Determining gestational age based on information from the *Birth in Brazil* study

Determinação da idade gestacional com base em informações do estudo *Nascer no Brasil*

Determinación de la edad gestacional en base a la información del estudio *Nacer en Brasil*

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Abstract

This study aimed at assessing the validity of different measures for estimating gestational age and to propose the creation of an algorithm for gestational age at birth estimates for the Birth in Brazil *survey – a study conducted in 2011-2012 with 23,940 postpartum women. We used early ultrasound imaging, performed between 7-20 weeks of gestation, as the reference method. All analyses were performed stratifying by payment of maternity care (public or private). When compared to early ultrasound imaging, we found a substantial intraclass correlation coefficient of ultrasound-based gestational age at admission measure (0.95 and 0.94) and of gestational age reported by postpartum women at interview measure (0.90 and 0.88) for the public and private payment of maternity care, respectively. Last menstrual period-based measures had lower intraclass correlation coefficients than the first two measures evaluated. This study suggests caution when using the last menstrual period as the first measure for estimating gestational age in Brazil, strengthening the use of information obtained from early ultrasound imaging results.*

Gestational Age; Premature Birth; Maternal and Child Health

Resumo

O objetivo deste estudo foi verificar a validade de diferentes métodos de estimação da idade gestacional e propor a criação de um algoritmo para cálculo da mesma para a pesquisa Nascer no Brasil *– estudo realizado em 2011-2012, com 23.940 puérperas. Utilizou-se a ultrassonografia precoce, realizada entre 7-20 semanas de gestação, como método de referência. Todas as análises foram estratificadas segundo tipo de pagamento do parto (público ou privado). Quando comparado à ultrassonografia precoce, foram encontrados coeficientes de correlação intraclasse substanciais tanto para o método idade gestacional na admissão baseado em ultrassonografia (0,95 and 0,94) quanto para o método idade gestacional relatada pela puérpera na entrevista (0,90 and 0,88), para o pagamento do parto público e privado, respectivamente. Medidas baseadas na data da última menstruação apresentaram coeficientes de correlação intraclasse menores. Este estudo sugere cautela ao se utilizar a data da última menstruação como primeiro método de estimação da idade gestacional no Brasil, fortalecendo o uso de informações oriundas de ultrassonografia precoce.*

Idade Gestacional; Nascimento Prematuro; Saúde Materno-Infantil

Introduction

In Brazil, the Information System on Live Birth (SINASC) has high coverage (98%), and the quality of its form-filling has improved over the years [1]. Until 2010, the Live Birth Certificate, the form that feeds SINASC, only allowed the record of aggregated information about gestational age, according to ranges of gestation duration, which favored classification errors. In 2011, this information came to be collected in a disaggregated way, according to weeks of gestation, with the main calculation method being the date of the last menstrual period (LMP) [2], and making possible the recording of gestational age information based on other assessment methods (physical examination or ultrasound imaging) [2]. However, these methods have different levels of validity [3,4,5,6], making the assessment of gestational age in the country more difficult.

In accordance with the National Institute for Health and Care Excellence, National Health Systems (NICE/NHS/UK) [7], an ultrasound (US) performed within 10 to 13 weeks and six days of pregnancy is considered the most accurate method to estimate the gestational age, considering that variation of fetal growth rate in this period is too small. On the other hand the LMP is the method recommended by the World Health Organization (WHO) [8] due to its high accessibility and low cost.

LMP-based gestational age is fallible in many cases, such as individual variation of the duration of the menstrual cycle, implantation bleeding, and, particularly, recall biases [9,10]. In Brazil, a high proportion of the population has low schooling – a feature associated to worse quality of information about LMP [5,6]. In a study carried out with users of the Brazilian Unified National Health System (SUS) in two cities, it was seen that LMP-calculated gestational age compared to early-US-estimated gestational age tends to overestimate both postmaturity and prematurity proportions, reaching 10.3% and 17.7 % of births, respectively [4].

Estimates of the proportion of prematurity in Brazil are highly variable. For 2010, the WHO report estimated a prevalence of 9.2% [11]; SINASC data, 7.1% (Health Informatics Department, SUS. http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sinasc/cnv/nvuf.def), and two local-coverage studies with primary data estimated a prevalence of 12.5% [4] and 14.8% [12]. Such discrepant results warrant caution when comparing proportions of prematurity, particularly if calculated with different estimation methods.

The aim of this study is to assess and validate different sources of information and measures to estimate the gestational age at birth in Brazil, and to suggest the development of an algorithm to calculate gestational age at birth.

Methodology

Design and size of the sample

Birth in Brazil is a national, hospital-based study with postpartum women and their newborn babies, carried out from February 2011 to October 2012. The sample was selected in three stages. The first included hospitals with 500 or more deliveries/year, stratified by the five macro-regions of Brazil, location (capital city or not), and type of hospital (private, public, and mixed). The second included days (at least seven days for each hospital), and the third included postpartum women. In each of the 266 hospitals in the sample, 90 postpartum women were interviewed, a total of 23,940 subjects. Further information on the design of the sample is detailed on Vasconcellos et al. [13]. In the first stage of the study, face-to-face interviews were held with the postpartum women during their hospital-stay, data about the woman and the newborn were collected from their medical records, and pictures of the pre-natal cards were taken. Interviews over the phone were held before six months and at twelve months after birth, to collect information on maternal and newborn outcomes. Detailed information on data collection is presented on do Carmo Leal et al. [14].

In each stratum, calculations for the sample included the outcome cesarean section, estimated at 46.6% (for the year 2007), with 5% significance level to detect differences of 14% among the types of hospitals, power of analysis of 95%, and design effect of 1.3, leading to a minimum sample of 450 women per stratum.

Data collection

Face-to-face interviews with postpartum women were held within 24 hours after birth, with information on their demographic and socioeconomic characteristics, source of payment of birth (public or private), obstetric history and gestational age at birth collected. In this interview data relating to US examinations were photographed directly from the original results kept by the postpartum women or from the prenatal cards. Information about the LMP was collected from maternal medical records, pre natal cards, and also reported by the postpartum woman during the interview. They were asked: "*What was the first day of your last period*?". If necessary, they

were led to think about an event that took place at the time of their last menses (for instance, a holiday, vacation, a weekend), to facilitate recollection. LMP or US-based information regarding gestational age at admission was also collected from the maternal medical records, when available. Information on the type of birth, sex of the newborn and birth weight was collected from the newborn medical records.

Calculation of the gestational age and Z scores of birth weight by gestational age

The methods to estimate gestational age at birth assessed in this article were: (1) calculated from the LMP reported by the postpartum woman at the interview (LMP substracted from the date of birth [15]); (2) gestational age at birth reported by the postpartum woman - information collected at the hospital interview with the woman; (3) calculated from the LMP registered in the maternal medical records (LMP substracted from the date of birth); (4) gestational age registered by the practitioner in the maternal medical records during admission for birth, with the LMP serving as reference (when birth was not on the same day of admission, the number of days between admission and birth was added to the gestational age); (5) gestational age registered by the practitioner in the maternal medical records during admission for birth, with the US serving as reference (when birth was not on the same day of admission, the number of days between admission and birth was added to the gestational age); and (6) calculated based on previous US examinations results kept by postpartum women or at the prenatal card (by subtracting the date of the examination from the date of birth and adding the estimated clinical gestational age in days at the time of examination). Gestational ages under 18 weeks or 45 weeks and over were considered implausible.

The LMP registered in the prenatal card was not used as an estimation method for gestational age, as there was a high matching rate between these and the ones registered on hospital medical records; thus, the later was used, as this information was available for a higher number of women.

As method of reference, the result of the first US, performed within seven and twenty weeks of pregnancy, and therefore called early US, was used, due to findings from investigations on the use of US to estimate gestational age [16,17].

The Z-scores of birth weight for gestational age were calculated with the use of world references for fetal weight, and birth weight percentiles adjusted by sex of the newborn. It was considered as being in the 50th percentile of weight-birth at 40 completed weeks of pregnancy the weight of 3,386.15g for boys and 3,276.45g for girls (based on data for Brazil presented on the WHO's *Global Survey on Maternal and Perinatal Health,* 2004-2008), and these birth weight values were used in the formula presented in the appendix of the article by Mikolajczyk et al. [18]. All newborns who were classified below or above three standard-deviations (SD) were pooled in two outlier categories (< -3 SD outliers and > 3 SD outliers), for presentation purposes.

Statistical analysis

The difference of gestational age in days was calculated, according to five categories: <-14; -14 to -8; -7 to 7, 8- to 4, and > 14 days. These difference ranges were selected for being cut-off points for discrepancy, in which a practitioner would replace an LMP-based gestational age for an US-based gestational age, being +/-7 days for a first trimester US, and +/-14 days for a second trimester US [5]. Positive values indicate that LMP-based gestational age estimates was higher than US-based estimates, whereas negative values indicate that LMP-based gestational age estimates was lower than US-based estimates.

The proportion of implausible gestational ages (< 18 weeks and ≥ 45 weeks) and outliers Z-scores of birth weight for gestational age (< -3 SD or > 3 SD) for all gestational age-estimation methods were calculated, and classified in order of increasing magnitude – from better to worse. Early US results were ranked first, as it was used as the method of reference. The analysis was stratified according to the source of payment of birth (public and private). Women whose birth was in public health-care facilities and women whose birth was in mixed facilities, but who were not covered by a private health insurance plans were considered as having a "public source of payment". Women whose birth was covered by a health insurance plan, whether birth was in mixed or private hospitals, and women whose birth was in private facilities, regardless of coverage by a health insurance plan were considered as having a "private source of payment".

This stratification was selected for being an easily accessible variable, which also reflects the way health services are organized, in addition of being a proxy variable for socioeconomic difference among these groups of women.

To assess the validity of the different methods to estimate the gestational age, intraclass correlation coefficients were calculated for both sources of payment (public and private) considering completed weeks of gestation.

To present the results, gestational age at birth was categorized in six groups (early premature: < 34 weeks; late premature: 34 to < 37 weeks; early term: 37 to < 39 weeks; full term: 39 to < 41 weeks; late term: 41 to < 42 weeks; and post-term: 42 < 45 weeks), considering the use of these gestational age ranges in the scientific literature to assess risk factors and perinatal outcomes [19,20].

Sensitivity, specificity and kappa concordance test were also calculated for the prematurity proportions (< 37 weeks of pregnancy). For these analyses, implausible gestational ages and outliers Z-scores of birth weight for gestational age were excluded, and pregnancy was considered an analysis unit, regardless of the outcome (live birth or stillbirth). The proportion of prematurity was calculated dividing the number of pregnancies of less than 37 weeks by the total number of pregnancies.

Considering the results from the previous analyses – related to implausible values, outliers, and concordance with early US of each method – an order of the methods used to calculate gestational age was established, and called an algorithm to calculate gestational age at birth. To calculate gestational age and proportion of prematurity with the use of the algorithm, information on all live births in the investigation was used, with the proportion of prematurity calculated by dividing the number of live births with less than 37 weeks by the total of live births.

In all stages, data was weighted according to the sample and analyzed considering complex samples, in order to incorporate the design effect. The analyses were performed with the use of the software IBM SPSS version 19 (IBM Corp., Armonk, United States) and Winpepi for Windows (http://www.brixtonhealth.com/pepi4windows.html).

This project was approved by the Research Ethics Committee, Sergio Arouca National School of Public Health, Oswaldo Cruz Foundation (ENSP/Fiocruz), authorization number 92/2010. Approval by the selected hospitals' Ethics Research Committees was sought, whenever required by their regulations.

Results

From the 23,940 postpartum women interviewed, 23,894 presented information from the maternal and the newborn medical records. Out of these women, 14,647 (61.3%) had information about US results, with 10,630 (44.5%) being of early US. During the interview, most of the postpartum women (23,231) mentioned the gestational age at birth, and a smaller number of women (18,728 - 78.4%) reported their LMP. Information on the LMP and gestational age registered in the maternal medical records (LMP-based or US-based) was available for 60.9%, 57.7% e 45.3% of the postpartum women, respectively.

The proportion of concordance (+/- 7 days) between the woman-reported LMP at the interview and the early US was 59.4%, with 24.6% of negative discordances (-14 to -8 and < -14 combined) and 16% of positive discordances (+8 to +14 and > +14 combined). This results showed a tendency for underestimation of the LMP-calculated gestational age (data not shown in a table).

The stratified analysis according to source of payment for childbirth shows that implausible gestational ages and outliers Z-scores of birth weight for gestational age were more frequent for women whose childbirth was paid by the public sector than for those paid by the private sector. US results showed similar frequencies for both implausible gestational ages and outliers, regardless of the time they were performed (Table 1).

Considering the two types of error (implausible gestational age and birth weight outliers), a top-down method, from better to worse, was established, for both public and private birthcare payment sources. Without considering US results, the US-based gestational age estimation method registered on the maternal medical records upon admission had the best result, followed by the gestational age reported by the postpartum woman at the interview, and lastly, the LMP-based methods, which, regardless of their origin, presented the highest frequencies of implausible gestational ages and outliers Z-scores of birth weight for gestational age , in both public and private birth payment sources (Table 1).

The crude proportion of prematurity, which included implausible gestational ages and birth weight outliers, ranged from 11.4%, when based on US results for any gestational age, to 16.9%, when based on the LMP registered on the maternal medical records for the public birthcare payment, and of 9.2%, when mentioned by the postpartum woman in the interview, to 14.9% if based on the LMP given in the interview, when source of payment was private. After excluding implausible gestational ages, the proportion of prematurity for public paid birthcare increased in almost all estimation methods, particularly those based on the LMP, once implausible gestational ages were concentrated in the ≥ 45 weeks group. The same was not true for private paid birthcare. After exclusion of outliers Z-scores of birth weight for gestational age, the proportion of prematurity decreased in both public and private

Table 1

Proportion of prematurity, implausible gestational ages, and outliers of birth weight for gestational age by the different gestational age estimation methods according to source of payment for the childbirth (public or private). Brazil, 2011-2012.

Method of estimation of gestational age at birth	n *	% prematurity *	Implausible gestational age (weeks)			n **	% prematurity **	Birthweight for gestational age outliers			n ***	% prematurity ***
			< 18 %	≥ 45 %	To-tal %			< -3DP %	> 3DP %	To-tal %		
Public												
Early US	8.391	12.0	0.1	1.5	1.6	8.257	12.1	0.3	2.8	3.1	7.948	10.1
US, any gestational age	12.190	11.4	0.0	1.8	1.8	11.966	11.6	0.2	2.5	2.7	11.542	9.8
US-based gestational age recorded on the maternal medical records	8.036	14.5	0.0	0.0	0.0	8.036	14.5	0.2	2.0	2.3	7.797	13.1
Gestational age stated by the woman in the interview	18.525	11.7	0.0	0.0	0.0	18.525	11.7	0.3	2.5	2.8	17.812	10.0
LMP-based gestational age recorded on the maternal chart	12.374	12.6	0.0	0.0	0.0	12.374	12.6	0.7	2.6	3.3	11.927	10.7
LMP recorded on the maternal chart	12.218	16.9	0.4	3.1	3.4	11.801	17.1	0.8	4.0	4.8	10.999	12.6
LMP stated by the woman in the interview	14.767	16.6	0.2	2.7	2.9	14.338	16.9	0.8	4.2	5.0	13.203	12.6
Private												
Early US	2.239	11.6	0.1	0.7	0.8	2.214	11.6	0.1	2.7	2.7	2.153	9.7
US, any gestational age	2.457	11.4	0.1	0.8	0.9	2.426	11.4	0.1	2.5	2.5	2.365	9.7
US-based gestational age recorded on the maternal chart	2.788	12.6	0.0	0.0	0.0	2.788	12.6	0.0	0.8	0.8	2.741	12.2
Gestational age stated by the woman in the interview	4.706	9.2	0.0	0.0	0.0	4.706	9.2	0.1	0.5	0.6	4.678	8.8
LMP- based gestational age recorded on the maternal chart	1.415	9.9	0.0	0.0	0.0	1.415	9.9	0.2	0.8	1.0	1.401	9.4
LMP recorded on the maternal chart	2.343	13.3	0.3	2.1	2.4	2.279	13.3	0.2	3.4	3.6	2.198	10.9
LMP stated by the woman in the interview	3.961	14.9	0.1	0.9	1.0	3.882	14.9	0.3	4.0	4.3	3.716	11.8

LMP: Last menstruation period; US: ultrasound imaging.

* Implausible gestational ages or outliers of birth weight for gestational age not excluded;

** After exclusion of implausible gestational ages;

*** After exclusion of implausible gestational ages and outliers of birth weight for gestational age;

Note: Early USI: performed between 7 weeks and 0 days, and 20 weeks and 6 days.

paid birthcare, as the outlier values were concentrated in the 3 SD and higher group. This was due to a higher frequency of premature, compared to full-term or post-term newborns, with birth weight incompatible with the estimated gestational age (Table 1).

Table 2 presents the five gestational age-estimation methods compared to the method of reference (early US), with an intraclass correlation coefficient order established, from best to worse. The two sources of birthcare payment (public and private) had significant and similar intraclass correlation coefficient, and the same ranking. It should be noted that all analyses performed, presented on Table 2, excluded both, implausible gestational ages and outliers Z-scores of birth weight for gestational age.

For the US-based gestational age method registered in the maternal medical records upon admission, US, the intraclass correlation coefficient was 0.954 for the public birthcare payment, and 0.936 for the private payment. For the method of gestational age reported by the postpartum woman at the interview, the coefficients were, respectively, 0.900 and 0.878. The three LMP-based gestational age methods presented lower intraclass correlation coefficients than the first two methods assessed, ranging from 0.898 to 0.848 for the public paid birthcare, and from 0.852 to 0.830 for the private (Table 2).

For the sensitivity to detect premature newborns, the method with the best result was, once again, the US-based gestational age method registered in the maternal medical records upon admission, for both sources of payment, public and private, with values of 84.9% and 76.2%, respectively. The worse results were for the methods LMP registered in the maternal medical records and LMP reported in the interview, with sensitivities of 70.6% and 69,4% for the public, and 74.9% and 72% for the private (Table 2).

Table 3 presents the proposed algorithm to estimate gestational age at birth, with the order of preference for each estimation method, and the number and proportion of postpartum women classified per each method. The order of preference of the methods was the same for both sources of payment, public and private, and was based on the lower frequency of outliers Z-scores of birth weight for gestational age and higher intraclass correlation coefficient, previously presented. Almost three fourths of postpartum women (74.1%) had the gestational age classified by US, 58.2% from the test result itself; 15.9% had the US-based gestational age registered on the maternal medical records; and 22.9% had their gestational age classified from the information provided in the interview. A very low proportion (1.1%) was classified by other methods. At the end, only 1.9% of the postpartum women were not classified (Table 3).

Table 4 presents the distribution of the gestational age at birth, estimated by US (method of reference) and by the algorithm proposed. The proportion of prematurity was 10.3% as indicated by early US, and 11.3% according to the algorithm. For the early US, the proportion of prematurity presented in this Table was slightly higher than the figure in Table 2, due to the different units of analysis used (total pregnancies in Table 2 and live births in Table 4).

Discussion

In this study, a careful exclusion of gestational age values with high likelihood of error was made (< 18 and ≥ 45 gestational weeks), which raised the confidence of the results found in this investigation. The existence of implausible gestational age information from both, LMP- and US- based estimates is due to the fact that dates were wrongly entered, leading data to be inconsistent with the calculated gestational age. In the case of LMP, it could have been the woman's mistaken recall, or a recording error on the hospital records. In the case of the US, the practitioner might have made a mistake while recording the date when the test was performed, or when transcribing it from the test to the medical records. This type of error is not seen when gestational age is registered in weeks, in which case gross errors would be easily noticed and confirmed from the weight and condition of the baby.

Another relevant aspect was the use of the fetal growth curve for outlier classification and exclusion, in order to minimize likely errors. Other studies have used this scheme to compare gestational-age assessment methods [3,21,22]. Such care seems appropriate for the Brazilian population, from the evidences of LMP-based gestational age estimation errors, with about 5% of outliers in birth weight for gestational age in the public, and 4% in the private sector.

It was noted that errors, implausible gestational ages and outliers, occurred more frequently among women whose birthcare was paid by the public sector versus the private sector, for all gestational-age estimation methods. For the US-based gestational-age estimation, differences between the public and private sectors were not expected, and may reflect differences in the quality of the tests. In its turn, gestational age given by the women and LMP-based gestational age estimations registered on the maternal medical records, the better results presented by the pri-

Table 2

Concordance between early US and the other gestational age estimation methods, and gestational age distribution in the public and private sectors after exclusion of implausible gestational ages and outliers of birth weight for gestational age. Brazil, 2011-2012.

	US performed between 7 and 20 weeks	US-based gestational age on maternal medical records	Gestational age reported by the woman in the interview	LMP-based methods		
				LMP-based gestational age on the maternal medical records	LMP on maternal medical records	LMP reported by the woman
Public						
Valid total *	7,948	3,965	7,936	5,560	5,236	6,152
ICC **	Reference	0.954	0.900	0.898	0.862	0.848
ICC (CI95%)	Reference	0.951-0.957	0.895-0.904	0.892-0.903	0.851-0.873	0.839-0.857
Rank of best ICCs	1	2	3	4	5	6
Gestational age ranges (%) [weeks]						
< 34	3.0	4.5	2.8	3.0	2.8	2.7
34 |--37	7.1	7.9	6.4	6.3	9.0	9.0
37 |--39	29.2	28.2	34.2	26.0	23.7	24.9
39 |--41	49.5	47.9	43.6	52.3	45.3	45.6
41 |--42	8.5	10.4	11.1	9.7	11.6	10.9
42 |--45	2.7	1.1	1.9	2.6	7.6	6.9
For prematurity ***	10.1	12.4	9.2	9.3	11.8	11.7
Kappa	Reference	0.83	0.69	0.68	0.63	0.60
Sensitivity (%)	Reference	84.9	68.0	70.3	70.6	69.4
Specificity (%)	Reference	98.0	97.3	97.3	95.5	94.6
Private						
Valid total *	2,153	1,346	2,120	746	1,170	1,804
ICC **	Reference	0.936	0.878	0.852	0.851	0.830
ICC (CI95%)	Reference	0.923-0.947	0.867-0.888	0.829-0.872	0.832-0.867	0.814-0.845
Rank of best ICCs	1	2	3	4	5	6
Gestational age ranges (%) [weeks]						
< 34	1.5	2.1	1.5	2.0	2.0	1.7
34 |--37	8.2	7.9	5.4	6.1	8.4	8.9
37 |--39	49.5	41.6	46.3	44.6	45.8	45.4
39 |--41	37.6	46.4	45.1	45.9	39.0	39.0
41 |--42	1.6	1.6	1.6	1.2	2.3	2.3
42 |--45	1.6	0.4	0.2	0.1	2.5	2.7
For prematurity ***	9.7	10.0	6.9	8.1	10.4	10.6
Kappa	Reference	0.78	0.75	0.74	0.71	0.66
Sensitivity (%)	Reference	76.2	66.0	68.4	74.9	72.0
Specificity (%)	Reference	98.2	99.4	98.7	97.0	96.2

ICC: intraclass correlation coefficient; LMP: last menstrual period; 95%CI: 95% confidence interval; US: ultrasound imaging.

* Total of women with gestational age estimated by the method of reference and by the method for comparison after exclusion of implausible gestational ages and outliers of birth weight for gestational age;

** Gestational age in completed weeks;

*** Premature vs. full-term and post-term combined.

Table 3

Order of preference for the use of each method to estimate gestational age at birth (calculation algorithm), and proportion of each method used. Brazil, 2011-2012.

Method for estimation of gestational age at birth:	Order of preference	Classified women					
		n *	%	n **	%	Algorithm ***	%
US (any gestational age)	1	14,647	61.3	13,907	58.2	13,907	58.2
US-based gestational age recorded on the maternal medical records	2	10,824	45.3	10,538	44.1	3,810	15.9
Gestational age reported by the woman in the interview	3	23,231	97.2	22,490	94.1	5,477	22.9
LMP-based gestational age recorded on the maternal medical records	4	13,789	57.7	13,328	55.8	146	0.6
LMP recorded on maternal medical records	5	14,561	60.9	13,197	55.2	56	0.2
LMP reported by the woman in the interview	6	18,728	78.4	16,919	70.8	53	0.2
Classified women						23,449	98.1
Non-classified women						445	1.9
Total of women						23,894	100.0

LMP: last menstruation period; USI: ultrasound imaging.

* Postpartum women with gestational age available per method, with no exclusion of implausible gestational ages or outliers of birth weight for gestational age;

** Postpartum women with gestational age available according to the method, after exclusion of implausible gestational ages and outliers of birth weight for gestational age;

*** Postpartum women with gestational age calculated according to the method in the final algorithm, after exclusion of implausible gestational ages and outliers of birth weight for gestational age.

Table 4

Comparison of gestational age at birth distribution estimated by early ultrasound (US) and the proposed algorithm – after exclusion of implausible gestational ages and outliers of birth weight for gestational age. Brazil, 2011-2012.

Gestational age (weeks)	US between 7 and 20 weeks			Algorithm		
	n	%	cumulative %	n	%	cumulative %
< 34	270	2.6	2.6	628	2.7	2.7
34	131	1.3	3.9	399	1.7	4.4
35	211	2.0	5.9	561	2.4	6.8
36	461	4.4	10.3	1,058	4.5	11.3
37	1,090	10.5	20.8	2,216	9.4	20.7
38	2,398	23.1	43.9	5,994	25.5	46.2
39	2,827	27.2	71.1	5,952	25.3	71.5
40	2,024	19.5	90.6	4,358	18.5	90.0
41	723	7.0	97.5	1,742	7.4	97.5
42	128	1.2	98.8	419	1.8	99.2
43	88	0.9	99.6	128	0.5	99.8
44	39	0.4	100.0	51	0.2	100.0
Live births classified	10,390	100.0		23,506	100.0	
Missing data	13,671	56.8		555	2.3	
All live births	24,061			24,061		

vate sector may be due to the better quality of information from the users of this sector, which was confirmed by the lower frequency of error when LMP information was provided directly by the woman at the interview. Another aspect that may contribute to a lower occurrence of error is the fact that, in the private sector, the prenatal practitioner is typically the one who will assist birth. [23].

It should be noted that, as the tool used did not allow the identification of women who paid for birthcare out-of-pocket, it is possible that some women who were attended in mixed facilities and were considered as being served by the public sector had actually paid for their birthcare. However, given that these women had socioeconomic characteristics similar to those served in public facilities, it is likely that this classification error occurred in a few cases only. As this is a non-differential classification error in relation to the investigated outcomes, one expects the magnitude of the observed associations to be lessened.

A much higher-than-expected proportion of outliers was found when US was the method of estimation; however, this frequency was slightly lower when late US was included (> 20 weeks). The estimation of gestational age with late USs, which use fetal measures (such as femur length, abdominal circumference, and biparietal diameter) as parameters may explain the lower occurrence of outliers, because with the progression of the pregnancy, fetal size variations become gestational age differences [24].

In this article, the proportion of prematurity was used to demonstrate how much these errors (implausible gestational age and outliers) affect gestational age estimation. The exclusion of implausible gestational age values, concentrated on values of > 45 weeks, did not change significantly the proportions of prematurity. On the other hand, the elimination of outliers related to values above 3 SD, significantly reduced the proportions of prematurity. These results show that errors are of both, gestational age overestimation (implausible, of more than 45 weeks), and underestimation (high proportion of values higher than 3 SD, more frequently found in newborns considered as premature). These corrections are advisable and currently necessary in Brazil, particularly for information from poorly-educated women, typically served by the public sector. Errors of gestational age estimation may cause misleading associations, when the characteristics of the mother are correlated to those of the newborns in individual analyses.

When the different gestational-age estimation methods were compared with early US (used as method of reference), it was seen that LMP showed the lower intraclass correlation coefficient. The proper entry of many numbers and recall biases from the women [9,10], in a setting of many unplanned pregnancies certainly aid to that. This pattern was seen in both types of birthcare payment (public and private); the latest composed of women with higher socioeconomic level. Gestational age estimated from US results, registered in the maternal medical records, was the method of stronger concordance with early US, which reinforced the decision to use primarily US-estimated gestational age performed at any gestational age in the algorithm. Local studies have demonstrated that the use of US for obstetric care is increasing in the country [25,26] and, in this study, the availability of reliable US information of childbirth was 60%, even in the absence of previous request.

It should be noted that the method of concordance of gestational age at birth reported by the mother at the interview with early US was higher than any LMP-based information (registered on the medical records or by the mother at the interview). It should be taken into account that the best gestational age information reported by the mother might have been influenced by results of US performed prior to admission for birth.

Using the algorithm for gestational age estimation proposed in this study, a proportion of prematurity of 11.3% was found, a figure similar to the one observed in local studies, but higher than values estimated by WHO and by SINASC data, which reinforces the observation of an increase in prematurity in Brazil in recent years. It should be stressed, however, that there are criticisms of the use of combined methods to estimate gestational age, as they present different accuracy levels [4,27]. Different prematurity proportions could be obtained if the proportion of women classified according to each method was different than the proportion observed. With the current recommendations for SINASC form filling, in which LMP is the primary method, higher proportions of prematurity are to be expected.

Among the limitations of this investigation, the first one to be pointed out is the use of US performed up to the 20th gestational week as a method of reference, since the most accurate estimation test is the one performed between the 10th and the 13th gestational weeks. Studies indicate, however, that US is a more accurate method than LMP, even if it is not performed so early in the pregnancy [16,17,28,29,30]. In addition, in Brazil, even considering that access to pre-natal care is almost universal (DATASUS. http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sinasc/cnv/nvuf.def),

it is known that before the 12th gestational week, its coverage is still low in the country [23]. Furthermore, there may be difficulties for scheduling the test, or some practitioners still may be unaware of the importance of early US to better estimate the gestational age.

Secondly, one can mention the use of US results as the method of reference in a non-standardized way, and by different practitioners is inapropriate for comparisons. As in this investigation we interviewed postpartum women, standardization of this test would be unfeasible. It should be highlighted that, in the daily care of childbirth facilities, it is the US tests performed by different practitioners in a non-standardized way that are available for the calculation of the gestational age, and for important medical decision making, being the results from this investigation more closely related to the daily practice of these practitioners.

It was not possible, either, to compare US results from different gestational ages, and only the earliest US examination performed was considered for each woman. However, a study with Brazilian women attended at the public health system showed that US performed after 20 gestational weeks presented percentages of concordance with early US higher than any other method [4].

Finally, an assessment of concordance was made for a reduced proportion of women (35% of the total), which only included those who reported LMP and also underwent early US examination. In this investigation, women who did not undergo early US had poorer education and were of lower socioeconomic classes (data not shown). It is likely that concordance between LMP and US in women with these characteristics is lower than the one found.

To conclude, this study showed that, in Brazil, LMP is considered a non-suitable method to estimate gestational age at birth, overestimating both prematurity and post-maturity, as opposed to the US, which is more accurate. Considering that prematurity is one of the most used indicators to predict perinatal outcomes and, later on, health conditions during childhood and adult life, it is crucial that gestational age be measured accurately. In SINASC, despite recent advancements, the registered information on gestational age is based primarily on LMP, which comes first in the order in which the form is completed. US performed in the first trimester of pregnancy , internationally recognized as the gold standard, is not mentioned; when it is used, it is registered in the “other methods” category, with no further specifications. Such SINASC form filling instruction should be reviewed, with more value placed on early US, including the date when the test was performed.

Resumen

El objetivo de este estudio fue verificar la validez de los diferentes métodos de estimación de la edad gestacional y proponer la creación de un algoritmo para calcular la edad gestacional en la investigación Nacer en Brasil. Se trata de un estudio de 2011 a 2012, con 23.940 mujeres en periodo de posparto. Como método de referencia utilizamos ecografías realizadas entre las 7 y 20 semanas de gestación. Todos los análisis se estratificaron por tipo de pago (público o privado). En comparación con la ecografía temprana, se encontraron significativos los coeficientes de correlación intraclase, tanto para el método de edad gestacional en el área de admisión, en base a la ecografía (0,95 y 0,94), como por el método de edad gestacional que informó la madre en la entrevista (0.90 y 0.88), para ambos tipos de servicio público y privado, respectivamente. Los datos sobre la base de la última menstruación mostraron coeficientes de correlación intraclase más pequeños. Este estudio sugiere precaución al usar la última menstruación, como primer método de estimación de la edad gestacional en Brasil, fortaleciéndose así el uso temprano de la información proveniente de la ecografía.

Edad Gestacional; Nacimiento Prematuro; Salud Materno-Infantil

Contributors

A. P. E. Pereira and M. C. Leal designed the article, conducted the field work, analyzed and interpreted the data, wrote, read and approved the final version of the manuscript. S. G. N. Gama and R. M. S. M. Domingues conducted the field work, analyzed and interpreted the data, wrote, read and approved the final version of the manuscript. A. O. C. Schilithz and M. H. Bastos took part in the analysis and interpretation of data, wrote, read and approved the final version of the manuscript.

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References

1. Mello-Jorge MHP, Laurenti R, Gotlieb SL. Análise da qualidade das estatísticas vitais brasileiras: a experiência de implantação do SIM e do SINASC. Ciênc Saúde Coletiva 2007; 12:643-54.
2. Departamento de Análise da Situação de Saúde, Secretaria de Vigilância em Saúde. Manual de instruções para o preenchimento da Declaração de Nascido Vivo. Brasília: Ministério da Saúde; 2011. (Série A Normas e Manuais Técnicos).
3. Callaghan WM, Dietz PM. Differences in birth weight for gestational age distributions according to the measures used to assign gestational age. Am J Epidemiol 2010; 171:826-36.
4. Pereira AP, Dias MA, Bastos MH, da Gama SG, Leal MC. Determining gestational age for public health care users in Brazil: comparison of methods and algorithm creation. BMC Res Notes 2013; 6:60.
5. Hoffman CS, Messer LC, Mendola P, Savitz DA, Herring AH, Hartmann KE. Comparison of gestational age at birth based on last menstrual period and ultrasound during the first trimester. Paediatr Perinat Epidemiol 2008; 22:587-96.
6. Wingate MS, Alexander GR, Buekens P, Vahratian A. Comparison of gestational age classifications: date of last menstrual period vs. clinical estimate. Ann Epidemiol 2007; 17:425-30.
7. National Institute for Health and Care Excellence. Antenal Care. Routine care for the healthy pregnant woman. London: National Institute for Health Care Excellence; 2008. (NICE clinical guideline 62).
8. World Health Organization. Home-based maternal records. Guidelines for development, adaptation and evaluation. Geneva: World Health Organization; 1994.
9. Waller DK, Spears WD, Gu Y, Cunningham GC. Assessing number-specific error in the recall of onset of last menstrual period. Paediatr Perinat Epidemiol 2000; 14:263-7.
10. Wegienka G, Baird DD. A comparison of recalled date of last menstrual period with prospectively recorded dates. J Womens Health (Larchmt) 2005; 14:248-52.
11. World Health Organization. Born too soon. The global action report on preterm birth. Geneva: World Health Organization; 2012.
12. Silveira MF, Barros FC, Sclowitz IK, Domingues MR, Mota DM, Fonseca SS, et al. Implementation of the INTERGROWTH-21st Project in Brazil. BJOG 2013; 120 Suppl 2:81-6.

13. Vasconcellos MTL, Silva PLN, Pereira APE, Schilithz AOC, Souza Junior PRB, Szwarcwald CL. Desenho da amostra *Nascer no Brasil*: Pesquisa Nacional sobre Parto e Nascimento. Cad Saúde Pública 2014; 30 Suppl:S49-58.
14. do Carmo Leal M, da Silva AA, Dias MA, da Gama SG, Rattner D, Moreira ME, et al. Birth in Brazil: national survey into labour and birth. Reprod Health 2012; 9:15.
15. Berg AT. Menstrual cycle length and the calculation of gestational age. Am J Epidemiol 1991; 133:585-9.
16. Whitworth M, Bricker L, Neilson JP, Dowswell T. Ultrasound for fetal assessment in early pregnancy. Cochrane Database Syst Rev 2010; (4):CD007058.
17. Caughey AB, Nicholson JM, Washington AE. First- vs second-trimester ultrasound: the effect on pregnancy dating and perinatal outcomes. Am J Obstet Gynecol 2008; 198:703 e1-5.
18. Mikolajczyk RT, Zhang J, Betran AP, Souza JP, Mori R, Gulmezoglu AM, et al. A global reference for fetal-weight and birth weight percentiles. Lancet 2011; 377:1855-61.
19. Spong CY, Mercer BM, D'Alton M, Kilpatrick S, Blackwell S, Saade G. Timing of indicated late-preterm and early-term birth. Obstet Gynecol 2011; 118 (2 Pt 1):323-33.
20. ACOG committee opinion no. 560: Medically indicated late-preterm and early-term deliveries. Obstet Gynecol 2013; 121:908-10.
21. Dietz PM, England LJ, Callaghan WM, Pearl M, Wier ML, Kharrazi M. A comparison of LMP-based and ultrasound-based estimates of gestational age using linked California livebirth and prenatal screening records. Paediatr Perinat Epidemiol 2007; 21:62-71.
22. Haglund B. Birth weight distributions by gestational age: comparison of LMP-based and ultrasound-based estimates of gestational age using data from the Swedish Birth Registry. Paediatr Perinat Epidemiol 2007; 21:72-8.
23. Viellas E, Domingues RMSM, Dias MAB, Gama SGN, Theme Filha MM, Costa JV, et al. Assistência pré-natal no Brasil. Cad Saúde Pública 2014; 30 Suppl:S85-100.
24. Konje JC, Abrams KR, Bell SC, Taylor DJ. Determination of gestational age after the 24th week of gestation from fetal kidney length measurements. Ultrasound Obstet Gynecol 2002; 19:592-7.
25. Gonçalves CV, Dias-da-Costa JS, Duarte G, Marcolin AC, Lima LC, Garlet G, et al. Avaliação da frequência de realização do exame físico das mamas, da colpocitologia cervical e da ultrassonografia obstétrica durante a assistência pré-natal: uma inversão de valores. Rev Assoc Méd Bras 2009; 55:290-5.
26. Chrestani MAD, Santos IS, Cesar JA, Winckler LS, Gonçalves TS, Neumann NA. Assistência à gestação e ao parto: resultados de dois estudos transversais em áreas pobres das regiões Norte e Nordeste do Brasil. Cad Saúde Pública 2008; 24:1609-18.
27. Hall ES, Folger AT, Kelly EA, Kamath-Rayne BD. Evaluation of gestational age estimate method on the calculation of preterm birth rates. Matern Child Health J 2014; 18:755-62.
28. Gardosi J, Geirsson RT. Routine ultrasound is the method of choice for dating pregnancy. Br J Obstet Gynaecol 1998; 105:933-6.
29. Kramer MS, McLean FH, Boyd ME, Usher RH. The validity of gestational age estimation by menstrual dating in term, preterm, and postterm gestations. JAMA 1988; 260:3306-8.
30. Morin I, Morin L, Zhang X, Platt RW, Blondel B, Breart G, et al. Determinants and consequences of discrepancies in menstrual and ultrasonographic gestational age estimates. BJOG 2005; 112:145-52.

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