatal demise, induction remained cost effective. The model was also robust to changes in cost inputs. If the cost of labor induction increases to $5000 per procedure (compared with our baseline estimate of $1,237), the cost-effectiveness of labor induction vs expectant management decreases to $61,430 per QALY gained.

Two-way sensitivity analysis was also performed to examine the effect of simultaneously varying 2 inputs. First, we investigated the impact of varying the probability of spontaneous labor within the next week along with the relative risk of cesarean delivery with induction of labor. Clinically, the determinants of successful induction may be similar to the predictors of spontaneous labor in the following week. Sensitivity analysis shows that even when the likelihood of spontaneous labor approaches 100%, if there is less than a 35% increase in the rate of cesarean with induction of labor, induction remains cost effective. For women with a below-average likelihood of spontaneous labor (<52%), induction remains cost-effective even if it results in more than a 50% increase in the likelihood of cesarean delivery. In this same group, induction remains cost-effective even if cost increases to 400% of baseline, or an additional $5000 per induction.

Probabilistic sensitivity analysis, or Monte Carlo simulation, was performed to test the robustness to uncertainty in multiple input variables simultaneously. In this method, for each simulation, or walk through the model, each variable has a value that is picked from a prespecified distribution; this is repeated over and over and the distribution of results obtained is examined. We found that in 24% of the simulation trials induction of labor at 41 weeks was cost saving (ie, this strategy was dominant because it was less expensive and more effective). In all remaining trials it was more effective but also more expensive.

Figure 3 shows the acceptability curve, which illustrates the proportion of Monte Carlo simulation trials in which each strategy is cost effective at various willingness-to-pay thresholds. Using a willingness-to-pay threshold of $100,000, induction of labor at 41 weeks is cost effective in 98.3% of the trials. At a willingness to pay of $50,000, it is cost effective in 96.2% of trials. In other words, if we, as a society, are willing to pay at least $50,000 for 1 additional QALY, then induction of labor at 41 weeks would be a cost-effective intervention 96% of the time.

FIGURE 2
Sensitivity analysis of relative risk of cesarean with induction

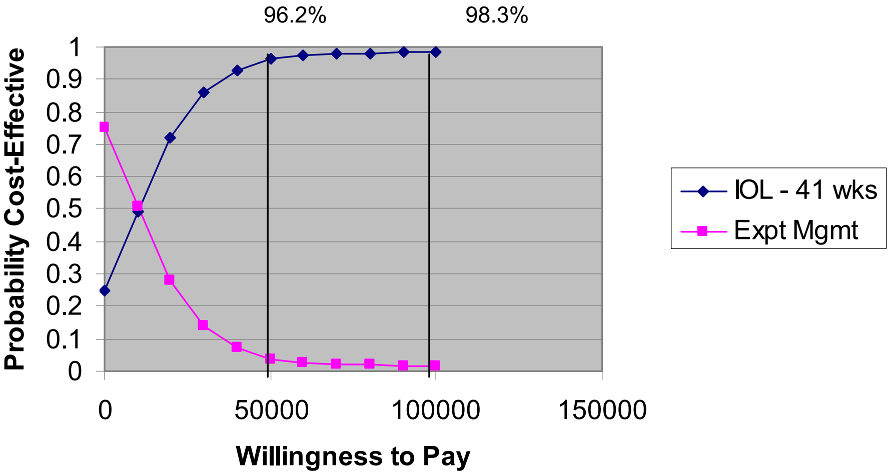


Kaimal. Elective induction of labor at 41 weeks. Am J Obstet Gynecol 2011.

COMMENT

Among a theoretical cohort of nulliparous women at 41 weeks' gestation, induction of labor improves maternal and

FIGURE 3
Monte Carlo simulation acceptability curve



IOL, induction of labor.

Kaimal. Elective induction of labor at 41 weeks. Am J Obstet Gynecol 2011.

neonatal outcomes. Induction of labor is a cost-effective strategy in more than 98% of scenarios if we are willing to pay $100,000 per QALY gained and in 96% of scenarios if $50,000 per QALY is defined as the threshold. The improvement in neonatal outcomes is expected because the outcomes examined (IUFD, shoulder dystocia, meconium aspiration syndrome) are known to increase with gestational age. Since induction of labor at term will always lead to a lower gestational age at delivery, this option will necessarily lead to reductions in these outcomes. Furthermore, when considering maternal outcomes, if a woman undergoes induction of labor, she is no longer at risk for the pregnancy complications associated with continuing gestation, such as preeclampsia. Therefore, these complications will also be reduced. These changes in outcomes are both intuitive and clinically relevant when comparing induction of labor to expectant management of pregnancy.

Although some clinical outcomes will likely be improved with a policy of induction of labor, the most concerning potential disadvantages of induction are an increased risk of cesarean delivery and an increase in costs associated with induction of labor. For the cohort considered here, women at 41 weeks, there is good evidence summarized in 2 recent systematic reviews of the literature that induction of labor does not increase the risk of cesarean delivery.[6,7] In fact, the data from 1 of these reviews,[7] a prior retrospective study,[15] a prospective study,[16] and the National Birth Cohort suggests that undergoing induction may confer a decreased risk of cesarean delivery when compared with expectant management at 41 weeks. However, because of the general controversy over the effect of elective induction of labor on cesarean delivery rates,[17] we examined all possibilities: an equal cesarean rate in women who are induced and those who are expectantly managed, a higher cesarean rate with induction, and a lower cesarean rate with induction.

Importantly, even if women undergoing induction of labor incur an increased risk of cesarean delivery, induction remains a cost-effective intervention until it leads to a cesarean rate 1.5 times the rate in the expectant management group (Figure 2). This is particularly relevant given the ongoing rise in the cesarean rate; 2003 cesarean rates were used in this study because of the availability of the National Birth Cohort data for calculating rates, but even with continued elevations, induction would be expected to remain cost-effective.

In a sensitivity analysis, examining the situations in which induction of labor becomes more effective as well as less expensive (dominant) defines a group that may benefit most from induction of labor at 41 weeks. Induction became a dominant strategy when the likelihood of spontaneous labor dropped below 25%. Women with a low likelihood of spontaneous labor, such as those with a low Bishop score, may also have a lower likelihood of successful induction, and additional costs may be incurred as the induction process may be prolonged. For these reasons, these women traditionally have been viewed as poor candidates for induction of labor. However, this is also the population that may benefit the most from this intervention because without induction, they are highly likely to remain pregnant for the next week, in many cases without significant cervical change, and thus potentially incur the negative outcomes associated with advancing gestational age in addition to those associated with induction of labor with an unfavorable cervix.

Based on this analysis, elective induction of labor at 41 weeks of gestation appears to be a cost-effective intervention. However, prior to implementing this policy, we must consider the additional factors that may influence our ability to achieve this outcome in the broader clinical context. For example, the chance of cesarean will be minimized during an induction of labor only if physicians allow adequate time for an induction to proceed. Clinicians who are responsible for simultaneous provision of intrapartum and outpatient obstetric care may experience both economic and time pressures to minimize the length of labor. This may be particularly problematic when allowing additional time in labor may help achieve a vaginal delivery. For example, several studies have shown that extending the time limit for the diagnosis of active phase arrest from 2 to 4 hours can result in vaginal deliveries in up to 60% of women initially receiving this diagnosis.[18,19] With regard to induction of labor in particular, Simon and Grobman[20] reported that when clinicians extended the definition of prolonged latent phase in the setting of induction of labor to 18 hours, one would achieve vaginal delivery in more than 60% of women being induced, and when such a threshold was extended beyond 24 hours, another third of these women would deliver vaginally.

As a result, as with all research findings, the question of whether elective induction of labor at 41 weeks is supported as a reasonable intervention is inextricably tied to how it will actually be implemented throughout all medical settings. Because many of the maternal outcomes are tied to the risk of cesarean delivery, there might be an increase in a number of patient complications if the cesarean rate actually rises with implementation of this policy. Furthermore, the long-term impact of a rising cesarean delivery rate may be revealed only in subsequent pregnancies, which were not included in the current model.

Model-based analyses of medical interventions have inherent limitations. No model is able to fully capture the complexity of a clinical situation or include all of the factors that a clinician integrates. Although we attempted to approximate the true clinical picture, we did not include every possible maternal and neonatal outcome. Rather, we incorporated a number of the more severe outcomes, specifically those that may be impacted by elective induction of labor, advancing gestational age, and mode of delivery.

We utilized the existing literature to obtain point estimates of the probabilities of outcomes to populate the model, and many of these studies may be underpowered or have biased results. However, through sensitivity analysis and Monte Carlo simulation, we were able to consider a wide range of values around our point estimates to estimate the impact of this uncertainty.

Furthermore, because of the paucity of published quality-of-life data on maternal preferences regarding induction of labor or complications such as preeclampsia, utilities could not be applied for many outcomes, and those that were applied were generalized from published literature regarding maternal preferences toward pregnancy loss. However, our results were robust to variation in utility inputs as well, which were important to include to incorporate outcomes other than perinatal mortality into the effectiveness considerations of the model. Nonetheless, additional preference data for specific outcomes related to induction of labor would allow for a more nuanced analysis because women's preferences for the process and outcomes of induction of labor may have a significant impact on patient satisfaction and cost-effectiveness.

Furthermore, the existing cost data utilized for the cost-effectiveness analysis is limited in that much of it was obtained more than 10 years ago, and it must be generalized from studies conducted in different clinical situations from this study. Although we conducted sensitivity analyses over wide ranges of these cost inputs, better cost data in this area would certainly facilitate more accurate estimates of the cost-effectiveness of elective induction of labor. Finally, this analysis considers only nulliparous women with low-risk pregnancies. In other populations, the effects may be magnified or attenuated.

While we acknowledge that no model is able to fully capture the complexity of a clinical situation or include all of the factors that a clinician integrates, decision analysis provides another perspective on the information currently available regarding the benefit of elective induction of labor at 41 weeks. Examining a theoretical cohort of women at 41 weeks' gestation and incorporating estimates of the uncertainty in our assumptions, we found that induction of labor is a cost-effective intervention that improves maternal and neonatal outcomes. However, if a strategy of elective induction of labor at 41 weeks is advocated, the avoidance of cesarean deliveries for failed inductions is critical; therefore, the heterogeneity in practice patterns and the definition of a failed induction must be carefully considered prior to adopting and after implementing this policy. ■

REFERENCES

1. Alexander JM, McIntire DD, Leveno KJ. Forty weeks and beyond: pregnancy outcomes by week of gestation. Obstet Gynecol 2000;96:291-4.
2. Caughey, AB, Washington AE, Laros RK. Neonatal complications of term pregnancy: rates by gestational age increase in a continuous, not threshold, fashion. Am J Obstet Gynecol 2005;192:185-90.
3. Cheng YW, Nicholson JM, Nakagawa S, Bruckner TA, Washington AE, Caughey AB. Perinatal outcomes in low-risk term pregnancies: do they differ by week of gestation? Am J Obstet Gynecol 2008;199:370.e1-7.
4. Bruckner TA, Cheng YW, Caughey AB. Increased neonatal mortality among normal-weight births beyond 41 weeks of gestation in California. Am J Obstet Gynecol 2008;199:421.e1-7.
5. American College of Obstetricians and Gynecologists. Clinical management guidelines for obstetricians gynecologists. ACOG practice bulletin no. 55: management of postterm pregnancy. September 2004, reaffirmed 2009 (replaces practice pattern number 6, October 1997). Obstet Gynecol 2004;104:639-46.
6. Gulmezoglu AM, Crowther CA, Middleton P. Induction of labour for improving birth outcomes for women at or beyond term. Cochrane Database Syst Rev 2006:CD004945.
7. Caughey AB, Sundaram V, Kaimal AJ, et al. Systematic review: elective induction of labor versus expectant management of pregnancy. Ann Intern Med 2009;151:252-63.
8. Cleary-Goldman J, Bettes B, Robinson JN, Norwitz E, D'Alton ME, Schulkin J. Postterm pregnancy: practice patterns of contemporary obstetricians and gynecologists. Am J Perinatol 2006;23:15-20.
9. Heffner LJ, Elkin E, Fretts RC. Impact of labor induction, gestational age, and maternal age on cesarean delivery rates. Obstet Gynecol 2003;102:287-93.
10. Vahratian A, Zhang J, Troendle JF, Sciscione AC, Hoffman MK. Labor progression and risk of cesarean delivery in electively induced nulliparas. Obstet Gynecol 2005;105:698-704.
11. Martin JA, Hamilton BE, Sutton PD, et al. Births: final data for 2005. National vital statistics reports, vol 56, no 6. Hyattsville, MD: National Center for Health Statistics; 2007.
12. Owens DK. Interpretation of cost-effectiveness analyses. J Gen Intern Med 1998;13:716-7.
13. Gold MR, Siegel JE, Russell LB, Weinstein MC. Cost-effectiveness in health and medicine. New York: Oxford University Press; 1996.
14. Caughey AB, Nicholson JM, Cheng YW, Lyell DJ, Washington AE. Induction of labor and cesarean delivery by gestational age. Am J Obstet Gynecol 2006;195:700-5.
15. Nicholson JM, Stenson MH, Kellar LC, Caughey AB, Macones GA. Active management of risk in nulliparous pregnancy at term: association between a higher preventive labor induction rate and improved birth outcomes. Am J Obstet Gynecol 2009;200:254.e1-13.
16. Hannah ME, Hannah WJ, Hellman J, Hewson S, Milner R, Willan A. Induction of labor as compared with serial antenatal monitoring in post-term pregnancy. A randomized controlled trial. The Canadian MultiCenter Post-Term Pregnancy Trial Group. N Engl J Med 1992;326:1587-92.

17. Grobman W. Elective induction: when? ever? Clin Obstet Gynecol 2007;50:537-46.
18. Rouse DJ, Owen J, Savage KG, Hauth JC. Active phase labor arrest: revisiting the 2-hour minimum. Obstet Gynecol 2001;98:550-4.
19. Henry DE, Cheng YC, Shaffer BL, Kaimal AJ, Bianco K, Caughey AB. Perinatal outcomes in the setting of active phase arrest of labor. Obstet Gynecol, 2008;112:1109-15.
20. Simon CE, Grobman WA. When has an induction failed? Obstet Gynecol 2005;105: 705-9.
21. Alexander JM, McIntyre DD, Leveno KJ. Prolonged pregnancy: induction of labor and cesarean births. Obstet Gynecol 2001;97: 911-5.
22. Smith GC. Life-table analysis of the risk of perinatal death at term and post term in singleton pregnancies. Am J Obstet Gynecol 2001; 184:489-96.
23. Caughey AB, Stotland NE, Washington AE, Escobar GJ. Maternal and obstetric complications of pregnancy are associated with increasing gestational age at term. Am J Obstet Gynecol 2007;196:155.e1-6.
24. Boulet SL, Alexander GR, Salihu HM, Pass M. Macrosomic births in the United States: determinants, outcomes, and proposed grades of risk. Am J Obstet Gynecol 2003;188:1372-8.
25. Sanchez-Ramos L, Olivier F, Delke I, Kaunitz AM. Labor induction versus expectant management for postterm pregnancies: a systematic review with meta-analysis. Obstet Gynecol 2003;101:1312-8.
26. Nesbitt TS, Gilbert WM, Herrchen B. Shoulder dystocia and associated risk factors with macrosomic infants born in California. Am J Obstet Gynecol 1998;179:476-80.
27. Rouse DJ, Owen J, Goldenberg RL, Cliver SP. The effectiveness and costs of elective cesarean delivery for fetal macrosomia diagnosed by ultrasound. JAMA 1996;276:1480-6.
28. Dargaville PA, Copnell B. The epidemiology of meconium aspiration syndrome: incidence, risk factors, therapies, and outcome. Pediatrics 2006;117:1712-21.
29. Bochner CJ, Williams J 3rd, Castro L, Medearis A, Hobel CJ, Wade M. The efficacy of starting postterm antenatal testing at 41 weeks as compared with 42 weeks of gestational age. Am J Obstet Gynecol 1988;159:550-4.
30. Caughey AB, Stotland NE, Escobar GJ. What is the best measure of maternal complications of term pregnancy: ongoing pregnancies or pregnancies delivered? Am J Obstet Gynecol 2003;189:1047-52.
31. Harper MA, Byington RP, Espeland MA, Naughton M, Meyer R, Lane K. Pregnancy-related death and health care services. Obstet Gynecol 2003;102:273-8.
32. Caughey AB, Angeja A, Vargas J, Gomez R, Washington AE. Quantitative evaluation of preference for mode of delivery in pregnant Chilean women. Med Decis Making 2003;23:634.
33. Kuppermann M, Nease RF, Learman LA, Gates E, Blumberg B, Washington AE. Procedure-related miscarriages and Down syndrome-affected births: implications for prenatal testing based on women's preferences. Obstet Gynecol 2000;96:511-6.
34. Goeree R, Hannah M, Hewson S. Cost-effectiveness of induction of labour versus serial antenatal monitoring in the Canadian Multicentre Postterm Pregnancy Trial. CMAJ 1995;152: 1445-50.
35. Bost BW. Cesarean delivery on demand: what will it cost? Am J Obstet Gynecol 2003; 188:1418-21; discussion 1421-3.
36. Gilbert WM, Nesbitt TS, Danielsen B. The cost of prematurity: quantification by gestational age and birthweight. Obstet Gynecol 2003:102:488-92.
37. Phibbs CS, Schmitt SK. Estimates of the cost and length of stay changes that can be attributed to one week increases in the gestational age for premature infants. Early Hum Dev 2006:82:85-95.