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Commentary

Further improving the accuracy of fetal foot length to confirm gestational duration: additional data

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In both the context of obstetric and abortion care, accurate dating is critical. Happily, better ultrasound dating continues to improve providers' ability to estimate gestational duration. Another approach to gestational dating is measuring fetal foot length directly, which is a routine procedure during pathologic examination of fetal specimens. Legal problems may arise when gestational dating based upon the fetal foot length is not concordant with other gestational age estimates.

In 2005, we published data and reference tables based on 1099 procedural abortion cases (aspiration abortions and dilation and evacuations) between 10 to 24 weeks to improve the use of fetal foot length to confirm dating, with our complete methods described [1]. In comparing three models for dating (last menstrual period [LMP] only, LMP confirmed by ultrasound, and ultrasound only), we determined that directly measured fetal foot lengths correlated closely with both gestational age estimated by LMP correlated with ultrasound and by ultrasound alone, with these two approaches leading to such extremely similar results that we published only the former. By contrast, dating by LMP alone proved less reliable, especially with advancing gestational duration.

Our table of fetal foot length values has been adapted as the standard by the National Abortion Federation. Table 1 updates our previous paper to correct a typographical error identified in the original table describing foot

lengths based on LMP confirmed by ultrasound [1]. Table 2 includes additional ultrasound-only estimates, which do not improve the model significantly. However, given the larger ultrasound-only sample (1,099 vs. 491) and its basis using size measurements alone, calculations based on ultrasound alone allows us to tighten the standard error further (Table 2). We originally had not included these ultrasound-alone values because of their similarity to those determined by LMP confirmed by ultrasound.

The most important conclusion of our 2005 study was that the century-old Streeter [2] fetal foot length table commonly used by pathologists was outdated. Both Mokkarala [cite] and Stevens [cite] analyzed specimens in their institutions based on a similar concern. All three modern studies showed that measured fetal foot lengths are highly consistent with modern gestational age estimates, which allows us to rely on foot length measurements to estimate gestational age when necessary. All three of these studies found that ultrasound-based dating created the best fit between gestational age and fetal foot length. Across the three populations, there was substantial variation in race and ethnic identity as well as age of participants. With the addition of the 469 cases reviewed by Mokkarala and 610 cases reviewed by Stevens, we can see that the modeling results are consistent across more than 2,000 records. Across the studies, modeling exercises found that the foot length ranges continue to perform well in a variety of populations, that the values were not modified by age, race or ethnicity--potential differences that were not assessed by Streeter.

Mokkarala and Stevens also looked for variation in the model results by parity and body mass index and found no statistically significant relationship. These results give us confidence that one reference range can be applied across diverse settings without requiring adjustment for these characteristics.

When comparing model results of the two more recent studies to the ranges predicted by our 2005 model, few values fell outside of our predictions. In Stevens, all mean measurements were within 0-2 mm of our values. In Mokkarala, few data fell outside what our “best dating” model would predict and none of the predicted values from our model fell beyond the 24-week range.

All three modern studies make the convincing argument that the Streeter measurements, favored by some pathologists, are less accurate. Current in utero dating standards allow for more precision given the ability to incorporate ultrasound measurements, a technology that was not available in 1920.

The Streeter measurements are subject to several critical problems. In the pre-ultrasound era, Streeter necessarily relied upon LMP alone in his 704-specimen sample. Still more problematic is that Streeter obtained virtually all of his specimens after spontaneous abortions, which meant that any slowed fetal growth before demise and the exact timing of demise could not be known and thus could not be accounted for in his dating, along with his not excluding any cases with anomalies that might have led to demise and

altered measurements. The three modern studies were careful in considering conditions that would alter the relationship between gestational age and foot length and thus excluded cases of fetal demise and known fetal malformation. Given Streeter's reliance on spontaneous abortion specimens, where demise occurred at some unmeasured earlier time, Mokkarela, Stevens and Drey predictably found fetal foot lengths that were greater than Streeter's means, most strikingly at later gestations. In fact, the discordance between using Streeter's measurements to evaluate fetal foot length and the inutero ultrasonography-based gestational foot length age estimates is exactly what led us to do our original study.

Similar to Streeter's methods, in Stevens and Mokkarala, pathologists measured foot lengths after formalin fixation, whereas in Drey [1], providers made measurements before fixation. Despite these differences in measurement methodology, the values were similar across the three studies. Regarding concerns about fixed versus fresh specimens, Streeter commented that the concerns with changes caused by formalin fixation were more an issue of specimen weight rather than length. It is unlikely that any significant change in foot length would be caused by formalin, or that changes due to formalin (if any) would outweigh the other inaccuracies in Streeter's dating. Although it seems unlikely that formalin fixation would alter measurements by more than a millimeter, such concerns could be eased by making the measurement prior to fixation. Pathologists could compare fetal foot length measurements before and after formalin fixation in

order to assess whether any important differences emerge. The main advantage for pathologists in continuing to use Streeter's table would lie in the third trimester, because none of the modern, more precisely dated tables extend beyond 24 weeks, whereas Streeter's includes values from up to 40 weeks.

We can be reassured by the similar conclusions of Mokkarala, Stevens and Drey, which together make a powerful case to update fetal foot length standards based on modern pregnancy dating standards. Although the National Abortion Federation adopted our previous "best dates" data as their standard—that of LMP confirmed by ultrasonography--one could argue that the ultrasound-only dated model published here, with its larger sample size and smaller standard error values, should be used instead as the most precise standard for dating pregnancy duration by fetal foot lengths up to 24 weeks.

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144Table 1.

145Fetal foot length based on regression model using last menstrual period

146dating confirmed by ultrasonography

Gestational duration (wk)	Midpoint foot length	Range (beginning week to end of week)	Range +- 1SD
10 to 11	4	2–5	0–6
11 to 12	7	5–8	4–10
12 to 13	10	8–11	7–13
13 to 14	13	12–14	10–16
14 to 15	16	15–17	13–19
15 to 16	20	18–21	16–23
16 to 17	23	21–24	19–26
17 to 18	26	24–27	23–29
18 to 19	29	27–30	25–32
19 to 20	32	31–33	29–36
20 to 21	35	34–37	32–39
21 to 22	39	37–40	35–42
22 to 23	42	40–43	38–45
23 to 24	45	43–46	41–49
24 to 25	48	47–49	44–52

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149SD, standard deviation

* Weeks of gestational duration as measured by the “best estimate” (i.e., gestational duration by last menstrual period confirmed by ultrasonography within 1 standard deviation of last menstrual period).

** Foot length calculated by the model at the midpoint of the week (e.g., midpoint of 10 to < 11 = 10 weeks, 3.5 days).

*** Range represents the foot length values from the beginning to the end of the week (e.g., range of 10 to < 11 = values from 70 to 76 days).

159 Table 2. Fetal foot length based on regression model using dating by

160 ultrasonography alone*

Gestational duration			Midpoint foot length	Range (beginning week to end of week)	Range +- 1 SD
10	to	11	3	2-5	2-5
11	to	12	7	5-8	5-8
12	to	13	10	8-11	8-11
13	to	14	13	11-15	11-15
14	to	15	16	15-18	14-18
15	to	16	19	18-21	18-21
16	to	17	23	21-24	21-24
17	to	18	26	24-27	24-28
18	to	19	29	27-31	27-31
19	to	20	32	31-34	30-34
20	to	21	35	34-37	34-37
21	to	22	39	37-40	37-40
22	to	23	42	40-43	40-44
23	to	24	45	43-47	43-47
24	to	25	48	47-50	46-50

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163 * Weeks of gestational duration as measured by ultrasound,

164 determined by biparietal diameter, using Hadlock values.

** Foot length calculated by the model at the midpoint of the week (e.g., midpoint of 10 to < 11 = 10 weeks, 3.5 days).

*** Range represents the foot length values from the beginning to the end of the week (e.g., range of 10 to < 11 = values from 70 to 76 days).