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Evaluating and Refining Claims-Based Algorithms for Pregnancy Outcomes and Gestational Age Estimation in Korea

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ABSTRACT

Background: A recently developed claims-based algorithm, originally designed using data from pregnancies with systemic lupus erythematosus, may enhance the identification of pregnancy episodes in Korean observational research. However, its applicability for estimating gestational age (GA) has not yet been validated in the general pregnant population. This study aimed to evaluate and refine the algorithm's performance.

Methods: We utilized nationwide claims data from the Korean National Health Insurance Service between February 27, 2021, and December 31, 2022, to identify pregnancy episodes, including deliveries, stillbirths (SBs), and abortive outcomes (ABs). GA for each episode was estimated using both the original and modified algorithms, which prioritized second-to-third trimester target scan (TS) codes and first-trimester TS codes, respectively. Identified episodes with GA outside clinically plausible ranges for each pregnancy outcome were either reclassified into different outcomes or excluded. Algorithm performance was evaluated based on the following three criteria: first, the agreement between the estimated GA and the specified GA range in delivery episodes with a preterm birth (PB) code; second, comparison of estimated preterm birth (ePB) rates with national statistics reported by the Korean Statistical Information Service (KOSIS); third, sensitivity analysis of ultrasound code prioritization on the ePB rate.

Results: Among 581,740 pregnancy episodes, 456,157 were deliveries, 3,050 were SB, and 122,533 were AB. Deliveries with a GA of less than 37 weeks were classified as ePB, with rates of 39.7% in the original algorithm and 11.9% in the modified algorithm. In delivery episodes with PB codes that included specified GA ranges, the modified algorithm demonstrated higher agreement with the specified GA compared to the original algorithm (96.4% vs. 75.2%). The ePB rate estimated by the modified algorithm was also more consistent with the 9.4% reported by KOSIS, compared to the original algorithm (12.0% vs. 39.8%).

Conclusion: The modified algorithm, which prioritized first-trimester TS codes, improved the accuracy of GA estimation and reduced the underestimation observed in the original algorithm.

Keywords: Algorithms; Pregnancy; Premature Birth; Administrative Claims Healthcare; Gestational Age

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Disclosure

The authors have no potential conflicts of interest to disclose.

Data Availability Statement

The database is not available due to privacy policy.

Author Contributions

Conceptualization: Kim HJ, Cho H, Choi NK. Data curation: Kim HJ. Formal analysis: Kim HJ. Investigation: Kim HJ, Cho H. Methodology: Kim HJ, Choi NK. Supervision: Choi NK. Validation: Cho H, Jung SY, Shin JY, Choe SA. Writing - original draft: Kim HJ. Writing - review & editing: Cho H, Jung SY, Shin JY, Choe SA, Choi NK.

INTRODUCTION

In most cases, randomized clinical trials are not feasible for pregnant women due to ethical concerns.¹ Observational studies are commonly used to assess safety during pregnancy, with claims data serving as a key resource for such research. However, the absence of clinical details, such as the last menstrual period (LMP) or delivery date, is a major limitation when using claims data for pregnancy related-studies.^{2,3} Accordingly, several countries have developed and validated algorithms to estimate LMP and end date of pregnancy in claims data.⁴⁻⁶ These algorithms typically estimate gestational age (GA) based on recorded diagnostic and procedural codes, thereby enhancing the utility of claims databases for maternal and perinatal health research. However, heterogeneity in clinical settings, coding practices, insurance systems, and data structure across countries present challenges to directly applying even well-validated international algorithms to domestic claims data.

In response, a pregnancy algorithm designed for research using Korean claims data was developed using the National Health Insurance Service (NHIS) database in December 2023.⁷ This algorithm (referred to as the original algorithm) integrates ultrasound, pre-term diagnosis, and abortion procedure codes to identify pregnancy episodes and assign GA to deliveries, stillbirths (SBs), and abortive outcomes (ABs), allowing for more precise GA estimation at the individual level. However, it was developed based on a cohort of approximately 5,800 patients with systemic lupus erythematosus, a population known to have a higher prevalence of adverse pregnancy outcomes, including preterm birth (PB). Therefore, its generalizability to broader populations remains to be evaluated. In addition, the original algorithm was developed using claims data from 2002 to 2018, a period selected to encompass the 2016 expansion of NHIS reimbursement for antenatal ultrasounds and preterm infant care.⁸ Broader definitions were thus applied during this timeframe to account for evolving diagnostic coding practices and to comprehensively capture pregnancy outcomes. However, updates may be needed to enhance the algorithm's applicability to more recent datasets. Moreover, unlike other studies that prioritize the service date of 1st trimester ultrasounds for LMP estimation, this algorithm gives the highest priority to 2nd–3rd trimester ultrasounds.^{9,10} Given that ultrasound codes have served as the primary source for LMP estimation since the reimbursement policy changes in 2016, this prioritization may substantially influence GA estimation.⁷

In this study, we developed a modified version of the algorithm by adjusting the priority order of ultrasound codes. Using Korea NHIS claims data from 2020 to 2022, we identified all pregnancies and applied both the original and modified algorithms to estimate GA. Consequently, we then aimed to 1) evaluate how the algorithm modification influenced GA assignment for full-term births (FBs), PB, SB, and AB, and 2) determine the optimal algorithm for identifying episodes in the general pregnancy.

METHODS**Data source**

This study utilized claims data from the NHIS in Korea between 2020 and 2022. The database contains nationwide records of medical utilization, including antenatal care services.¹¹

Identification of pregnancy episodes

Pregnancy episodes were identified among women aged 18 to 49 years who experienced at least one pregnancy outcome between February 27, 2021, and December 31, 2022. A woman could have experienced multiple pregnancy outcomes during the study period. The scenario illustrated in Fig. 1 demonstrates how pregnancy outcomes including delivery, SB, and AB, were identified for a single woman. Over the study period, the woman had records of three deliveries, one SB, and two ABs, identified based on Korean Standard Classification of Diseases and causes of death, 8th revision (KCD-8) codes and related-procedures (Fig. 1, Supplementary Table 1). For AB, a more restrictive definition (KCD-8: O02–O06) was applied than in the previous study in order to minimize the inclusion of hospital visits unrelated to actual abortive events.⁷

Pregnancy outcomes were initially assessed independently within each pregnancy outcome category to ensure clinically plausible durations between preceding and subsequent outcomes (Fig. 1). The minimum required durations were determined based on prior studies and clinician opinion: 182 days between deliveries, 168 days between SBs, and 56 days between ABs (Supplementary Table 2).^{4,9,12} Identical pregnancy outcomes occurring within these

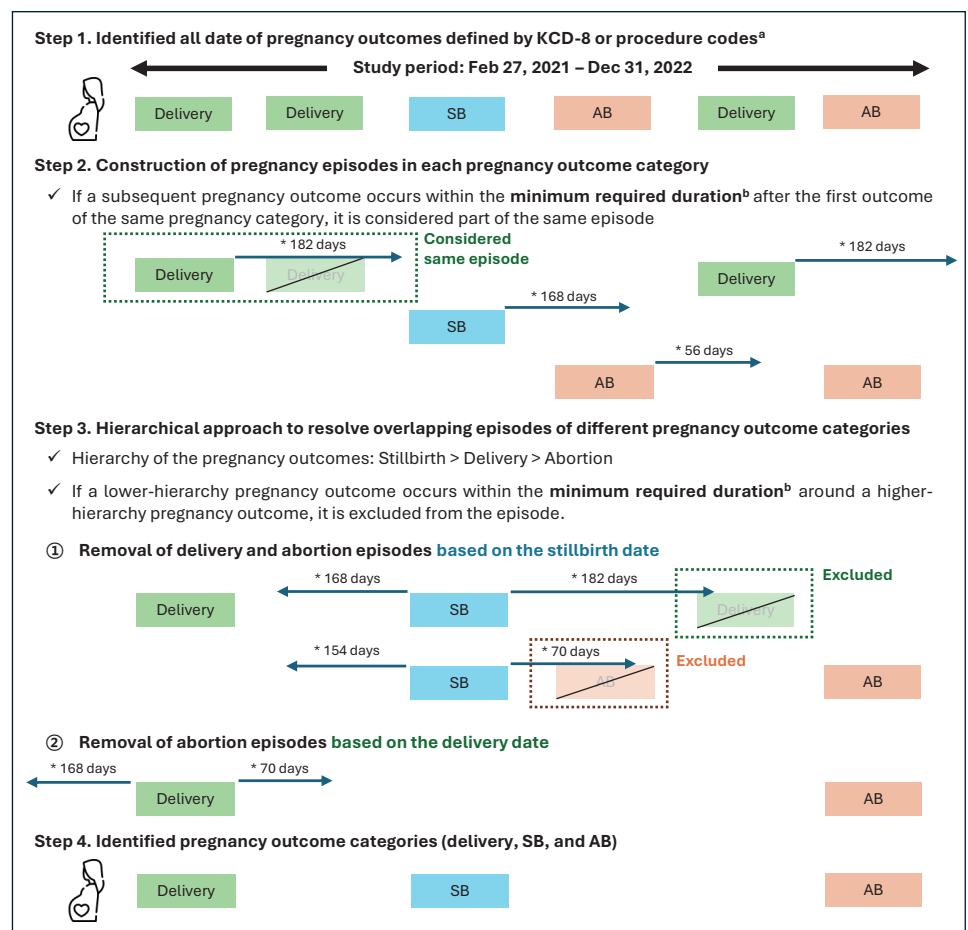


Fig. 1. Overview of pregnancy episode identification. KCD-8 = 8th edition of the Korean Standard Classification of Diseases, SB = stillbirth, AB = abortive outcome. ^aSupplementary Table 1 for definitions of pregnancy outcomes. ^bSupplementary Table 2 for minimum interval criteria between episodes.

durations after the initial outcome were considered part of the same episode, whereas those occurring beyond the durations were treated as separate episodes and served as a new reference for evaluating subsequent outcomes. Therefore, the second delivery in the scenario was considered as the same episode, and the third delivery was retained as a separate episode. All SB and AB episodes met the required durations and were retained as separate episodes.

Next, a hierarchical approach was then applied to ensure the minimum required intervals between different pregnancy outcome categories, in the order of SB, delivery, and AB (**Fig. 1**, **Supplementary Table 2**). Based on the SB episode, the subsequent delivery and the first subsequent AB occurred within the minimum durations and were therefore excluded. Subsequently, based on the retained delivery episode, no AB episodes overlapped with its minimum duration. As a result, one delivery, one SB, and one AB episode were ultimately retained for the woman (**Fig. 1**).

Algorithm modification

Fig. 2 illustrates the structure of the original and modified algorithms and their application in estimating LMP for the episodes identified in the scenario in **Fig. 1**. The algorithm detects antenatal care codes related to AB, ultrasound, or PB that were recorded within the observation window or before the end date of pregnancy (**Supplementary Table 3**). As multiple services may be recorded within this window, a hierarchical priority is applied to determine which code to use for LMP estimation (**Fig. 2**). In the original algorithm, ultrasound codes were categorized into four levels as follows: 2nd–3rd trimester target scan (2nd–3rd trimester TS), 1st trimester target scan (1st trimester TS), 1st trimester general scan (1st trimester GS), and 2nd–3rd trimester general scan (2nd–3rd trimester GS). PB codes with a specified GA were prioritized over those without one. All AB procedure codes were assigned the same priority as the highest-ranked ultrasound and PB codes. To assess the impact of ultrasound hierarchy on GA estimation, we developed modified versions of the algorithm in which only the prioritization of ultrasound codes was altered, while keeping all other structures unchanged. The modified hierarchy was informed by current reimbursement guidelines and clinician opinions.¹³ The 1st trimester TS reimbursed only once during pregnancy within a narrow window of 11–13 weeks, was considered the most accurate reference for GA estimation in claims data (**Supplementary Table 4**). Therefore, the modified algorithms prioritized 1st trimester TS, with the final hierarchy as follows: 1st trimester TS, 2nd–3rd trimester TS, 1st trimester GS, and 2nd–3rd trimester GS. GS codes, which may be reimbursed up to two or three times during pregnancy and cover a broad GA range (0–13 weeks for 1st trimester; 14 weeks to term for 2nd–3rd trimester), were consistently assigned lower priority, as in the original algorithm.

LMP estimation

In the scenario, a 1st trimester TS, a 2nd–3rd-trimester TS, and a PB code with a specified GA were recorded prior to the delivery episode, an AB procedure code was present before the SB episode, and no relevant codes were present before the AB episode (**Fig. 2**). If at least one antenatal care code was identified within an episode, the LMP was calculated by subtracting either the GA value or the midpoint of the GA range specified in the code from the pregnancy outcome date or the ultrasound service date (**Supplementary Table 3**).⁹ If no relevant codes were available, a fixed GA was assigned based on the type of pregnancy outcome (**Supplementary Table 5**). As multiple GA estimates were generated for the delivery episode, the smallest GA among those assigned the highest priority was selected (**Fig. 2**). A GA of 160 days based on the 2nd–3rd trimester TS code and a GA of 196 days based on the PB code was selected in the original algorithm and in the modified algorithm, respectively.

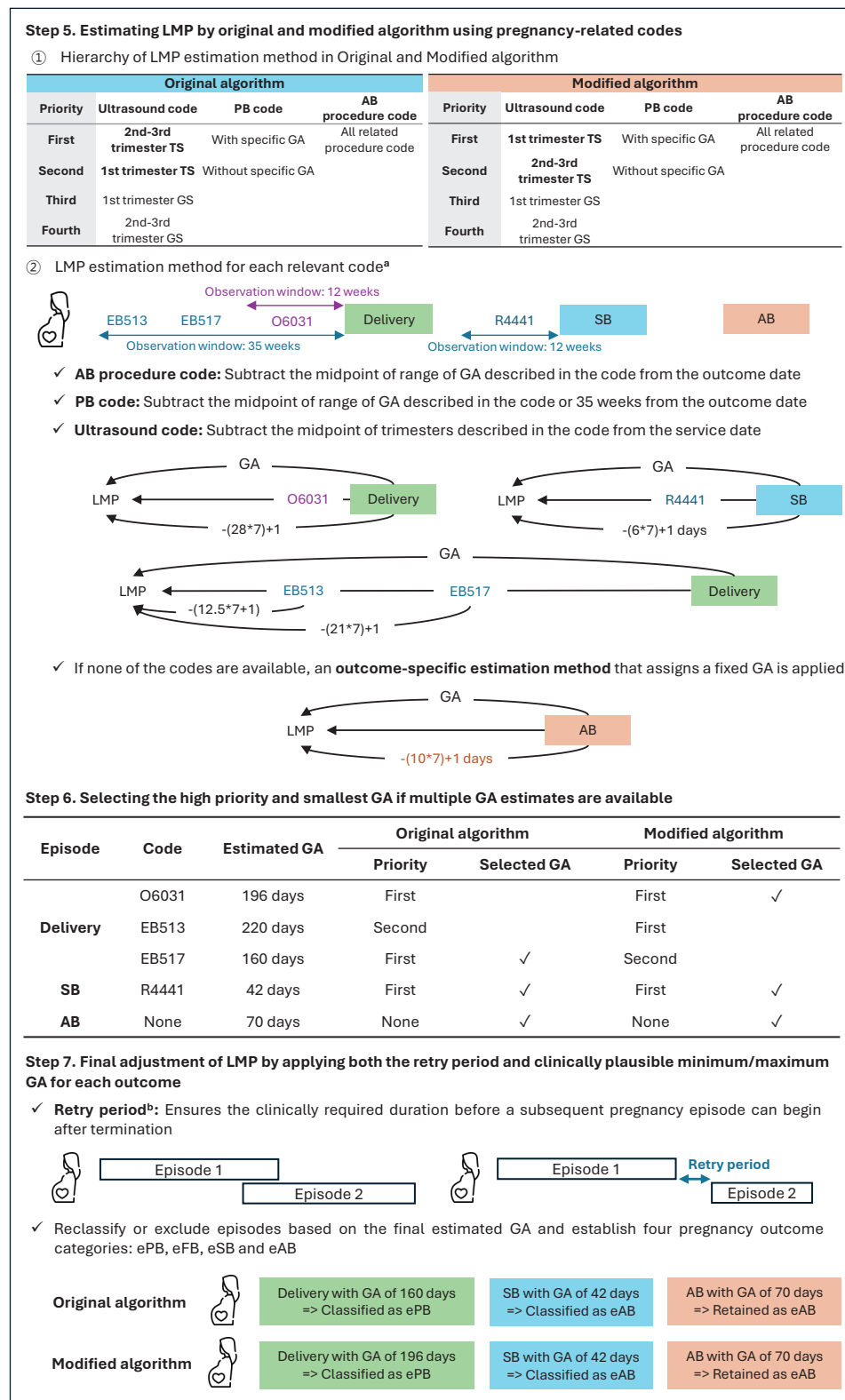


Fig. 2. Overview of algorithm modification and LMP estimation.

LMP = last menstrual period, PB = preterm birth, AB = abortive outcome, TS = target scan, GA = gestational age, GS = general scan, SB = stillbirth, ePB = estimated preterm birth, eFB = estimated full-term birth, eSB = estimated stillbirth, eAB = estimated abortive outcome.

^aSupplementary Tables 3 and 5 for GA values assigned to each code type in LMP estimation. ^bSupplementary Table 6 for definitions of retry periods required between pregnancy outcomes.

After estimating the LMP, a 'retry period' was applied to ensure a clinically plausible interval between the end date of the preceding pregnancy episode and the LMP of the subsequent episode (**Fig. 2, Supplementary Table 6**). Finally, episodes that did not fall within the minimum or maximum GA range for each pregnancy outcome were either reclassified into a different pregnancy outcome category or excluded. Specifically, delivery with an estimated GA of less than 20 weeks or greater than 42 weeks were excluded. Those between 20 and less than 37 weeks were reclassified as PB, while the remainder were classified as FB. For SB, those with GA below 20 weeks were reclassified as AB, and those above 42 weeks were excluded. AB with an estimated GA exceeding 20 weeks were also excluded. As a result, pregnancy outcomes were categorized into four groups based on estimated GA: estimated full-term birth (eFB), estimated preterm birth (ePB), estimated stillbirth (eSB), and estimated abortive outcome (eAB). In the scenario, the estimated GA for the delivery and SB episodes did not meet the minimum GA criteria required for each pregnancy outcome and were thus reclassified as ePB and eAB.

Evaluation of algorithm performance

To compare estimated GA between the two algorithms, we calculated the median, first quartile, and third quartile to summarize the GA distribution for each pregnancy outcome. For each algorithm, the performance was evaluated by assessing the proportion of episodes that were reclassified into different pregnancy outcome categories or excluded based on the estimated GA. In particular, because ePB episodes were determined exclusively by estimated GA regardless of the presence of PB codes, additional evaluation was conducted using the following three approaches. First, for delivery episodes that included a PB code with a specified GA range, agreement was assessed by determining whether the estimated GA from each algorithm fell within that specified range in the code. Episodes were classified as 'agreement' if the estimated GA was within the range, 'near agreement' if within seven days of the range, and 'disagreement' otherwise. Second, the ePB rates estimated by each algorithm were compared with national statistics reported by the Korean Statistical Information Service (KOSIS) for 2021–2022.¹⁴ Third, sensitivity analyses were further conducted for 24 combinations of ultrasound code prioritization. One of the four ultrasound types was assigned the highest priority for ePB estimation, while the remaining three were arranged in all six possible sequences. All statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA).

Ethics statement

Patient consent was not required for analyses of secondary claims data from de-identified human records, and we received confirmation of research ethics exemption from the Institutional Review Board (IRB) of Ewha Womans University (IRB number ewha-202211-0022-01). Informed consent was waived because of the retrospective nature of the study.

RESULTS

A total of 543,535 pregnant women aged 18–49 who experienced a delivery, SB, or AB between February 27, 2021, and December 31, 2022, were identified using NHIS claims data. These women had 581,740 pregnancy episodes, comprising 456,157 deliveries, 3,050 SBs, and 122,533 ABs (**Table 1**).

The original algorithm estimated a median GA of 37.6 weeks for delivery episodes, whereas the modified algorithm estimated a longer median of 38.8 weeks. This gap led to a substantial

Table 1. Distribution of estimated GA according to algorithm

Pregnancy outcome	No. of episodes	Algorithm	Estimated GA				
			Median (Q1–Q3)	< 20 wk	20–37 wk	37–42 wk	> 42 wk
Delivery	456,157	Original	37.6 (35.7–38.9)	39 (0.0) ^a	181,054 (39.7) ^b	273,846 (60.0) ^d	1,218 (0.3) ^a
		Modified	38.8 (37.9–39.6)	50 (0.0) ^a	54,462 (11.9) ^b	400,646 (87.8) ^d	999 (0.2) ^a
SB	3,050	Original	21.6 (17.9–27.9)	1,175 (38.5) ^c	1,867 (61.2) ^d		8 (0.3) ^a
		Modified	21.6 (17.1–27.9)	1,241 (40.7) ^c	1,803 (59.1) ^d		6 (0.2) ^a
AB	122,533	Original	6.9 (5.9–7.7)	122,297 (99.8) ^d	236 (0.2) ^a		-
		Modified	6.9 (5.9–7.7)	122,320 (99.8) ^d	213 (0.2) ^a		-

Values are presented as number (%).

GA = gestational age, Q1 = first quartile, Q3 = third quartile, SB = stillbirth, AB = abortive outcome.

^aEpisodes that should be excluded from pregnancy episodes. ^bEpisodes that should be further classified into preterm birth. ^cEpisodes that should be further classified into AB. ^dWell-classified episodes.

variation in the proportion of deliveries classified as ePB, with 39.7% under the original algorithm and 11.9% under the modified algorithm. In contrast, both algorithms estimated identical median GA estimates for SB and AB, at 21.6 weeks and 6.9 weeks, respectively. The proportion of SB episodes reclassified as AB was also comparable, with 38.5% under the original and 40.7% under the modified algorithm. Only a small proportion of episodes, approximately 0.2–0.3% per pregnancy outcome category, was excluded by both algorithms.

Among the 456,157 delivery episodes, 15,132 (3.3%) had a PB code during pregnancy, of which 14,406 (95.2%) included a specified GA range (Fig. 3). The original algorithm showed 75.2%

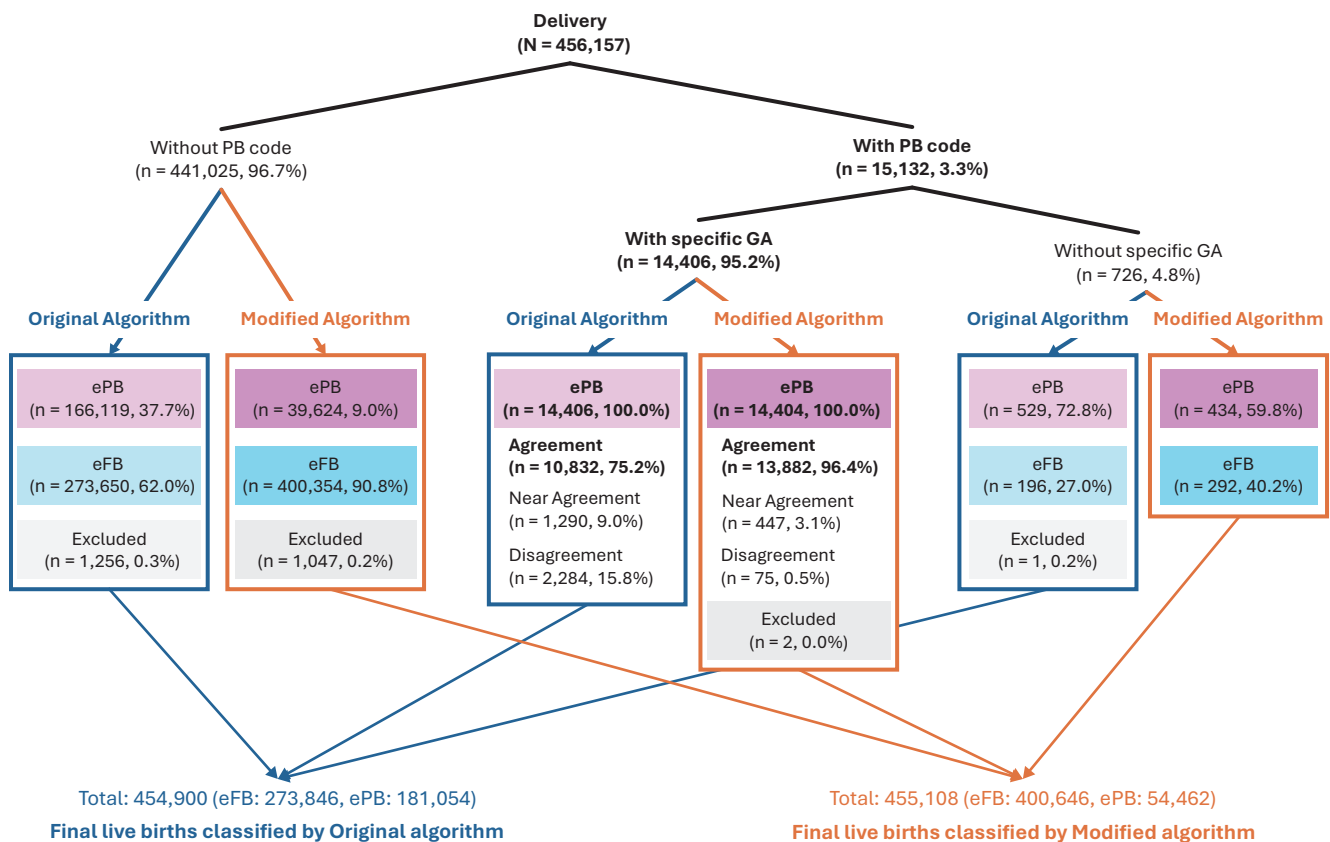


Fig. 3. Agreement between specified GA in PB codes and GA estimated by the algorithm.

PB = preterm birth, GA = gestational age, eFB = estimated full-term birth, ePB = estimated preterm birth.

Table 2. Rates of preterm birth, stillbirth, and abortive outcome estimated by algorithms in pregnancies

Algorithm	Birth identification period	No. of pregnancy episodes					ePB rate (%) ^c	eSB rate (‰) ^d	eAB rate (%) ^e
		Total pregnancy ^a	Live birth ^b	ePB	eSB	eAB			
Original	Feb 27, 2021–Dec 31, 2022	580,239	454,900	181,054	1,867	123,472	39.8	4.1	21.3
Modified		580,472	455,108	54,462	1,803	123,561	12.0	3.9	21.3
KOSIS	2021–2022	-	509,748	48,033	-	-	9.4	-	-

ePB = estimated preterm birth, eSB = estimated stillbirth, eAB = estimated abortive outcome, KOSIS = Korean Statistical Information Service.

^aThe sum of live birth, stillbirth and abortive outcome episodes. ^bThe sum of preterm episodes and full-term episodes. ^cPreterm birth episodes per 100 live birth episode. ^dStillbirth episodes per 1,000 live birth and stillbirth. ^eAbortive outcome episodes per 100 pregnancies.

agreement with the specified range, whereas the modified algorithm represented 96.4%. Among the remaining 726 episodes without a specified GA range, 72.8% were classified as ePB under the original algorithm, compared to 59.8% under the modified algorithm.

After reclassification according to estimated GA, the total number of estimated live births including eFB and ePB was 445,900 under the original algorithm and 455,108 under the modified algorithm (Table 2). Given the 2-month gap between our study period (February 27, 2021–December 31, 2022) and the KOSIS reporting period (2021–2022), the estimates from both algorithms were reasonably consistent with the 509,748 live births reported by KOSIS.¹⁴ However, the ePB rate estimated by the original algorithm was 39.8 per 100 births, whereas the modified algorithm produced a substantially lower rate of 12.0 per 100 births. The latter was much closer to the national average of 9.4 per 100 births reported by KOSIS for 2021–2022. The eSB rates were estimated at 3.9 to 4.1 per 1,000 live births and SBs, and the eAB rate at 21.3 per 100 pregnancies. These could not be directly compared, however, as KOSIS does not report SB or AB rates.

Sensitivity analyses further showed that the ePB rate varied substantially depending on which ultrasound code was prioritized in the algorithm (Supplementary Table 7). Specifically, algorithms prioritizing 1st trimester TS codes consistently produced lower ePB rates (12.0–12.6%) compared to those prioritizing other ultrasound codes (39.8–98.4%). Notably, the modified algorithm used in this study produced the lowest ePB rate (12.0%) among the 24 combinations analyzed.

In the modified algorithm, the median GA estimates were 38.9 weeks for eFB, 35.4 weeks for ePB, 26.5 weeks for eSB, and 6.9 weeks for eAB (Supplementary Table 8). The 1st trimester TS code was the most commonly used for estimating LMP in eFB (98.4%), ePB (63.4%), and eSB (86.2%) (Supplementary Table 9). In contrast, eAB episodes primarily used the 1st trimester GS code (49.0%), followed by AB procedure codes with GA under 12 weeks (33.0%).

DISCUSSION

This study evaluated the performance of GA estimation for pregnancy outcomes, including deliveries, SBs, and ABs, using the NHIS claims database based on both a previously developed pregnancy algorithm and its modified versions. Both algorithms identified a similar number of live births, which closely aligned with national statistics reported by KOSIS. However, the final ePB rate estimated by the original algorithm was 39.8%, notably higher than the national average of 9.4% reported by KOSIS for 2021–2022, suggesting a potential underestimation of GA. In contrast, the modified algorithm estimated a relatively lower ePB rate of 12.0%. Although this rate remained slightly higher than the national statistics from KOSIS, it fell within a plausible range when compared to

PB rates reported in the United States (US) (10.4%) and worldwide (4–16%).^{15,16} Interestingly, the ePB rate generated by the modified algorithm was similar to that reported in a US study using a 13-step claims-based algorithm that prioritized 1st trimester ultrasound codes, both in terms of its magnitude and its tendency to overestimate. That study estimated a PB rate of 12.3%, which exceeded the 9.9% recorded in the US Vital Statistics Birth File.⁹

The discrepancy in ePB rates between the two algorithms appeared to be driven by differences in ultrasound code hierarchy for GA estimation. Sensitivity analyses indicated that GA underestimation was minimized when prioritizing 1st trimester TS over other ultrasound types. Moreover, in delivery episodes with PB codes specifying a GA range, the modified algorithm showed greater agreement with the specified GA than the original algorithm (96.4% vs. 75.2%). These results highlight its improved accuracy in estimating GA. In contrast, among episodes with PB codes that did not specify GA (i.e., KCD-8 codes: O601, O603, O6019, O6039), 59.8% to 72.8% were classified as ePB, while the remainder were reclassified as eFB. These results suggest that PB codes without a specified GA may not always reflect actual pre-term labor, and thus caution is warranted when defining the PB episodes.

In our study, 38.5% to 40.7% of SB cases were reclassified as eAB, resulting in a final eSB rate of 3.9 to 4.1 per 1,000 live births and SBs. These estimates are within the range reported in prior studies (1.74–7.0 per 1,000).¹⁷⁻¹⁹ However, identifying SBs from claims data remains challenging.²⁰ Indeed, SBs had the highest likelihood of being associated with conflicting pregnancy outcomes, such as AB, recorded together on the same day.⁸ Zhu et al.²¹ reported that excluding SB cases with other pregnancy outcome codes increased the positive predictive value (PPV) from 71% to 80.6%, with most false-positive SB cases being spontaneous or induced AB. Likewise, Andrade et al.²² found that the highest PPV (82.5% [95% confidence interval, 70.9–91.0]) was achieved when an algorithm incorporated both International Classification of Diseases, 10th revision codes indicating GA and intrauterine fetal death or excluded cases with other conflicting pregnancy outcomes. In our algorithm, SB was prioritized over other outcomes during episode identification, which may have led to the misclassification of AB as SB in cases involving conflicting diagnostic codes.

This is the first study to evaluate an algorithm specifically developed for the Korean claims database to identify pregnancy episodes in a general population of pregnant women.

The modified algorithm which prioritized 1st trimester TS, indicated improved performance in identifying PB episodes. A key limitation was its reliance on aggregate statistics reported by KOSIS as an external benchmark, rather than validation through clinical records or linked data sources. Moreover, due to the absence of official reporting on SB or AB rates by KOSIS, the performance of the algorithm for these outcomes could not be assessed.

Future research should aim to validate GA estimates using gold-standard data, such as electronic medical records from representative hospitals. Another limitation is that the algorithm was not designed to capture certain types of AB-related diagnoses, such as ectopic pregnancies and hydatidiform moles (KCD-8 codes: O00 and O01), or non-live birth outcomes that were assigned only procedure codes without diagnosis codes. Therefore, the algorithm may underestimate the actual burden of non-live birth events especially when applied in studies aiming to capture all pregnancies in the general population. Reported pregnancy loss rates in Korea have varied widely, ranging from 18.0% to 35.8%, depending on the definition

of non-live birth applied in studies.^{19,23,24} Lastly, our algorithm produced a higher ePB rate compared to the rate reported by KOSIS, which may be attributable to several factors. First, our study did not include births from the first two months of 2021 (January and February). According to KOSIS, 17.7% of total births in 2021 occurred during this period, which is higher than in other months.²⁵ As the number of live births served as the denominator in calculating the ePB rate, the exclusion of these months may have contributed to an overestimation of ePB. In addition, our algorithms did not distinguish between singleton and multiple pregnancies within a single episode. If two pregnancy outcomes occurred on the same or adjacent dates, the algorithm retained the outcome with higher hierarchical priority, or the earlier one if priority was equal. For instance, in twin pregnancies where one was terminated as SB or PB and the other as FB, the SB or PB was retained. This approach may have contributed to a potential underestimation of eFB and may have led to an overestimation of ePB or eSB rate. Based on the modified algorithm, approximately 2.8% of episodes included codes indicating multiple pregnancies prior to the end date of pregnancy (**Supplementary Table 10**). If all multiple pregnancies are excluded, the ePB rate decreased to 10.7%.

Nevertheless, because this limitation applies to both algorithms, it is unlikely to affect the conclusion that the modified algorithm is more effective in identifying ePB episodes. Future studies should consider applying advanced predictive models, such as machine learning approaches, to compare a broader set of candidate algorithms and develop models with improved performance. A previous study suggested that a random forest model incorporating between 24 and 246 predictors related to pregnancy outcomes outperformed traditional methods that relied solely on fixed GA or antenatal care records in estimating GA.²⁶ Therefore, although the findings of this study offer valuable methodological insights for future research using Korean claims data, further validation using gold standards and comparative evaluation with various candidate algorithms is needed to enhance the reliability of the results.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1

Definition of pregnancy outcomes

Supplementary Table 2

Clinically plausible duration required for subsequent episode

Supplementary Table 3

Estimation of LMP with presence of abortive outcome-related, sonography, and preterm codes

Supplementary Table 4

Eligibility criteria for reimbursement of antenatal ultrasound

Supplementary Table 5

Estimation of LMP without presence of abortive outcome-related, sonography, and pre-term codes (Outcome-specific estimates)

Supplementary Table 6

Retry period

Supplementary Table 7

Sensitivity analysis of preterm birth rate by varying the ultrasound priority in the algorithm

Supplementary Table 8

Distribution of gestational age for the final estimated pregnancy outcomes assigned by algorithms

Supplementary Table 9

Codes for estimating LMP in the Modified algorithm

Supplementary Table 10

Proportion of multiple pregnancies among episodes identified by the modified algorithm

REFERENCES

1. Andrade SE, Bérard A, Nordeng HME, Wood ME, van Gelder MMHJ, Toh S. Administrative claims data versus augmented pregnancy data for the study of pharmaceutical treatments in pregnancy. *Curr Epidemiol Rep* 2017;4(2):106-16. [PUBMED](#) | [CROSSREF](#)
2. Park JS, Lee CH. Clinical study using healthcare claims database. *J Rheum Dis* 2021;28(3):119-25. [PUBMED](#) | [CROSSREF](#)
3. Ailes EC, Simeone RM, Dawson AL, Petersen EE, Gilboa SM. Using insurance claims data to identify and estimate critical periods in pregnancy: an application to antidepressants. *Birth Defects Res A Clin Mol Teratol* 2016;106(11):927-34. [PUBMED](#) | [CROSSREF](#)
4. Matcho A, Ryan P, Fife D, Giffkins D, Knoll C, Friedman A. Inferring pregnancy episodes and outcomes within a network of observational databases. *PLoS One* 2018;13(2):e0192033. [PUBMED](#) | [CROSSREF](#)
5. MacDonald SC, Cohen JM, Panchaud A, McElrath TF, Huybrechts KF, Hernández-Díaz S. Identifying pregnancies in insurance claims data: methods and application to retinoid teratogenic surveillance. *Pharmacoepidemiol Drug Saf* 2019;28(9):1211-21. [PUBMED](#) | [CROSSREF](#)
6. Ailes EC, Zhu W, Clark EA, Huang YA, Lampe MA, Kourtis AP, et al. Identification of pregnancies and their outcomes in healthcare claims data, 2008–2019: an algorithm. *PLoS One* 2023;18(4):e0284893. [PUBMED](#) | [CROSSREF](#)
7. Jung YS, Song YJ, Keum J, Lee JW, Jang EJ, Cho SK, et al. Identifying pregnancy episodes and estimating the last menstrual period using an administrative database in Korea: an application to patients with systemic lupus erythematosus. *Epidemiol Health* 2024;46:e2024012. [PUBMED](#) | [CROSSREF](#)
8. Kim K, Chae J, Kim S, Lee D, Kim K. Establishment of ultrasonic adequacy evaluation plan. <https://repository.hira.or.kr/bitstream/2019.oak/1501/2/%EC%B4%88%EC%9D%8C%ED%8C%8C%20%EC%A0%81%EC%A0%95%EC%84%B1%20%ED%8F%89%EA%B0%80%20%EB%B0%A9%EC%95%88%20%EB%A7%88%EB%A0%A8.pdf>. Updated 2018. Accessed June 30, 2023.
9. Moll K, Wong HL, Fingar K, Hobbi S, Sheng M, Burrell TA, et al. Validating claims-based algorithms determining pregnancy outcomes and gestational age using a linked claims-electronic medical record database. *Drug Saf* 2021;44(11):1151-64. [PUBMED](#) | [CROSSREF](#)
10. Kim K, Bolormaa E, Gwak E, Shin JY, Choi NK, Choe YJ, et al. Maternal exposures to COVID-19 vaccine and adverse birth outcomes: national population study in Korea. *J Korean Med Sci* 2025;40(17):e63. [PUBMED](#) | [CROSSREF](#)

11. Kyoung DS, Kim HS. Understanding and utilizing claim data from the Korean National Health Insurance Service (NHIS) and Health Insurance Review & Assessment (HIRA) database for research. *J Lipid Atheroscler* 2022;11(2):103-10. [PUBMED](#) | [CROSSREF](#)
12. Sarayani A, Albogami Y, Thai TN, Smolinski NE, Patel P, Wang Y, et al. Prenatal exposure to teratogenic medications in the era of Risk Evaluation and Mitigation Strategies. *Am J Obstet Gynecol* 2022;227(2):263.e1-38. [PUBMED](#) | [CROSSREF](#)
13. Health Insurance Review & Assessment Service. Expansion of health insurance coverage for ultrasound examinations including pregnant women starting October 1 [press release]. <https://www.hira.or.kr/bbsDummy.do?pgmid=HIRAA020041000100&brdScnBltno=4&brdBltno=9227#none>. Updated 2016. Accessed June 30, 2023.
14. Statistics Korea. *Birth Statistics in 2022*. Daejeon, Korea: Statistics Korea; 2023.
15. Centers for Disease Control and Prevention. Preterm birth. <https://www.cdc.gov/maternal-infant-health/preterm-birth/index.html>. Updated 2023. Accessed February 14, 2025.
16. Liang X, Lyu Y, Li J, Li Y, Chi C. Global, regional, and national burden of preterm birth, 1990–2021: a systematic analysis from the global burden of disease study 2021. *EClinicalMedicine* 2024;76:102840. [PUBMED](#) | [CROSSREF](#)
17. Comfort H, McHugh TA, Schumacher AE, Harris A, May EA, Paulson KR, et al. Global, regional, and national stillbirths at 20 weeks' gestation or longer in 204 countries and territories, 1990–2021: findings from the Global Burden of Disease study 2021. *Lancet* 2024;404(10466):1955-88. [PUBMED](#) | [CROSSREF](#)
18. Kim JW, Jung JY, Kim HA, Yang JI, Kwak DW, Suh CH. Lupus low disease activity state achievement is important for reducing adverse outcomes in pregnant patients with systemic lupus erythematosus. *J Rheumatol* 2021;48(5):707-16. [PUBMED](#) | [CROSSREF](#)
19. Kim CB, Choe SA, Kim T, Kim MH, Ryu J, Oh JW, et al. Risk of adverse pregnancy outcomes by maternal occupational status: a national population-based study in South Korea. *J Occup Health* 2023;65(1):e12380. [PUBMED](#) | [CROSSREF](#)
20. Likis FE, Sathe NA, Carnahan R, McPheeters ML. A systematic review of validated methods to capture stillbirth and spontaneous abortion using administrative or claims data. *Vaccine* 2013;31 Suppl 10:K74-82. [PUBMED](#) | [CROSSREF](#)
21. Zhu Y, Bateman BT, Hernandez-Diaz S, Gray KJ, Straub L, Reimers RM, et al. Validation of claims-based algorithms to identify non-live birth outcomes. *Pharmacoepidemiol Drug Saf* 2023;32(4):468-74. [PUBMED](#) | [CROSSREF](#)
22. Andrade SE, Shinde M, Moore Simas TA, Bird ST, Bohn J, Haynes K, et al. Validation of an ICD-10-based algorithm to identify stillbirth in the Sentinel System. *Pharmacoepidemiol Drug Saf* 2021;30(9):1175-83. [PUBMED](#) | [CROSSREF](#)
23. Kim JH, Kim S, Ryu KJ, Park H, Kim YJ, Choe SA. Socioeconomic factors and abortive outcomes of clinical pregnancy after embryo transfer in the setting of universal health insurance coverage of IVF. *J Korean Med Sci* 2023;38(38):e293. [PUBMED](#) | [CROSSREF](#)
24. Korea Biomedical Review. 30% of Korean pregnancies ended in miscarriage over the last decade: data. <https://www.koreabiomed.com/news/articleView.html?idxno=22228>. Updated 2023. Accessed March 25, 2025.
25. Statistics Korea. Vital statistics (number) by Month for Provinces. https://kosis.kr/statHtml/statHtml.do?sso=ok&returnurl=https%3A%2F%2Fkosis.kr%3A443%2FstatHtml%2FstatHtml.do%3Fconn_path%3D12%26tblId%3DDT_1B8000G%26orgId%3D101%26. Updated 2025. Accessed July 2, 2025.
26. Zhu Y, Thai TN, Hernandez-Diaz S, Bateman BT, Winterstein AG, Straub L, et al. Development and validation of algorithms to estimate live birth gestational age in medicaid analytic eXtract data. *Epidemiology* 2023;34(1):69-79. [PUBMED](#) | [CROSSREF](#)