Association of endometrial thickness with live birth rate: a study using the Society for Assisted Reproductive Technology Clinic Outcome Reporting System

Kathryn Schmiech, M.D.,[a] Mengmeng Li, M.D., M.S.P.H.,[b] Lucy X. Chen, M.D.,[c] Mark P. Dow, Ph.D.,[a] and Valerie L. Baker, M.D., M.P.P.[a]

[a] Division of Reproductive Endocrinology and Infertility, Department of Gynecology and Obstetrics, Johns Hopkins University School of Medicine, Lutherville, Maryland; [b] Department of Population, Family and Reproductive Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland; and [c] CCRM Fertility of Virginia Beach, Virginia Beach, Virginia

Objective: To assess the relationship between endometrial thickness (EMT) and live birth rates (LBRs) in fresh embryo transfer and frozen embryo transfer (FET) with and without preimplantation genetic testing (PGT).
Design: Retrospective cohort study using the Society for Assisted Reproductive Technology Clinic Outcome Reporting System.
Subjects: Autologous in vitro fertilization fresh embryo transfer and FET cycles initiated in 2019–2020.
Exposure: Endometrial thickness measured in millimeters.
Main Outcome Measures: Live birth rate.
Results: A total of 244,001 embryo transfer cycles met the inclusion criteria (100,419 FET cycles with PGT, 96,249 FET cycles without PGT, and 47,333 fresh embryo transfer cycles). An increase in EMT was associated with an increase in LBR among all cycle types until a threshold of 9 mm, after which there was minimal increase in LBR. Before 9 mm, each 1-mm increase in EMT was associated with a relative increase in the odds of live birth by 19% for FET with PGT (adjusted odds ratio [aOR], 1.19; 95% confidence interval [CI], 1.66–1.22), 13% for FET without PGT (aOR, 1.13; 95% CI, 1.09–1.16), and 15% for fresh embryo transfer (aOR, 1.15; 95% CI, 1.09–1.20).
Conclusion: The LBR increased with an increase in EMT for fresh and frozen transfers with or without PGT until a threshold of 9 mm, beyond which the LBR plateaued. There was no thickness above 9 mm associated with a decrease in LBR. (Fertil Steril® 2025;124:79–87. ©2025 by American Society for Reproductive Medicine.)
El resumen está disponible en Español al final del artículo.

Key Words: Endometrial thickness, frozen embryo transfer, preimplantation genetic testing, live birth rate

In patients undergoing in vitro fertilization (IVF), the endometrium is routinely evaluated before embryo transfer with an ultrasound measurement of the endometrial thickness (EMT), which is often used as a marker of expected endometrial receptivity. The impact of EMT is an area for possible intervention to improve IVF success; however, a minimal or maximum threshold remains controversial.

Although a thin endometrial lining has been associated with a decrease in live birth rate (LBR) (1–6), a thickness at which the birth rate declines or plateaus has not been established. When the endometrium is thin, the functional layer is thin or absent, allowing the embryo to implant closer to the spiral arteries with higher vascularity and inappropriately high oxygen concentration of the basal endometrium (7, 8). However, the data on EMT in both fresh embryo transfer and frozen embryo transfer (FET) are inconsistent. Particularly, data on FET remain limited, specifically frozen

Received July 11, 2024; revised December 28, 2024; accepted December 30, 2024; published online January 3, 2025.
Supported by the Edward E. Wallach Research Award at Johns Hopkins University School of Medicine, Baltimore, Maryland.
Presented in an oral presentation at the Pacific Coast Reproductive Society Annual Meeting, Indian Wells, California March 20–23, 2024.
Correspondence: Kathryn Schmiech, M.D., Division of Reproductive Endocrinology and Infertility, Department of Gynecology and Obstetrics, Johns Hopkins University School of Medicine, 10751 Falls Road, Falls Concourse Suite 280, Lutherville, Maryland 21093 (E-mail: Kschmie2@jhu.edu).

Fertil Steril® Vol. 124, No. 1, July 2025 0015-0282/$36.00

https://doi.org/10.1016/j.fertnstert.2024.12.032

transfer of embryos screened with preimplantation genetic testing (PGT) for aneuploidy (9). In addition to inconsistencies in the literature, there is a lack of US data with a large sample size.

The Society for Assisted Reproductive Technology (SART) Clinic Outcome Reporting System (CORS) database contains data from most assisted reproductive technology (ART) clinics in the United States and provides treatment details for research purposes (10). This study aimed to expand on current knowledge with the use of a nationally representative population to assess the relationship between EMT and LBR using the SART CORS database. Frozen embryo transfer cycles with and without PGT as well as fresh embryo transfer cycles were analyzed. We hypothesized an initial positive correlation of EMT with LBR and seek to determine if there is a threshold effect above which the LBR plateaus or declines.

MATERIALS AND METHODS

This study was reviewed and approved by the Johns Hopkins Institutional Review Board (IRB00377324).

Study population

The data used for this study were obtained from the SART CORS. Data were collected through voluntary submission, verified by SART, and reported to the Centers for Disease Control and Prevention in compliance with the Fertility Clinic Success Rate and Certification Act of 1992 (Public Law 102-493). SART maintains Health Insurance Portability and Accountability Act–compliant business associate agreements with reporting clinics. In 2004, after a contract change with the Centers for Disease Control and Prevention, SART gained access to the SART CORS data system for the purposes of conducting research. Over 90% of all ART cycles in the United States are performed at SART member clinics. The SART annually selects up to 10 clinics, approximately 2.5% of SART clinics, for an on-site validation visit using metrics and a blinded selection process to identify outlier clinics. Medical records are reviewed during the validation visit to verify the designation, outcome, and reporting of cycles. Clinics with significant systematic reporting errors undergo data correction. Six primary metrics and 26 secondary metrics are used for clinic selection. The metrics include low prospective reporting for both egg retrieval cycles and total cycles, high live birth rates in the various age groups, low cancellation rate, high percentage of total fertility preservation cycles, high percentage of embryo banking and oocyte banking cycles, high percentage of fertility preservation cycles where oocytes were thawed or embryos were transferred within a year, high percentage of deleted cycles, high percentage of cycles converted from intrauterine insemination, and low percentage of cycles in which no embryos were suitable for transfer with and without PGT. SART does not validate the accuracy of data entry fields such as gonadotropin dosage, number of oocytes retrieved, number of fertilized oocytes, number of embryos cryopreserved, PGT results, or demographic fields such age and diagnosis.

A proposal for the study was approved by the SART CORS Research Committee before providing deidentified data. Among initially requested data of a total of 586,239 cycles, 305,927 cycles represented autologous IVF fresh embryo transfer and FET cycles in SART CORS from 2019 to 2020. Embryo transfer cycles reported in 2021 with a linked autologous fresh or frozen IVF cycle start from 2019 to 2020 were also included in the data set. Only cycles in which an embryo transfer was performed were included. There were 9,223 cycles cancelled due to inadequate EMT. Cycles with missing information on EMT (n = 26,665), cycle outcome (n = 883), and PGT status (n = 33,780) were excluded. If the EMT was ≤ 1 or ≥ 30 mm, the cycle was excluded due to concern for input errors (n = 325). Cycles including a transfer of both fresh and thawed embryos were excluded (n = 273). A flowchart of study population selection is presented in Supplemental Figure 1 (available online).

Measures

Exposure and outcome. The exposure of interest was the EMT (continuous, measured in millimeter [mm]). Endometrial thickness was recorded by individual clinics in SART CORS with instructions to report the "most recent endometrial thickness in mm." The primary outcome was LBR (yes vs. no), reported per embryo transfer. The LBR was analyzed for all cycles and then stratified by cycle type (fresh vs. frozen transfer) and PGT status for FET (yes vs. no).

Covariates. On the basis of existing literature (11–14), we identified the following variables as the confounders that were adjusted in the regression analyses: maternal demographics (age at cycle start [continuous], race [White vs. Black vs. Asian vs. Hispanic Latino vs. Other vs. multiracial/multiethnicity], body mass index [BMI; normal, BMI of 18.50–24.99 kg/m^2, vs. underweight, BMI of $<$18.49 kg/m^2, vs. overweight, BMI of 25.0–29.99 kg/m^2, vs. obese, BMI of $\geq$30 kg/m^2], smoking [3 months before cycle start, no vs. yes], and parity [nulligravida vs. nonnulligravida]) and IVF cycle characteristics (cycle year [2019 vs. 2020 vs. 2021], infertility diagnosis [male factor vs. diminished ovarian reserve vs. polycystic ovary syndrome vs. endometriosis vs. uterine factor vs. tubal factor vs. multiple diagnoses vs. other vs. unexplained], ovarian stimulation protocol [no stimulation vs. agonist flare only vs. agonist suppression only vs. agonist flare and agonist suppression vs. agonist flare and antagonist suppression vs. agonist suppression and antagonist suppression], follicle-stimulating hormone [FSH] dosage [continuous], number of retrieved oocytes [continuous], and number of embryos transferred [continuous]). The estradiol and progesterone levels are not included in SART CORS data and, therefore, could not be included in the analysis. Operationalization of all covariates in the regression model is listed in Supplemental Table 1 (available online).

Statistical analysis

We first examined percentage of missingness on covariates and observed the magnitudes ranged from minimal to moderate on the following covariates: FSH dosage (0.02%); parity (0.08%); infertility diagnosis (8.74%); maternal smoking (10.62%); maternal BMI (11.80%); and maternal race (29.05%). We next conducted imputation by Multiple

Imputation by Chained Equations algorithm to address covariate missing values. Specifically, missing values on continuous, binary, categorical, and ordinal variables were imputed by predictive mean matching, logistic, multinomial logistic, and ordered logistic regression imputation methods, respectively. We performed 20 iterations for the burn-in period to obtain imputations, and a total of 50 imputed data sets were generated for subsequent regression analyses. Standard errors of the regression parameter estimates and the *P* values were computed using the Rubin rules (15).

We descriptively compared maternal demographics and IVF cycle characteristics between the final analytic population (n = 244,001) and the excluded population (n = 286,552) (Supplemental Table 2). The differed characteristics (defined by $P<.05$) were employed in a stabilized inverse probability weight computation, which was used in all logistic regression analyses to account for possible selection bias of our final analytic sample relative to the original study population.

Maternal and IVF cycle characteristics in preimputed data for the whole cohort and by EMT are shown within all cycles in Table 1, fresh cycles in Supplemental Table 3, frozen cycles without PGT in Supplemental Table 4, and frozen cycles with PGT in Supplemental Table 5. We performed descriptive comparisons for these characteristics by an EMT of ≤9 vs. >9 mm because this cutoff was used in the logistic regression described in the following. The continuous variables were compared by a Student's *t* test or Wilcoxon rank sum test contingent on distribution normality and equal variance. The binary and categorical variables were compared using a χ^2 test or Fisher's exact test as appropriate.

Logistic regression analyses were conducted within cycle type (fresh vs. frozen cycles without PGT vs. frozen cycles with PGT). We employed the restricted cubic spline method, without covariate adjustment, to examine linearity assumption between EMT (mm) and LBR among all cycles (Fig. 1) and within fresh cycles (Supplemental Fig. 2), frozen cycles without PGT (Supplemental Fig. 3), and frozen cycles with PGT cycles (Supplemental Fig. 4). An EMT cutoff, or knot, at 9 mm was chosen on the basis of the linearity assessment. Endometrial thickness was operationalized as a continuous variable, where we introduced a spline term with the cutoff at 9 mm in the regression analyses to model the nonlinear relationship. Association between EMT and LBR was then evaluated by stabilized inverse probability weight–weighted unadjusted and adjusted logistic regression as described earlier. Given correlations among multiple cycles from the same participant, we employed cluster-robust standard error estimation in the regression models. Odds ratios (ORs) were calculated to quantify the association, interpreted as the relative increase in the odds of live birth per 1-mm increase in EMT before and after the cutoff of 9 mm. Regression models for fresh and frozen cycles were adjusted for the same set of covariates listed in the covariates section, except for ovarian stimulation protocol and FSH dosage, which were adjusted for fresh but not for frozen cycles. The associations were further evaluated by embryo developmental stage (cleaved embryo vs. blastocyst transfer) for non-PGT cycles.

We conducted a series of sensitivity analyses to examine the robustness of our main findings. Particularly, we analyzed first transfer cycles (n = 163,538) to verify findings from the main models where statistical algorithm was applied to account for correlations from multiple cycles within a participant. An additional analysis adjusted for maternal age at embryo cryopreservation as a covariate for frozen transfers rather than FET cycle start. Furthermore, we controlled for recurrent pregnancy loss and removed smoking as a covariate given the small proportion of smokers in the population.

Given the number of regression analyses, the Bonferroni correction was used to redefine statistical significance. Using this correction, two-sided *P* values of $<.00625$ (0.05/8) were considered statistically significant, rather than .05. Statistical analyses were conducted using Stata MP 18.0 (StataCorp LLC, College Station, TX).

RESULTS

A total of 244,001 embryo transfer cycles met the inclusion criteria: 100,419 (41.2%) FET cycles with PGT; 96,249 (39.4%) FET cycles without PGT; and 47,333 (19.4%) fresh embryo transfer cycles. A flowsheet of included cycles is shown in Supplemental Figure 1. Demographic and cycle characteristics for all patients are shown in Table 1. Characteristics for participants within specific cycle type are presented in Supplemental Tables 3–5.

Among the total transfer cycles (n = 244,001), the mean age at cycle start was 35.1 years. Of those with race reported (70.9%), 69.5% were White, 14.3% were Asian, 7.5% were Black, and 6.8% were Latino, and 1.9% were other/multiracial. For cycles with BMI reported, 46.1% were normal weight, 26.3% were overweight, 25.6% were obese, 2.0% were underweight, and 11.8% had missing BMI. Most cycles included nonsmokers (98.3%). The most prevalent infertility diagnosis for undergoing an IVF cycle was male factor (26.4%), and approximately one fifth (17.4%) of cycles were performed due to multiple infertility diagnoses. Single embryo transfer was predominant across cycle types (fresh cycles, 57.3%, vs. frozen cycles without PGT, 72.3%, vs. frozen cycles with PGT, 95.1%). Blastocyst embryo transfer accounted for 87.9% of total cycles.

In terms of EMT, there were 2,585 with an EMT of <6 mm (1.1%), 7,050 with an EMT of 6–7 mm (2.9%), 26,935 (11.0%) with an EMT of 7–8 mm, 50,041 (20.5%) with an EMT of 8–9 mm, 46,829 (19.2%) with an EMT of 9–10 mm, and 110,561 (45.3%) with an EMT of ≥ 10 mm.

Crude and adjusted associations between EMT and LBR are presented in Table 2. Odds ratios represent the relative changes in the odds of live birth per 1-mm increase in EMT. The univariate linearity assumption (Fig. 1) showed a nonlinear relationship between LBR and EMT with the cut point at 9 mm. Therefore, separate ORs were given for EMTs of ≤9 and >9 mm. Collinearity was not observed from the regression model as indicated by total variance inflation factors of 2.04, 1.80, and 1.74 for fresh cycles, frozen cycles without PGT, and frozen cycles with PGT, respectively.

For FET with PGT, each 1-mm increase in EMT was associated with a relative increase in the odds by 19% (adjusted OR

TABLE 1

Demographic and in vitro fertilization cycle characteristics among all analytic cycles.

Demographics and cycle characteristics	Total N = 244,001	EMT ≤9 mm N = 101,254	EMT >9 mm N = 142,747	*P* value
Maternal demographics				
Age at treatment cycle start (mean [SD])	35.1 (4.4)	35.2 (4.3)	35.0 (4.4)	<.001
Race				<.001
White	120,282 (69.5%)	50,468 (71.7%)	69,814 (68.0%)	
Black	13,036 (7.5%)	4,705 (6.7%)	8,331 (8.1%)	
Asian	24,804 (14.3%)	9,689 (13.8%)	15,115 (14.7%)	
Hispanic Latino	11,686 (6.8%)	4,188 (5.9%)	7,498 (7.3%)	
Other	801 (0.5%)	311 (0.4%)	490 (0.5%)	
Multiracial/multiethnicity	2,502 (1.4%)	1,040 (1.5%)	1,462 (1.4%)	
Missing	70,890 (29.1%)	30,853 (30.5%)	40,037 (28.0%)	
BMI				<.001
Normal	99,122 (46.1%)	43,104 (48.7%)	56,018 (44.2%)	
Underweight	4,405 (2.0%)	2,003 (2.3%)	2,402 (1.9%)	
Overweight	56,528 (26.3%)	22,747 (25.7%)	33,781 (26.7%)	
Obese	55,150 (25.6%)	20,625 (23.3%)	34,525 (27.2%)	
Missing	28,796 (11.8%)	12,775 (12.6%)	16,021 (11.2%)	
Nulligravida				<.001
No	155,524 (63.8%)	63,472 (62.7%)	92,052 (64.5%)	
Yes	88,293 (36.2%)	37,718 (37.3%)	50,575 (35.5%)	
Missing	184 (0.1%)	64 (0.1%)	120 (0.1%)	
Smoking (3 mo before cycle start)				.018
No	214,477 (98.3%)	88,901 (98.3%)	125,576 (98.4%)	
Yes	3,600 (1.7%)	1,563 (1.7%)	2,037 (1.6%)	
Missing	25,924 (10.6%)	10,790 (10.7%)	15,134 (10.6%)	
IVF cycle characteristics				
Reporting cycle year				<.001
2019	107,825 (44.2%)	43,818 (43.3%)	64,007 (44.8%)	
2020	105,920 (43.4%)	43,980 (43.4%)	61,940 (43.4%)	
2021[a]	30,256 (12.4%)	13,456 (13.3%)	16,800 (11.8%)	
Infertility diagnosis				<.001
Male factor	58,694 (26.4%)	23,347 (25.5%)	35,347 (27.0%)	
Diminished ovarian reserve	25,294 (11.4%)	11,080 (12.1%)	14,214 (10.8%)	
PCOS	1,589 (0.7%)	763 (0.8%)	826 (0.6%)	
Endometriosis	8,980 (4.0%)	3,354 (3.7%)	5,626 (4.3%)	
Uterine factor	5,085 (2.3%)	2,489 (2.7%)	2,596 (2.0%)	
Tubal factor	18,298 (8.2%)	6,890 (7.5%)	11,408 (8.7%)	
Multiple diagnosis	38,651 (17.4%)	15,799 (17.2%)	22,852 (17.4%)	
Other	33,784 (15.2%)	14,581 (15.9%)	19,203 (14.7%)	
Unexplained	32,305 (14.5%)	13,339 (14.6%)	18,966 (14.5%)	
Missing	21,321 (8.7%)	9,612 (9.5%)	11,709 (8.2%)	
Ovarian stimulation protocol				<.001[b]
No ovarian stimulation	174,165 (71.4%)	78,204 (77.2%)	95,961 (67.2%)	
Agonist flare only	6,397 (2.6%)	2,087 (2.1%)	4,310 (3.0%)	
Agonist suppression only	26,301 (10.8%)	9,559 (9.4%)	16,742 (11.7%)	
Antagonist suppression only	36,896 (15.1%)	11,309 (11.2%)	25,587 (17.9%)	
Agonist flare and agonist suppression	9 (0.0)	4 (0.0)	5 (0.0)	
Agonist flare and antagonist suppression	125 (0.1%)	44 (0.0)	81 (0.1%)	
Agonist suppression and antagonist suppression	108 (0.0)	47 (0.0)	61 (0.0)	
No. of retrieved oocytes (median [IQR])	15 (9–22)	15 (9–22)	15 (9–22)	<.001[c]
No. of embryos transferred				<.001[c]
Fresh cycles				
1	27,106 (57.3%)	7,838 (54.7%)	19,268 (58.4%)	
2	16,412 (34.7%)	5,147 (35.9%)	11,265 (34.1%)	
3+	3,815 (8.1%)	1,354 (9.4%)	2,461 (7.5%)	
Frozen cycles without PGT				
1	69,668 (72.3%)	29,711 (71.8%)	39,957 (72.8%)	
2	24,610 (25.6%)	10,669 (25.8%)	13,941 (25.4%)	
3+	1,971 (2.1%)	978 (2.4%)	993 (1.8%)	

Schmiech. Endometrial thickness and live birth. Fertil Steril 2025.

TABLE 1

Continued.

Demographics and cycle characteristics	Total N = 244,001	EMT ≤9 mm N = 101,254	EMT >9 mm N = 142,747	*P* value
Frozen cycles with PGT				
1	95,483 (95.1%)	43,352 (95.2%)	52,131 (95.0%)	
2	4,867 (4.9%)	2,166 (4.8%)	2,701 (4.9%)	
3+	69 (0.1%)	39 (0.1%)	30 (0.1%)	
Assisted hatching (all embryos)				<.001
No	65,403 (27.0%)	24,444 (24.3%)	40,959 (28.9%)	
Yes	176,651 (73.0%)	76,032 (75.7%)	100,619 (71.1%)	
Missing	1,947 (0.8%)	778 (0.8%)	1,169 (0.8%)	
Embryo developmental stage at transfer				<.001
Cleaved embryo	29,579 (12.1%)	11,668 (11.5%)	17,911 (12.5%)	
Blastocyst	214,422 (87.9%)	89,586 (88.5%)	124,836 (87.5%)	
Live birth				<.001
No	133,877 (54.9%)	57,796 (57.1%)	76,081 (53.3%)	
Yes	110,124 (45.1%)	43,458 (42.9%)	66,666 (46.7%)	

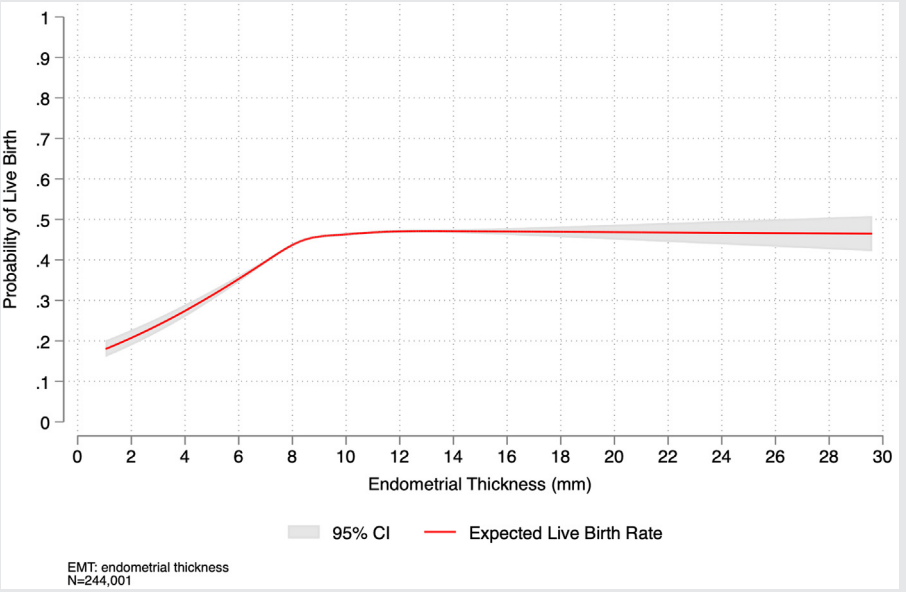
Note: Distribution of each indicator was computed among cycles with complete information, excluding cycles with missing values on a particular indicator. BMI = body mass index; EMT = endometrial thickness; IQR = interquartile range; IVF = in vitro fertilization; PCOS = polycystic ovary syndrome; PGT = preimplantation genetic testing.
[a] Transfer cycles reported in 2021 that were linked to a retrieval or frozen embryo transfer cycle start in 2019–2020 were included.
[b] Fisher's exact test.
[c] Wilcoxon rank sum test.

Schmiech. Endometrial thickness and live birth. Fertil Steril 2025.

[aOR], 1.19; 95% confidence interval [CI], 1.16–1.22) up to 9 mm and a 2% (aOR, 1.02; 95% CI, 1.00–1.03) increase beyond 9 mm. For FET without PGT, each 1-mm increase in EMT was associated with a 13% (aOR, 1.13; 95% CI, 1.09–1.16) increase in the odds up to 9 mm and a 2% (aOR, 1.02; 95% CI, 1.01–1.04) increase beyond 9 mm. Among fresh cycles, each 1-mm increase in EMT was associated with an increased odds of 15% (aOR, 1.15; 95% CI, 1.09–1.20) when EMT was ≤9 mm and of 4% (aOR, 1.04; 95% CI, 1.02–1.06) when EMT was >9 mm. For all cycle types, there was no maximum thickness over 9 mm at which the LBR declined.

The analyses were further stratified by embryo development stage (Table 3). We similarly observed that increased odds of live birth were associated with a 1-mm increase in

FIGURE 1



Univariate linearity assessments for endometrial thickness (EMT) and probability of live birth in all cycles (N = 244,001). CI = confidence interval.

Schmiech. Endometrial thickness and live birth. Fertil Steril 2025.

TABLE 2

Association between endometrial thickness and live birth by cycle type.

Live birth	Crude OR (95%CI)	Adjusted OR (95% CI)	*P* value	Statistical significance (after Bonferroni correction)
Fresh cycles (N = 47,333)	Crude OR (95% CI)	Adjusted OR (95% CI)[a]		
EMT ≤9 mm	1.20 (1.15–1.25)	1.15 (1.09–1.20)	<.001	Significant
EMT >9 mm	1.06 (1.04–1.07)	1.04 (1.02–1.06)	<.001	Significant
Frozen cycles without PGT (N = 96,249)	Crude OR (95% CI)	Adjusted OR (95% CI)[b]		
EMT ≤9 mm	1.14 (1.11–1.17)	1.13 (1.09–1.16)	<.001	Significant
EMT >9 mm	1.02 (1.01–1.04)	1.02 (1.01-1.04)	<.001	Significant
Frozen cycles with PGT (N = 100,419)	Crude OR (95% CI)	Adjusted OR (95% CI)[b]		
EMT ≤9 mm	1.18 (1.15–1.21)	1.19 (1.16–1.22)	<.001	Significant
EMT >9 mm	1.01 (1.00–1.03)	1.02 (1.00–1.03)	<.001	Significant

Note: Odds ratios represent the relative changes in the odds of live birth per 1-mm increase in endometrial thickness, separately for EMTs of ≤9 and >9 mm. Statistical significance after Bonferroni correction was determined by a *P* value of <.00625 (0.05/8). CI = confidence interval; EMT = endometrial thickness; OR = odds ratio; PGT = preimplantation genetic testing.
[a] Model adjusted for maternal demographics (age at cycle start, race, body mass index, smoking, and parity) and in vitro fertilization cycle characteristics (cycle year, infertility, ovarian stimulation protocol, follicle-stimulating hormone dosage, number of retrieved oocytes, number of embryos transferred, PGT, and embryo developmental stage).
[b] Model adjusted for maternal demographics (age at cycle start, race, body mass index, smoking, and parity) and in vitro fertilization cycle characteristics (cycle year, infertility, number of retrieved oocytes, number of embryos transferred, and embryo developmental stage).

Schmiech. Endometrial thickness and live birth. Fertil Steril 2025.

EMT when EMT was ≤9 mm, whereas there was minimal or no increase in the odds of live birth when EMT exceeded this threshold. After adjusting for maternal demographics and cycle characteristics, a 1-mm increase in EMT up to 9 mm was associated with increased odds of live birth by 16% (aOR, 1.16; 95% CI, 1.08–1.24) for cleaved embryo transfers and 13% (aOR, 1.13; 95% CI, 1.09–1.18) for blastocyst transfers among fresh cycles, by 15% (aOR, 1.15; 95% CI, 1.04–1.28) for cleaved embryo transfers and 12% (aOR, 1.12; 95% CI, 1.09–1.14) for blastocyst transfers among frozen cycles without PGT, and by 18% (aOR, 1.18; 95% CI, 1.15–1.20) for blastocyst transfers among frozen cycles with PGT. Using a *P* value adjusted for multiple regression analyses, the association between EMT and LBR was statistically significant for

TABLE 3

Association between endometrial thickness and live birth on the basis of cycle type and embryo developmental stage.

Live birth	Crude OR (95% CI)	Adjusted OR (95% CI)	*P* value	Statistical significance (after Bonferroni correction)
Fresh cycles	Crude OR (95% CI)	Adjusted OR (95% CI)[a]		
Cleaved embryo transfer (N = 17,521)				
EMT ≤9 mm	1.19 (1.11–1.25)	1.16 (1.08–1.24)	<.001	Significant
EMT >9 mm	1.03 (1.01–1.06)	1.02 (0.99–1.05)	.126	Nonsignificant
Blastocyst transfer (N = 29,812)				
EMT ≤9 mm	1.16 (1.12–1.21)	1.13 (1.09–1.18)	<.001	Significant
EMT >9 mm	1.06 (1.04–1.07)	1.06 (1.05–1.07)	<.001	Significant
Frozen cycles without PGT	Crude OR (95% CI)	Adjusted OR (95% CI)[b]		
Cleaved embryo transfer (N = 9,818)				
EMT ≤9 mm	1.17 (1.05–1.31)	1.15 (1.04–1.28)	.009	Nonsignificant
EMT >9 mm	1.01 (0.97–1.06)	1.01 (0.96–1.06)	.791	Nonsignificant
Blastocyst transfer (N = 86,431)				
EMT ≤9 mm	1.13 (1.10–1.15)	1.12 (1.09–1.14)	<.001	Significant
EMT >9 mm	1.02 (1.01–1.03)	1.03 (1.02–1.04)	<.001	Significant
Frozen cycles with PGT	Crude OR (95% CI)	Adjusted OR (95% CI)[b]		
Blastocyst transfer (N = 98,179)				
EMT ≤9 mm	1.17 (1.15–1.20)	1.18 (1.15–1.20)	<.001	Significant
EMT >9 mm	1.02 (1.01–1.03)	1.02 (1.01–1.03)	<.001	Significant

Note: Odds ratios represent the relative changes in the odds of live birth per 1-mm increase in endometrial thickness, separately for EMTs of ≤9 and >9 mm. Statistical significance after Bonferroni correction was determined by a *P* value of <.00625 (0.05/8). CI = confidence interval; EMT = endometrial thickness; OR = odds ratio; PGT = preimplantation genetic testing.
[a] Model adjusted for maternal demographics (age at cycle start, race, body mass index, smoking, and parity) and in vitro fertilization cycle characteristics (cycle year, infertility, ovarian stimulation protocol, follicle-stimulating hormone dosage, number of retrieved oocytes, and number of embryos transferred).
[b] Model adjusted for maternal demographics (age at cycle start, race, body mass index, smoking, and parity) and in vitro fertilization cycle characteristics (cycle year, infertility, number of retrieved oocytes, and number of embryos transferred).

Schmiech. Endometrial thickness and live birth. Fertil Steril 2025.

all blastocyst transfer cycles. However, the association in cleaved FET was not statistically significant, although the CI did not cross 1 due to the importance of correcting for multiple regression analyses (Table 3).

tWhen analyzing first transfer cycles only, the associations were consistent with the initial findings (Supplemental Tables 6 and 7). Additional analyses including adjusting for maternal age at embryo cryopreservation rather than transfer cycle start in FET cycles, adjusting for a diagnosis of recurrent pregnancy loss, and removing smoking all showed consistent associations (Supplemental Tables 8–13). We additionally performed the regression analysis with the full data without imputation to examine the impact of imputed data on associations of interest, and the results were very consistent with those from multiple imputations data (Supplemental Tables 14 and 15).

DISCUSSION

To our knowledge, this is the largest study to date examining the relationship between EMT and LBR and includes a diverse US population with the largest sample of FET with PGT. In this cohort, the LBR increased with each 1-mm increase in EMT. This association was more significant when EMT was $\leq$9 mm. After an EMT of 9 mm, the association between LBR and EMT plateaued with $\leq$5% increase in LBR per 1-mm increase in EMT. This association was noted in fresh embryo transfer and FET with or without PGT. The results represent the relative change in the odds of live birth per 1-mm increase in EMT. For example, in someone with an estimated chance of live birth of 40%, a relative increase of 19% now gives an LBR of 47.6% with a 1-mm increase in EMT.

The associations were significant particularly for blastocyst transfers, whereas after adjusting the *P* value for the number of regression models, the association for cleavage-stage transfers were nonsignificant. This is possibly due to the fact that there were fewer cleavage-stage transfers available for analysis. The fact that there was no upper limit above which the LBR decreased is reassuring that the endometrium was not "too thick" in the ART population who often will have had screening of the uterine cavity to rule out abnormalities such as endometrial polyps before embryo transfer.

These results are consistent with a Canadian retrospective database study by Mahutte et al. (1) of fresh embryo transfer and FET that reported a plateau in LBRs after EMTs of 10–12 mm in fresh embryo transfer and 7–10 mm in FET but no thickness at which the LBRs worsened. The investigators noted that an EMT of $<$6 mm significantly reduced the chance of live birth. This study evaluated EMT in 2-mm increments and did not include information on PGT status. An additional Canadian database study by Liu et al. (2) reported a decrease in LBR with each millimeter decrease in EMT below 8 mm for fresh embryo transfer and 7 mm for FET. However, the investigators recommended that larger cohort studies, including those with a larger number of cycles with an EMT of $<$7 mm such as ours, were needed to confirm their findings. These studies differ from that by Shakerian et al. (16) who found in a single-center study that EMT was not associated with live birth in fresh embryo transfer or FET. This study also differed from ours in that the investigators did not distinguish PGT from non-PGT cycles. Ata et al. (17) investigated frozen euploid blastocyst transfers and reported no threshold under which the LBR decreased. None of these involved a US population.

This study contributes significantly to the field through several strengths. First, our findings and conclusions were made on the basis of a nationally representative sample, which enhances their generalizability. The size of the data set compared with prior literature, particularly the large number of cycles with thin endometrium and the large number of PGT cycles, is a strength of our study. Furthermore, in our regression analyses, we controlled for maternal and IVF cycle characteristics to minimize confounding effects. Additionally, we applied inverse probability weighting to the analyses to minimize the risk of sample selection bias. We performed a separate analysis of first transfer cycles only, which showed consistent results with the whole cohort. Finally, we analyzed the data per 1-mm increase in EMT, and our cut point of 9 mm was based on an initial linearity assessment of the relationship.

There are several limitations associated with our study. Given the observational data with a retrospective design, our findings cannot infer a causal relationship between EMT and LBR. Although we controlled for a comprehensive set of confounders, our results remain subject to unmeasured confounding. Furthermore, SART CORS does not include data regarding endometrial preparation protocols, endometrial pattern (18), or reproducibility of endometrial assessment between sonographers. Although many cycles with thin lining were included, the data regarding the EMT for cancelled cycles are limited because we do not have information regarding cutoffs for which particular clinics may cancel.

It is important to note that nonmodifiable factors that influenced EMT may not be captured in these observational data. Some patients may not be able to achieve a thickness of 9 mm due to inherent uterine factors, and given that there are pregnancies in cycles with lower EMT, the results of this study should not preclude embryo transfer. Future studies could compare if switching to a different FET protocol in the same patient results in a different EMT and improved chance of live birth.

CONCLUSION

In this large data set, the LBR increased with increasing EMT for fresh and frozen transfers, with or without PGT, up to a threshold of 9 mm. Beyond this threshold, the LBR plateaued. There was no thickness above 9 mm associated with a decrease in LBR. This study can be used for patient counseling but, given the limitations of observational data, should not be used to preclude embryo transfer for cycles in which the endometrial lining does not attain a specific EMT.

Acknowledgments

The authors thank the Society for Assisted Reproductive Technology (SART) for the data set and all SART members for providing clinical information to the SART Clinic Outcome Reporting System database for use by researches. Without the efforts of SART members, this research would not have been possible.

CRediT Authorship Contribution Statement

Kathryn Schmiech: Writing – original draft, Methodology, Funding acquisition, Conceptualization. **Mengmeng Li:** Writing – review & editing, Methodology, Formal analysis. **Lucy X. Chen:** Writing – review & editing, Conceptualization. **Mark P. Dow:** Writing – review & editing, Conceptualization. **Valerie L. Baker:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of Interests

K.S. has nothing to disclose. M.L. has nothing to disclose. L.X.C. has nothing to disclose. M.P.D. has nothing to disclose. V.L.B. is on the Society for Assisted Reproductive Technology Executive Council.

REFERENCES

1. Mahutte N, Hartman M, Meng L, Lanes A, Luo ZC, Liu KE. Optimal endometrial thickness in fresh and frozen-thaw in vitro fertilization cycles: an analysis of live birth rates from 96,000 autologous embryo transfers. Fertil Steril 2022;117:792–800.
2. Liu KE, Hartman M, Hartman A, Luo ZC, Mahutte N. The impact of a thin endometrial lining on fresh and frozen-thaw IVF outcomes: an analysis of over 40 000 embryo transfers. Hum Reprod 2018;33:1883–8.
3. El-Toukhy T, Coomarasamy A, Khairy M, Sunkara K, Seed P, Khalaf Y, et al. The relationship between endometrial thickness and outcome of medicated frozen embryo replacement cycles. Fertil Steril 2008;89:832–9.
4. Bu Z, Wang K, Dai W, Sun Y. Endometrial thickness significantly affects clinical pregnancy and live birth rates in frozen-thawed embryo transfer cycles. Gynecol Endocrinol 2016;32:524–8.
5. Gallos ID, Khairy M, Chu J, Rajkhowa M, Tobias A, Campbell A, et al. Optimal endometrial thickness to maximize live births and minimize pregnancy losses: analysis of 25,767 fresh embryo transfers. Reprod Biomed Online 2018;37:542–8.
6. Kasius A, Smit JG, Torrance HL, Eijkemans MJ, Mol BW, Opmeer BC, et al. Endometrial thickness and pregnancy rates after IVF: a systematic review and meta-analysis. Hum Reprod Update 2014;20:530–41.
7. Casper RF. It's time to pay attention to the endometrium. Fertil Steril 2011;96:519–21.
8. Catt JW, Henman M. Toxic effects of oxygen on human embryo development. Hum Reprod 2000;15:199–206.
9. (The writing group) for the participants to the 2022 Lugano RIF Workshop, Pirtea P, Cedars MI, Devine K, Ata B, Franasiak J, et al. Recurrent implantation failure: reality or a statistical mirage?: consensus statement from the July 1, 2022 Lugano workshop on recurrent implantation failure. Fertil Steril 2023;120:45–59.
10. Curchoe CL, Tarafdar O, Aquilina MC, Seifer DB. SART CORS IVF registry: looking to the past to shape future perspectives. J Assist Reprod Genet 2022;39:2607–16.
11. Luke B, Brown MB, Stern JE, Missmer SA, Fujimoto VY, Leach R. Racial and ethnic disparities in assisted reproductive technology pregnancy and live birth rates within body mass index categories. Fertil Steril 2011;95:1661–6.
12. Klonoff-Cohen H, Natarajan L, Marrs R, Yee B. Effects of female and male smoking on success rates of IVF and gamete intra-fallopian transfer. Hum Reprod 2001;16:1382–90.
13. Kim HO, Sung N, Song IO. Predictors of live birth and pregnancy success after in vitro fertilization in infertile women aged 40 and over. Clin Exp Reprod Med 2017;44:111–7.
14. Kluge L, Källén K, Thurin-Kjellberg A, Wennerholm UB, Bergh C. The association between body mass index and live birth and maternal and perinatal outcomes after in-vitro fertilization: a national cohort study. Front Endocrinol (Lausanne) 2023;14:1239702.
15. Rubin DB. Multiple imputation for nonresponse in surveys. New Jersey: John Wilety & Sons, Inc.; 2004.
16. Shakerian B, Turkgeldi E, Yildiz S, Keles I, Ata B. Endometrial thickness is not predictive for live birth after embryo transfer, even without a cutoff. Fertil Steril 2021;116:130–7.
17. Ata B, Liñán A, Kalafat E, Ruíz F, Melado L, Bayram A, et al. Effect of the endometrial thickness on the live birth rate: insights from 959 single euploid frozen embryo transfers without a cutoff for thickness. Fertil Steril 2023;120:91–8.
18. Gingold JA, Lee JA, Rodriguez-Purata J, Whitehouse MC, Sandler B, Grunfeld L, et al. Endometrial pattern, but not endometrial thickness, affects implantation rates in euploid embryo transfers. Fertil Steril 2015;104:620–8.e5.

Asociación del grosor endometrial con la tasa de nacidos vivos: estudio mediante el sistema de notificación de resultados clínicos de la Sociedad de Tecnología de Reproducción Asistida

Objetivo: evaluar la relación entre el grosor endometrial (GE) y las tasas de nacidos vivos (TNV) en la transferencia de embriones frescos y la transferencia de embriones congelados (TEC) con y sin pruebas genéticas preimplantacionales (PGP).

Diseño: estudio de cohortes retrospectivo utilizando el sistema de notificación de resultados clínicos de la Sociedad de Tecnología de Reproducción Asistida.

Sujetos: transferencia de embriones frescos de fertilización in vitro autóloga y ciclos de TEC iniciados en 2019 a 2020.

Exposición: grosor endometrial medido en milímetros.

Criterios de valoración principales: tasa de nacidos vivos.

Resultados: un total de 244.001 ciclos de transferencia de embriones cumplieron los criterios de inclusión (100.419 ciclos de TEC con PGP, 96.249 ciclos de TEC sin PGP y 47.333 ciclos de transferencia de embriones frescos). Un aumento del GE se asoció a un aumento de la TNV en todos los tipos de ciclos hasta un umbral de 9 mm, a partir del cual el aumento de la TNV fue mínimo. Antes de los 9 mm, cada aumento de 1 mm en el GE se asoció con un aumento relativo de las probabilidades de nacidos vivos del 19 % para la TEC con PGP (razón de posibilidades ajustada [ORa], 1,19; intervalo de confianza [IC] del 95 %, 1,66-1,22), del 13 % para la TEC sin PGP (ORa, 1,13; IC del 95 %, 1,09-1,16) y del 15 % para la transferencia de embriones frescos (ORa, 1,15; IC del 95 %, 1,09-1,20).

Conclusiones: la TNV aumentó con un aumento del GE para las transferencias de embriones frescos y congelados con o sin PGP hasta un umbral de 9 mm, más allá del cual la TNV se estabilizó. No se observó ningún grosor superior a 9 mm asociado a una disminución de la TNV.