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A Decision Analysis Model of One-Year Effectiveness of Intended Postplacental Compared With Intended Delayed Postpartum Intrauterine Devices

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Abstract

Objective: To compare, using decision analysis methodology, the one-year probability of pregnancy after intended postplacental intrauterine device (IUD) insertion with intended delayed insertion at an outpatient postpartum visit (delayed postpartum placement).

Methods: We developed an evidence-based decision model with the primary outcome of one-year probability of pregnancy. We compared one-year probability of pregnancy following intended postplacental or intended delayed postpartum IUD placement. We obtained estimates from the literature for the proportions of the following: mode of delivery, successful IUD placement, IUD type, postpartum visit attendance, IUD expulsion, IUD discontinuation, and contraceptive use, choice, and efficacy after IUD discontinuation. We performed sensitivity analyses and a Monte Carlo simulation to account for variations in proportion estimates.

Results: One-year probabilities of pregnancy among a theoretical cohort of 2,500,000 women intending to receive a postplacental IUD following vaginal birth and 1,250,000 women intending to receive a postplacental IUD following Cesarean birth were 17.3% and 11.2% respectively; the one-year probability of pregnancy among a theoretical cohort of 2,500,000 women intending to receive a delayed postpartum IUD was 24.6%. For delayed postpartum IUD placement to have effectiveness equal to postplacental placement, 91.4% of women delivering vaginally and 99.7% of women delivering by Cesarean would need to attend postpartum care. Once placed, the effectiveness of postplacental IUDs was lower than that of delayed postpartum IUDs: one-year probabilities of pregnancy following IUD placement at a vaginal birth, Cesarean birth, and an outpatient postpartum visit were 15.4%, 6.6%, and 3.9%, respectively.

Discussion: After accounting for factors that affect successful IUD placement and retention, this decision model indicates that intended postplacental IUD insertion results in a lower one-year probability of pregnancy as compared to intended delayed postpartum IUD insertion.

Précis:

Decision analysis methodology indicates that intended postplacental intrauterine devices have higher effectiveness at one year than intended delayed postpartum intrauterine devices.

Introduction:

Following a live birth, the World Health Organization recommends a minimum of 24 months before attempting a subsequent pregnancy¹. Initiation of long-acting reversible contraception (LARC) at the time of delivery decreases rapid repeat births^{2,3}, and immediate postplacental placement of an intrauterine device (IUD) is safe^{4,5} and cost-effective⁶.

Intrauterine devices (IUDs) have failure rates of 0.2–0.8 pregnancies/100 woman-years with perfect use⁷, but these rates do not account for IUD discontinuation or expulsion. Although postplacental IUD placement ensures that women leave the hospital with contraception, it also results in a higher proportion of IUD expulsions, with rates ranging from 5.8–24%^{8–15}, as compared to 2.9–3.5%^{10,13,14,16–25} after delayed postpartum IUD placement (at an outpatient postpartum visit)^{4,5,14,26,27}. Higher expulsion rates may in turn result in decreased contraceptive efficacy. The proportion of women who attend a postpartum visit ranges from 65–90%^{13,18,25,26,28–30}, and the proportion of women intending IUD placement at this visit who actually receive an IUD varies from 22.6–100%^{13,28,29}. Actual placement of an intended IUD is of course critical to its effectiveness. The term “effectiveness” refers to how well a method works in actual practice, as opposed to “efficacy,” which refers to how well a method works in clinical trials³¹.

Our objective was to use computational decision analysis to model the effectiveness of immediate and delayed postpartum IUD placement. We compared the one-year probabilities of pregnancy after intended postplacental IUD insertion after vaginal or Cesarean birth with intended delayed postpartum insertion, incorporating factors that influence successful device placement and retention.

Materials and Methods:

We used a Monte Carlo computational decision model to evaluate one-year probability of pregnancy in two groups: women intending postplacental IUD placement within 10 minutes of placental delivery, and those intending delayed postpartum IUD placement. The Monte Carlo simulation method accounts for the probability distribution of outcomes with inherent uncertainty, using decision trees (Figures 1 and 2). We chose to compare intended IUD placement rather than actual IUD placement to model the common clinical and life circumstances that limit access to IUDs in both populations. Probability of pregnancy in our model was considered to be the inverse of IUD effectiveness, and we chose a one-year endpoint so that our effectiveness estimates could be compared with established one-year

estimates of contraceptive efficacy. We built and analyzed our model using TreeAge Pro modeling software (Williamstown, MA, 2017).

Prior to creating our model, we made an *a priori* selection of the following factors that we hypothesized would affect IUD effectiveness after postplacental or delayed placement: mode of delivery, successful IUD placement, IUD type, postpartum visit attendance, IUD expulsion, detection of expulsion, partial expulsion, IUD discontinuation, and contraceptive use, choice, and efficacy after IUD discontinuation. We included estimates of contraceptive discontinuation and switching into our effectiveness model in order to simulate the common experiences of women who have IUD expulsion or choose to discontinue a method, to provide a realistic estimate of pregnancy probability. Although we did not include estimates of intrapartum events that would affect eligibility for a postplacental IUD, we included an estimate of the proportion of intended postplacental IUDs that were actually placed; non-placement was due to factors such as withdrawal of consent, infection, precipitous birth, and hemorrhage³².

To identify probability estimates for each event in the model, we conducted a literature review using PubMed and a combination of the following search terms: “IUD”, “intrauterine device”, “contraception failure”, “copper”, “postpartum IUD”, “postplacental”, “levonorgestrel”, “Cesarean delivery”, “vaginal delivery”, “continuation”, “discontinuation”, and “expulsion”. In addition, we reviewed the references of relevant articles for additional sources. For each event, two authors (T.H., S.S.) reviewed each article and selected the most likely probability, called the “base case value,” from the trial that was methodologically superior, based on robustness of study design and sample size. Randomized controlled trials and prospective cohort studies were selected when possible. For studies that followed participants for less than one year, values for each of the estimates were carried forward and assumed to be one-year estimates.

Base case values were selected for the one-year probabilities and ranges of complete and partial IUD expulsion, detection of expulsion, and elective discontinuation of IUDs, after postplacental or delayed placement. When data were available, we incorporated likely differences in outcomes of copper versus levonorgestrel IUDs, and vaginal versus Cesarean deliveries. The model also incorporated evidence-based probabilities of choosing a copper versus a levonorgestrel IUD. In addition, for the delayed postpartum model, we selected base case values for the proportion of women who return for a postpartum visit, and for the proportion of women initially desiring a delayed postpartum IUD who actually receive it.

We constructed three decision trees as maps of the possible outcomes after 1) intended postplacental IUD placement after vaginal birth, 2) intended postplacental IUD placement after Cesarean birth, and 3) intended delayed postpartum IUD placement. Each branch point is called a “node,” and the outcomes of each node incorporate the base case probabilities determined from the literature (Figures 1 and 2). At every node in the model where a patient lacked a contraceptive method, we assumed she would restart the contraception selection process, except in the case of undetected IUD expulsion. We modeled this process by first estimating the probability that the patient would use contraception^{12,33}, and then estimating the proportion of women who would select long acting reversible contraception (LARC)

compared with any other reversible method. Annual effectiveness rates were selected for different forms of contraception^{7,34,35}.

Our simulation models computed the mean effectiveness of postplacental and delayed postpartum IUD insertion in the base case scenario (Scenario 1). Our models used a theoretical cohort of 2,500,000 women for the delayed postpartum and vaginal postplacental models, and 1,250,000 women for the Cesarean model³⁶.

In order to determine variation around the mean effectiveness, we performed one-way deterministic sensitivity analysis for all probabilities with uncertainty. Deterministic sensitivity assesses how changes in the model inputs affect model outputs, varying a single parameter at a time across its range. Probabilities of contraceptive failure for individual methods have precise estimates from the literature, so the highest reasonable and lowest reasonable values for method failure were estimated only for use of no contraceptive method and the partially expelled IUD. Probabilities were varied individually from the lowest to the highest reasonable value identified from our literature review, to identify which variables had the largest effect on the difference in contraceptive outcome between intended delayed postpartum or postplacental insertion. To further explore the influence of the probability of a woman returning for her routine interval postpartum visit, this probability was varied from 0.0% to 100.0%. This allowed us to identify the threshold proportion of women returning for a postpartum visit at which a postplacental IUD and a delayed postpartum IUD would have the same expected effectiveness.

We then performed probabilistic sensitivity analysis using a hypothetical sample of 10,000 cycles to account for uncertainty in the true value of our events, and to simulate the effect of adjusting for a range of parameters simultaneously. We created beta distributions for all probabilities with uncertainty by setting the highest reasonable value and lowest reasonable value as the upper and lower bounds of the 95% confidence interval, and the base case value as the mean. These distributions were used to randomly sample all probabilities in the model simultaneously, to determine the proportion of the 10,000 scenarios in which intended postplacental IUD placement had higher effectiveness than delayed postpartum insertion. We varied all probabilities in the model in this fashion with the exception of the effectiveness of each contraceptive method, for which estimates are precise.

Finally, the probabilities representing the return to clinic rate, postplacental IUD placement rate, and delayed postpartum IUD placement rate were manipulated and the model was run again to evaluate two additional clinical scenarios. In Scenario 2, we assessed the effectiveness of delayed postpartum versus postplacental IUDs if all patients were to return for a clinic follow-up visit, and thus set the probability of a patient returning to clinic at 100.0% in both the vaginal and Cesarean models. This scenario provided an estimate of IUD effectiveness in a practice with very high rates of postpartum follow-up. Scenario 3 offered an individual-level estimate of contraceptive effectiveness for women who have an IUD inserted immediately postpartum or at a postpartum visit, incorporating the probabilities of discontinuation and expulsion. In this scenario, the probability of a patient returning to clinic, the probability of delayed insertion, and the probability of immediate insertion were all set at 100.0%. All other values remained at their baseline values. This scenario provided

an estimate of the maximum contraceptive efficacy an individual IUD user could expect, assuming she encountered no external barriers to IUD placement.

As this study utilized data solely from previously published work with no identifiable patient information, the University of Pennsylvania Institutional Review Board deemed it to be non-human subjects research, and approval was not required.

Results:

The base case and range values for each node in our decision tree were determined from our literature search (Table 1). Based on these values, our decision model predicted that among a theoretical cohort of 2,500,000 women intending to receive a postplacental IUD following vaginal birth, 1,250,000 women intending a postplacental IUD after Cesarean birth, and 2,500,000 women intending a delayed postpartum IUD, 17.3%, 11.2%, and 24.6%, respectively, would become pregnant by one year after birth (Table 2). In our model, most women intending postplacental vaginal, postplacental Cesarean, and delayed postpartum IUD placement were using some form of contraception at one year postpartum. Women who intended to use a delayed postpartum IUD were less likely than those intending to use a postplacental IUD to be using any form of contraception at one year. Of women intending a postplacental IUD, 12.4% of women delivering vaginally and 10.3% of women delivering by Cesarean section were modeled to be using no contraception at one year. Of women intending to receive a delayed postpartum IUD, 27.6% were modeled to be using no contraception at one year (Table 2).

One-way deterministic sensitivity analysis indicated that the difference in effectiveness of intended postplacental and delayed postpartum IUD placement after vaginal and Cesarean birth was driven primarily by probability of a patient returning to clinic for the delayed IUD placement visit (Figure 3). Thus, we varied the probability of a patient returning to clinic through the expected range, 65–90%^{13,18,25,26,28,29}. If the proportion of women returning for a postpartum visit was 65.0%, the one-year effectiveness of a postplacental IUD after vaginal birth was 19.6% higher than a delayed postpartum IUD; if the proportion of women returning for a postpartum visit was 90%, the effectiveness of a postplacental IUD after vaginal birth was 1.0% higher than a delayed postpartum IUD. Effectiveness of intended IUDs placed at Cesarean birth was 25.7% and 7.2% higher than intended delayed IUDs, respectively, if the proportion of women returning for a postpartum visit was varied across the same range. Postplacental IUD insertion was favored until the probability of a patient returning to clinic is above 91.4% following vaginal birth, and 99.7% following Cesarean birth (Figure 3).

The results of the probabilistic sensitivity analysis were consistent with the one-way sensitivity analyses (Figure 4), demonstrating that intended postplacental IUD insertion increased contraceptive effectiveness in 99.6% of scenarios following vaginal birth and 100.0% of scenarios following Cesarean birth. In the probabilistic sensitivity analysis, the mean improvement in effectiveness due to postplacental insertion compared to delayed postpartum insertion was 7.3% and 13.4% for vaginal and Cesarean deliveries, respectively (Figure 4).

In the scenario in which all women were assumed to return to clinic for their 6-week follow up visit (Scenario 2), and in the scenario in which all women received their intended IUD (Scenario 3), one-year probability of pregnancy rates for delayed postpartum IUDs were 11.0% and 3.9%, respectively (Table 3), and were lower than the one-year probability of pregnancy after postplacental IUD placement. If all women received their intended IUD, one-year probabilities of pregnancy following IUD placement at a vaginal birth, Cesarean birth, and an outpatient postpartum visit were 15.4%, 6.6%, and 3.9%, respectively.

Discussion:

In this decision analysis, the one-year probabilities of pregnancy among women intending to receive a postplacental IUD following vaginal or Cesarean birth were 17.3% and 11.2% respectively, and 24.6% for women intending to receive a delayed postpartum IUD. These were much higher than the typical <1% failure rate quoted for interval IUDs; that rate does not account for the multitude of factors that affect peripartum IUD initiation and continuation. Given that effectiveness is only one of many attributes of a contraceptive method, these results should be interpreted in the larger clinical context in which postpartum contraception counseling occurs.

Differences in IUD effectiveness by placement timing in our model were driven by higher pregnancy rates in women who did not receive their intended IUD, primarily due to follow-up visit nonattendance. Return to clinic rates must exceed 90% to favor the effectiveness of delayed postpartum insertion over immediate postplacental placement from a programmatic perspective.

We manipulated the probabilities of our model to evaluate two additional scenarios: Scenario 2, 100% likelihood to return to clinic for postpartum follow-up, to allow for a practice-level determination of benefit of a postplacental IUD program, and Scenario 3, 100% adherence to the intended insertion plan, to allow for an individual-level determination of the benefit of a postplacental IUD. In both of these scenarios, delayed postpartum placement had higher effectiveness than postplacental placement. These data allow providers to make determinations regarding the value of a postplacental IUD program in their practice, and to provide individualized counseling women about postpartum IUD placement in practices that offer postplacental IUD placement.

Our study is similar to a 2015 cost-effectiveness study⁶ in which postplacental and delayed IUD placement resulted in 27/1000 and 78/1000 unintended pregnancies at one year, respectively. However, we incorporated additional nodes in our decision tree, including the proportion of women who did not receive an intended postplacental IUD. We also provided data regarding differential effectiveness of a postplacental IUD placed after Cesarean versus vaginal birth.

Strengths of our research include the integration of a large evidence base that incorporates most clinical outcomes that influence IUD effectiveness. In addition, we provide a novel framework for considering contraceptive effectiveness. Previously published estimates of

contraceptive effectiveness assume contraceptive continuation at one year⁷. Our findings illuminate the implications of contraceptive switching and IUD expulsion on pregnancy risk.

Limitations of this study are inherent to its design, which utilized probability estimates from previously published data. For some probability estimates, including partial expulsion,¹² complete expulsion¹³ and discontinuation¹¹ of the LNG IUD after intended postplacental IUD placement, we carried forward 3-¹¹ or 6-month^{12,13} estimates and assumed them to be 12-month estimates. Although this could have resulted in overestimating effectiveness, our deterministic sensitivity analysis showed that these estimates did not have a significant effect on the outcome throughout their ranges. We did not include in our analyses differential published estimates for the proportions of women who attend postpartum follow-up after vaginal versus Cesarean birth³⁰. However, our sensitivity analyses demonstrated that postplacental placement resulted in a higher effectiveness than delayed IUD placement across the range of estimates for the proportion of women who return for follow-up (65–90%). Finally, our research does not capture the patient-centered outcomes of women's satisfaction with peripartum contraceptive method choice, the desiredness of subsequent pregnancies, or the clinical implications for women with partially expelled IUDs¹² or non-visible IUD strings^{9,12} that frequently occur after postplacental IUD placement.

In conclusion, despite higher rates of expulsion, decision analysis showed that intended postplacental IUDs were more effective for pregnancy prevention at one year postpartum than intended delayed postpartum IUDs. However, once placed, the effectiveness of a delayed postpartum IUD was superior to that of a postplacental IUD. Thus, the public health and individual benefits of a postplacental IUD program may conflict, and a high level of attention to the informed consent process is required. Health systems should work to improve access to postplacental IUDs, which is often limited by lack of infrastructure and insurance reimbursement for immediate postpartum LARC³⁷. Women should be counseled regarding postpartum contraception during antenatal care rather than during admission for delivery. Counseling should review all potential complications, and state that a postplacental IUD is most beneficial those who are unlikely to obtain an IUD in the delayed postpartum period. The findings from our analysis should be confirmed in a large multicenter, prospective, comparative study of postplacental versus delayed postpartum IUD insertion.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Decision tree model of postplacental intrauterine device (IUD) placement, used for both vaginal and cesarean birth. Probabilities at each decision node add up to 100% and are listed with their references in Table 1. The modeled one-year probability of pregnancy after intended vaginal postplacental IUD is 17.3%. The modeled one-year probability of pregnancy after intended cesarean postplacental IUD is 11.2%. LNG-IUD, levonorgestrel-releasing intrauterine device; LARC, long-acting reversible contraceptives.

Figure 2.

Decision tree model of delayed postpartum intrauterine device (IUD) placement. The delayed postpartum IUD model contains an additional modeling the probability of a patient returning for a postpartum follow-up visit. Probabilities at each decision node add up to 100% and are listed with their references in Table 1. The modeled one-year probability of pregnancy after intended delayed postpartum IUD is 24.6%. LNG-IUD, levonorgestrel-releasing intrauterine device; LARC, long-acting reversible contraceptives.

Figure 4.

Probabilistic sensitivity analysis for the postpartum intrauterine device (IUD) decision model. For 10,000 theoretical scenarios, the probabilities for each decision (input) were varied across the ranges displayed in Table 1. Each *vertical bar* represents the percent of the 10,000 scenarios that showed improved effectiveness of postplacental as compared with delayed postpartum insertion (output). The *vertical line* represents the threshold for effectiveness of postplacental insertion (*bars to the right* favor postplacental insertion). A total of 9,957 vaginal model scenarios favor immediate postplacental insertion. All 10,000 cesarean model scenarios favor immediate postplacental insertion. The additional percentage increase in efficacy expected with immediate postplacental insertion are as follows: vaginal: 7.30% (2.55%, 7.19%, 12.41%); cesarean: 13.38% (8.35%, 13.33%, 18.65%). Values reported are mean (5th percentile, 50th percentile, 95th percentile, respectively).

Table 1:
Base case and range of probabilities used in postplacental and delayed postpartum IUD decision model

Base case references are listed in the right column, with references for the ranges in superscript. Ranges listed as NA (not applicable) have well-established precise values described in the literature. All percentages are assumed to be one-year estimates.

Variable	Base case (%)	Range (%)	Base case reference and references for range
Variables used in both vaginal and Cesarean section postplacental IUD models			
IUD placed immediately postplacentally	70.0	70.0–100	Jatlaoui et al. ^{13,32}
Variables used for the vaginal postplacental IUD model			
Partial expulsion	16.0	5.0–16.0	Gurney et al. ^{8,11,12}
<i>Copper IUD</i>			
Complete expulsion	5.8	5.8–14.3	Sucak et al. ^{8–12}
Discontinuation	11.3	2.2–11.3	Sucak et al. ^{8,9,12,38}
<i>LNG IUD</i>			
Complete expulsion	24.0	17.0–27.3	Chen et al. ^{11,13–15}
Discontinuation	2.8	2.0–2.9	Eggenbrotten et al. ^{11,13–15}
Variables used for Cesarean postplacental IUD model			
<i>Copper and LNG IUD</i>			
Expulsion	5.0	0–15	Sucak et al. ^{8,9,17,27,39–42}
Discontinuation	16.0	0–16	Sucak et al. ^{8,9,17,27,39–42}
Partial expulsion	3.1	3.1–16.0	Sucak et al. ^{8,12}
Variables used for delayed postpartum IUD model			
Patient returns for postpartum visit	81.6	65–90	Chen et al. ^{13,18,25,26,28–30}
IUD placed at postpartum visit	60.5	22.6–100	Ogburn et al. ^{13,28,29}
<i>Copper IUD</i>			
Expulsion	3.5	0–5.5	Rowe et al. ^{10,16–21}
Discontinuation	9.9	4.7–20.2	Rowe et al. ^{10,16–21}
<i>LNG IUD</i>			
Expulsion	2.9	0–12	Rowe et al. ^{13,14,16,19,20,22–25}
Discontinuation	13.6	0–35.7	Rowe et al. ^{13,14,16,19,20,22–25}
Variables used in all models			
Efficacy of using no contraception	15.0	15–60	Trussel et al. ^{7,43}
LARC contraception efficacy	99.7	NA	Winner et al. ³⁵
Non-LARC contraception efficacy	95.2	NA	Winner et al. ³⁵
Copper IUD efficacy	99.4	NA	Trussel et al. ⁷
LNG IUD efficacy	99.8	NA	Trussel et al. ⁷
Partial expulsion IUD efficacy	35.0	35–80	Anteby et al. ^{34,44}
Proportion of women selecting a copper IUD	17	9.7–30	Secura et al. ^{32,45,46}

Variable	Base case (%)	Range (%)	Base case reference and references for range
Proportion of women selecting a LNG IUD	83	69–90.2	Secura et al. ^{32,45,46}
Recognition of IUD expulsion	84	69.2–90	Goldwaithe et al. ^{11–13,47}
Use of contraception after IUD removal/expulsion	77.4	77.4–89.6	Gurney et al. ^{12,33}
Choice of LARC method	31	12–67	Loewenberg Weisband et al. ^{29,33,45,46,48,49}

Table 2.
Percentage of women using each class of contraceptive method at one year

Estimates are derived from the base case IUD decision model. Women in the partial IUD expulsion group were assumed to be using their original IUD at one year, unrecognized as partially expelled.

	Intended postplacental vaginal IUD (%)	Intended postplacental Cesarean IUD (%)	Intended delayed postpartum IUD (%)
Original IUD			
LNG IUD	36.1	44.9	34.4
Copper IUD	8.4	9.2	7.3
Unrecognized partially expelled IUD	8.5	1.7	-
<i>Total</i>	53.0	55.8	41.7
New contraceptive method			
Non-LARC Method	28.2	23.3	21.2
LARC Method	10.7	10.5	9.5
No Contraception	12.4	10.3	27.5
Any LARC method	63.7	66.3	51.2

Table 3:
Summary of one-year probability of pregnancy estimates in three modeled scenarios: 1) the primary decision model, 2) a scenario in which all women return for postpartum follow-up, and 3) a scenario in which all women receive their intended IUD.

The base case scenario, or Scenario 1, uses the primary decision model estimates derived from the literature to provide estimates of IUD effectiveness after intended postplacental placement after vaginal birth, intended postplacental placement after Cesarean birth, and intended delayed postpartum placement. Scenario 2 models a theoretical setting in which all women would present for postpartum follow-up; here, we set the percentage of women returning for postpartum follow-up to 100%. This allows for practice-level assessment of benefit of a postplacental IUD program. Scenario 3 models a theoretical setting in which all women would receive their intended IUD; here, we set the percent of women who return for follow-up and the percent of women who receive their intended IUD at 100%. This allows for individual-level assessment of the benefit of a postplacental IUD.

	Scenario 1: Base case	Scenario 2: All return for postpartum follow-up	Scenario 3: All receive their intended IUD
Assumptions			
Percent who return for postpartum follow-up	81.6 ^{13,18,25,26,28,29}	100	100
Percent who receive an intended postplacental IUD	74 ^{13,32}	74 ^{13,32}	100
Percent who receive an intended delayed postpartum IUD	60.5 ^{13,28,29}	60.5 ^{13,28,29}	100
One-year probability of pregnancy estimates (percent)			
Vaginal postplacental IUD model	17.3	17.3	15.4
Cesarean postplacental IUD model	11.2	11.2	6.6
Delayed postpartum IUD model	24.6	11.0	3.9