Abstract

Background: Previous studies have revealed conflicting results for the Breastfeeding Assessment Score (BAS) in predicting early breastfeeding cessation. Our objective was to externally validate the BAS and provide summary accuracy estimates for this clinical prediction model.

Methods: We used the original data from a prospective cohort study. Additional studies were identified by searching electronic databases (Medline, Embase, Cumulative Index to Nursing and Allied Health Literature, and Cochrane) from 2002 to 2013 and contacting research groups that had derived or validated the BAS. Prospective cohort studies were eligible if the BAS was computed at baseline and mothers were followed up for breastfeeding cessation. Two physicians extracted relevant information and independently assessed the methodological quality for the included studies.

Results: In the external validation cohort, 22 of 424 mothers (5.2%) discontinued breastfeeding within 14 days of infant age. The BAS predicted early breastfeeding cessation with an area under the curve of 0.70 (95% confidence interval [CI]: 0.65 to 0.74) and inadequate calibration. When restricting the meta-analysis to 3169 mother-infant pairs enrolled in 4 higher-quality studies, a BAS value <8 predicted early cessation with 0.80 sensitivity (95% CI: 0.69 to 0.91) and 0.51 specificity (95% CI: 0.32 to 0.70) summary estimates.

Conclusions: Substantial between-study heterogeneity limited the interpretation of summary accuracy estimates. The BAS predicts early breastfeeding cessation with moderate accuracy, although local recalibration is advised before implementation. Further study is warranted to determine whether the BAS can help pediatricians in identifying mother-infant pairs that may benefit from more extensive breastfeeding assessment and support.

DOI: 10.1542/peds.2014-3072

Accepted for publication Feb 4, 2015

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Based on the benefits of breastfeeding for infant and mother health, current guidelines advocate exclusive breastfeeding for the first 6 months of life, continuing to 1 year or more with the addition of complementary food at 6 months of age.\textsuperscript{1} Although the rate of breastfeeding initiation has increased over the past decade in Western countries,\textsuperscript{2} between 10% and 30% of mothers who initiate breastfeeding fail to continue by 2 weeks of infant age.\textsuperscript{3,4} Mothers who discontinue breastfeeding prematurely often report a lack of confidence in their ability to breastfeed, a high prevalence of problems such as painful breasts and nipples or latching difficulties, and a lack of appropriate guidance.\textsuperscript{3–5}

Several breastfeeding assessment tools have been developed with various purposes ranging from identifying feeding problems in neonates to assessing maternal attitudes and confidence.\textsuperscript{6–7} Although these tools have demonstrated moderate to acceptable validity and reliability in accordance with psychometric theory,\textsuperscript{6–8} only scarce data exist on their accuracy in predicting early breastfeeding cessation.

The Breastfeeding Assessment Score\textsuperscript{9} (BAS) is a clinical prediction model designed to assist health care providers in identifying breastfeeding mothers at higher risk for early cessation and who may benefit from support by pediatricians or lactation consultants.\textsuperscript{10} The BAS comprises 8 clinical variables that are routinely available in the maternity ward. Five variables (maternal age, previous breastfeeding experience, latching difficulty, breastfeeding interval, and number of bottles in hospital) are scored on a 0 to 2 scale (Table 1). Three variables are scored as $-2$ (previous breast surgery, pregnancy-induced hypertension, and vacuum vaginal delivery). The BAS ranges from $-6$ to 10, with a lower score representing a higher risk for early breastfeeding cessation. In the original derivation cohort,\textsuperscript{9} the breastfeeding cessation rate by 10 days of age was 21% for mother–infant pairs with a BAS value lower than 8 compared with 5% for those with a BAS value equal to or higher than 8. Although the BAS has been adopted in various settings,\textsuperscript{11–13} previous accuracy studies have revealed conflicting results.\textsuperscript{14–16} and summary accuracy estimates are still lacking for this clinical prediction model.

Our primary objective was to externally validate the accuracy of the BAS in predicting early breastfeeding cessation, using the original data from a prospective cohort study. Our secondary objective was to provide summary accuracy estimates for the BAS prediction of early cessation among women who were breastfeeding on discharge from hospital, based on the findings from a systematic review with meta-analysis of prospective cohort studies.

### METHODS

#### Study Design

We used the original data from a controlled pre- and postintervention study involving 8 maternity units in France.\textsuperscript{12} To prevent duplicate publication of data from the same study,\textsuperscript{14} we analyzed the data for mothers enrolled during the postintervention study period in the present article. All enrolled mothers provided informed consent for participation and follow-up. The study protocol was approved by the Ethics Committee of the French Data Protection Agency (Comité Consultatif sur le Traitement de l’Information en matière de Recherche dans le domaine de la Santé, Paris, France).

#### Study Population

Seven days a week, consecutive mother–infant pairs were assessed for eligibility and enrolled by a physician in each maternity unit. Mothers were eligible if they had

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**TABLE 1 Point Scoring System for the BAS**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>$\beta$ (95% CI)</th>
<th>Points$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age, y</td>
<td>$-0.51$ (−0.80 to $-0.22$)</td>
<td>0</td>
</tr>
<tr>
<td>&lt;21</td>
<td>$-0.85$ (−1.18 to $-0.51$)</td>
<td>2</td>
</tr>
<tr>
<td>21–24</td>
<td>0.67 to 0.00</td>
<td>0</td>
</tr>
<tr>
<td>&gt;24</td>
<td>0.74 to 0.00</td>
<td>1</td>
</tr>
<tr>
<td>Previous breastfeeding experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure</td>
<td>0.74 to 0.19</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>0.19</td>
<td>1</td>
</tr>
<tr>
<td>Success</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latching difficulty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every feeding</td>
<td>0.67 to 0.00</td>
<td>0</td>
</tr>
<tr>
<td>Half the feedings</td>
<td>0.67 to 0.00</td>
<td>1</td>
</tr>
<tr>
<td>&lt;3 feedings</td>
<td>0.67 to 0.00</td>
<td>2</td>
</tr>
<tr>
<td>Breastfeeding interval, every hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\geq 6$</td>
<td>0.67 to 0.00</td>
<td>0</td>
</tr>
<tr>
<td>3–6</td>
<td>0.67 to 0.00</td>
<td>1</td>
</tr>
<tr>
<td>&lt;3</td>
<td>0.67 to 0.00</td>
<td>2</td>
</tr>
<tr>
<td>No. of bottles of formula before enrollment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\geq 2$</td>
<td>0.67 to 0.00</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0.67 to 0.00</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0.67 to 0.00</td>
<td>2</td>
</tr>
<tr>
<td>Previous breast surgery</td>
<td>0.05 to 0.86</td>
<td>$-2$</td>
</tr>
<tr>
<td>Maternal hypertension during pregnancy</td>
<td>0.03 to 0.61</td>
<td>$-2$</td>
</tr>
<tr>
<td>Vacuum vaginal delivery</td>
<td>0.01 to 0.95</td>
<td>$-2$</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.51 to 2.21</td>
<td>$-2$</td>
</tr>
</tbody>
</table>

$^a$ The BAS for a mother–infant pair is obtained by summing the points for each applicable characteristic (range, −6 to 10). Mother–infant pairs with a BAS $&lt;8$ yielded a cessation rate of 21% within 7 to 10 d of birth in the original derivation cohort.\textsuperscript{3}
given birth to a healthy singleton infant (ie, gestational age from 37 to 42 completed weeks and weight ≥2500 g) and were breastfeeding on the day of discharge. Mother–infant pairs were excluded if the infant was admitted to a neonatal unit or if the mother was <18 years of age, refused to participate in the study, was unable to speak French, or was unlikely to complete follow-up because of psychosocial problems such as homelessness.

**Data Collection**

A midwife or a pediatrician in each maternity unit prospectively collected detailed data on baseline characteristics, maternity ward practices, and the 8 clinical predictors that comprised the BAS by using a case report form. Based on data prospectively collected during the maternity stay, we retrospectively computed the BAS for each mother–infant pair (Table 1).

**Outcome Measure**

The primary outcome measure was breastfeeding cessation within 14 days of infant age. As part of the original study,12 2 trained research assistants blinded to the BAS results conducted structured follow-up telephone interviews with mothers to obtain data on breastfeeding continuation at 1 and 6 months postpartum. They asked whether the mother was still breastfeeding on the day of the interview or within the previous 24 hours. If the mother was no longer breastfeeding, the research assistant asked the age at which the infant had been weaned and the reasons for weaning. The duration of any breastfeeding was computed as the time from birth to breastfeeding discontinuation. Consistent with World Health Organization terminology,17 any breastfeeding was defined as infant receipt of breast milk, including exclusive breastfeeding, predominant breastfeeding, or complementary feeding.

**Systematic Review and Meta-analysis**

The review complied with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement18 and with the recommendations from the Cochrane diagnostic test accuracy working group.19 The inclusion criteria and analysis methods were prespecified and documented in a protocol (PROSPERO registration number 2013: CRD42013005184). Briefly, prospective cohort studies were eligible if BAS was computed at baseline and mother–infant pairs were followed up for breastfeeding cessation. Consistent with the inclusion criteria of the original BAS derivation cohort study,9 the review focused primarily on studies enrolling consecutive mothers who had given birth to healthy infants (with a gestational age between 35 and 42 completed weeks) and were breastfeeding on the day of discharge.

**Data Sources and Searches**

Studies were identified by searching the following electronic databases: Medline via PubMed (2002), Embase (2002), Cumulative Index to Nursing and Allied Health Literature via EBSCOhost (2002), and Cochrane Central Register of Controlled Trials. The last search was conducted on April 21, 2014. The search strategy used both standardized subject headings (ie, Medical Subject Headings [MeSH] and EMTREE) and text words, with adjustments made to account for differences in indexing across databases (Supplemental Tables 6, 7, 8, and 9). No language or type of document restrictions and no methodology filters were used. The electronic search was supplemented by scanning the reference lists of original articles identified as being potentially relevant and those of the previously published reviews for additional studies. We contacted research groups that were involved in the derivation or validation of the BAS to identify ongoing or completed but not yet published relevant studies.

**Study Selection**

One review author (Dr Labarère) screened the titles and abstracts, where available, of all records identified by the search strategy. Full-text articles of records identified as being potentially relevant were independently assessed by 2 review authors (Drs Raskovalova and Labarère) for inclusion.

**Data Extraction**

Using a data abstraction form, the 2 review authors independently extracted the following information for each primary study: publication details, country, setting, enrollment period, study design, recruitment, sample size, baseline mother–infant pair characteristics, reference standard, follow-up period for assessing breastfeeding status, BAS details, and the numbers of true-positive, false-positive, false-negative, and true-negative cases. Primary data were requested from corresponding authors when core data required for the meta-analysis yielded inconsistencies or could not be extracted from the main record or additional citations in the reference list. Studies for which sufficient details on outcome data were not available despite contacting the authors were excluded from the meta-analysis.

**Assessment of Study Quality**

The 2 review authors independently assessed the methodological quality of the included studies, using a checklist adapted from the Quality Assessment of Diagnostic Accuracy Studies (QUADAS)-2 tool.20 The QUADAS-2 tool comprises 4 domains: patient selection, index test, reference standard, and flow and timing. Each domain is evaluated in terms of risk of bias, whereas the first 3 domains are also assessed with respect to applicability to clinical practice.20 No primary study was excluded on the basis of methodological quality assessment results.
Statistical Analysis

Baseline characteristics of mother–infant pairs enrolled in the external validation cohort study were reported as percentages for categorical variables and means and SDs or medians and interquartile ranges (IQRs; ie, 25th and 75th percentiles) for continuous variables. The predictive performance of the BAS was evaluated in terms of both discrimination and calibration.21 Discrimination referred to the ability of the BAS to distinguish mothers with and without early breastfeeding cessation. It was quantified by the area under the receiver operating characteristic (ROC) curve. Consistent with the original derivation study,9 we also estimated the sensitivity, specificity, positive predictive value, and negative predictive value for a BAS value lower than 8.

Calibration measured the agreement between BAS-predicted probability and observed frequency of early breastfeeding cessation. Predicted probabilities of early cessation were derived by using β logistic regression coefficients for BAS predictors and intercept as supplied by the developers (Table 1). Calibration was evaluated graphically by plotting observed early breastfeeding cessation frequencies against the predicted probabilities for mothers grouped by BAS values.22 A calibration plot on the 45° line denoted perfect agreement between BAS-predicted probabilities and observed frequencies over the whole range of probabilities. Calibration was formally assessed by using the calibration-in-the-large estimate (ie, mean difference between BAS-predicted and observed rates) and the unreliability (U)-statistic, which is a joint test of calibration logistic regression intercept and slope coefficients (the intercept is 0 and the slope 1 for well-calibrated clinical prediction models).22

Observations with missing values for 1 or more BAS predictors were discarded from the main analysis. However, we performed multiple imputations of missing values to assess the robustness of the findings. For this purpose, all individual predictors comprising the BAS and early breastfeeding cessation status were entered into the imputation model. Fifty imputed data sets were created with a total run length of 50 000 iterations and imputations made every 1000 iterations.

For every primary study included in the meta-analysis, we computed sensitivity and specificity point estimates, as well as corresponding 95% confidence intervals (CIs) from the extracted data, for a BAS value lower than 8. Data synthesis was performed by using an “exact” binomial extension of the bivariate mixed-effect regression model for meta-analysis of diagnostic test accuracy studies.23,24 This model hierarchically accounts for within- and between-study variability of index test sensitivity and specificity.25 Summary sensitivity and specificity estimates were derived from bivariate mixed-effect regression model parameter estimates.

Between-study heterogeneity was evaluated graphically by examining coupled forest plots of sensitivity and specificity and statistically by using the I² inconsistency index.26 The I² index provides an estimate of the percentage of total variance across studies due to heterogeneity rather than chance. An I² index of 0% indicates no evidence of heterogeneity and higher values reflect increasing heterogeneity.26 To assess the robustness of the findings, we performed a subgroup analysis restricted to primary studies fulfilling 5 or more QUADAS-2 tool criteria.

Evidence of selective reporting bias was assessed graphically by examining a scatterplot of the log of the diagnostic odds ratio against the inverse of the square root of the effective sample size.27 Asymmetry was formally evaluated for statistical significance by using effective sample size-weighted regression.27 Two-sided P values <0.05 were considered statistically significant. Analyses were performed by using Stata version 11.0 (Stata Corp, College Station, TX) and RevMan.

RESULTS

External Validation of the BAS

Of 565 mothers enrolled in the original study, 2 were excluded because an exclusion criterion was discovered after enrollment and 64 declined follow-up interviews, leaving an analytical sample of 499 mother–infant pairs. Mothers who declined follow-up interviews were less educated (43.3% vs 27.1% had a high school degree or less, P = .009) and more likely to use a pacifier during the maternity ward stay (35.5% vs 23.4%, P = .04), in comparison with those included in the analytical sample.

The median age for all mothers was 30 years (IQR, 27–33), 231 (46.3%) were primiparous, and 77 (15.4%) gave birth by cesarean delivery (Table 2). Kaplan–Meier point estimates of breastfeeding rates were 88% and 32% at 1 and 6 months of infant age, respectively. Of the 424

| Maternal age, median (IQR), years | 30 (27–33) |
| Single, n (%) | 10 (2.0) |
| Unemployed, n (%) | 35 (7.2) |
| High school degree or less, n (%) | 131 (27.1) |
| Smoking during pregnancy, n (%) | 55 (10.7) |
| Primiparous, n (%) | 231 (46.3) |
| Epidural anesthesia, n (%) | 379 (75.9) |
| Cesarean delivery, n (%) | 77 (15.4) |
| Birth weight, mean (SD), g | 3387 (422) |
| Breastfed within 1 h of birth, n (%) | 316 (66.9) |
| Pacifier use, n (%) | 113 (23.4) |
| Length of stay, median (IQR), days | 4 (4–5) |
| BAS <8, n (%) | 188 (44.3) |

* Values were missing for maternal age (n = 5), marital status (n = 4), educational level (n = 16), smoking status (n = 5), birth weight (n = 2), breastfeeding within 1 h of birth (n = 27), pacifier use (n = 16), length of stay (n = 5), and BAS (n = 75).
mothers for whom the BAS could be calculated, 188 (44.3%) had a score lower than 8. The BAS was undocumented for 75 mothers (15.0%) because of a missing value for 1 or more predictors comprising this score. No baseline characteristics, maternity ward practices, or breastfeeding-related outcomes were associated with undocumented BAS values.

Overall, 28 mothers (5.6%) failed to continue breastfeeding by 14 days of infant age. The BAS yielded an area under the ROC curve of 0.70 (95% CI: 0.65 to 0.74) for predicting early breastfeeding cessation. A BAS value lower than 8 predicted breastfeeding cessation within 14 days of infant age with a sensitivity of 77.3% and a positive predictive value of 9.0% (Table 4).

Calibration was inadequate graphically in the external validation cohort (Supplemental Fig 3): the BAS overestimated early breastfeeding cessation rates, as reflected by calibration-in-the-large estimate equal to 5.6% (95% CI: 3.5 to 7.8; Table 4). Logistic regression calibration coefficients (intercept = \(-0.85\), \(P < .001\), and slope = 0.88, \(P = .65\)) and \(U\)-statistic (\(P < .001\)) confirmed highly significant departures of observed frequencies from BAS-predicted probabilities of early breastfeeding cessation. Discrimination and calibration measure estimates remained rather unchanged after multiple imputation of missing values for the predictors that comprised the BAS (Supplemental Tables 10, 11, and 12).

**Systematic Review and Meta-analysis**

**Literature Search**

A total of 288 unique citations were identified through database searching (Fig 1). Nine additional records were identified through other sources. After excluding 278 citations on the basis of the title and abstract review, the full text of 19 articles was retrieved for more thorough review. Five studies, including the present one and totaling 3630 mother–infant pairs, were included in the meta-analysis (Table 5). Reasons for exclusion of the remaining articles include derivation or validation of another clinical prediction model (\(n = 10\)), partially redundant data (\(n = 3\)), insufficient data (\(n = 1\)), and qualitative study design (\(n = 1\); Supplemental Table 13).

**Characteristics of Included Studies**

Two studies were conducted in the United States, whereas the other studies enrolled patients in Western Europe. All studies were prospective in design and recruited consecutive mother–infant pairs. The median prevalence of early breastfeeding cessation was 10.6%, ranging from 2.6% to 33.4% across studies (Table 5).

**Assessment of Study Quality**

Four primary studies, including the present one, fulfilled 5 or more of the QUADAS-2 tool criteria (Supplemental Table 14).9,14,15

### Table 3: Accuracy Estimates for the BAS in Predicting Breastfeeding Cessation Within 14 Days of Infant Age (n = 424)

<table>
<thead>
<tr>
<th>Breastfeeding Cessationa by 14 d of Infant Age, No.</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAS &lt; 8</td>
<td>17</td>
<td>231</td>
</tr>
<tr>
<td>BAS ≥ 8</td>
<td>171</td>
<td>77</td>
</tr>
<tr>
<td>Sensitivity (95% CI)</td>
<td>77.3 (54.8 to 92.2)</td>
<td>57.5 (52.5 to 62.3)</td>
</tr>
<tr>
<td>Specificity (95% CI)</td>
<td>9.0 (5.4 to 14.1)</td>
<td>97.9 (95.1 to 99.3)</td>
</tr>
<tr>
<td>PPV (95% CI)</td>
<td>0.70 (0.65 to 0.74)</td>
<td></td>
</tr>
<tr>
<td>NPV (95% CI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUC (95% CI)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive value.

a Seventy-five observations with a missing value for 1 or more clinical predictors comprising the BAS were discarded from the analysis.

### Table 4: Observed and BAS-Predicted Rates of Early Breastfeeding Cessation in the Derivation and External Validation Cohorts

<table>
<thead>
<tr>
<th>BAS</th>
<th>Cessation Rate by 7–10 d in the Derivation Cohortb</th>
<th>Cessation Rate by 14 d in the Validation Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Patients</td>
<td>BAS-Predicted, %</td>
<td>Observed, %</td>
</tr>
<tr>
<td>10</td>
<td>175</td>
<td>3.2</td>
</tr>
<tr>
<td>9</td>
<td>298</td>
<td>5.1</td>
</tr>
<tr>
<td>8</td>
<td>244</td>
<td>8.1</td>
</tr>
<tr>
<td>7</td>
<td>183</td>
<td>12.7</td>
</tr>
<tr>
<td>6</td>
<td>101</td>
<td>19.2</td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>28.1</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>39.0</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>51.2</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>63.2</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>73.8</td>
</tr>
<tr>
<td>&lt;1</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>All patients</td>
<td>1075</td>
<td>10.5</td>
</tr>
</tbody>
</table>

b Seventy-five observations with a missing value for 1 or more clinical predictors comprising the BAS were discarded from the main analysis.

b Calibration-in-the-large estimate is relevant only for external validation because there is a correspondence between the average predicted probability and observed frequency of the event of early breastfeeding cessation in the derivation cohort.22 Calibration-in-the-large estimate was 5.6% (95% CI: 3.5 to 7.8) in the external validation cohort.
study,16 which recruited a convenience sample, evaluated a reduced BAS, and used cessation of exclusive breastfeeding within 30 days of infant age as the reference standard, was at higher risk for selection bias and applicability concerns.

Accuracy of the BAS in Predicting Early Breastfeeding Cessation

Point estimates for BAS predictive performance with a value lower than 8 ranged from 0.52 to 0.92 for sensitivity ($I^2$: 95%) and from 0.23 to 0.79 for specificity ($I^2$: 99%) across 5 studies providing data for 3549 mother–infant pairs (Fig 2). The summary estimates were 0.75 (95% CI: 0.59 to 0.86) for sensitivity and 0.58 (95% CI: 0.39 to 0.74) for specificity. No evidence of selective reporting was found graphically (Supplemental Fig 4) or statistically ($P = .44$).

When restricting the analysis to 3169 mother–infant pairs enrolled in the 4 studies fulfilling 5 or more QUADAS-2 tool criteria, a BAS value lower than 8 predicted early breastfeeding cessation with summary estimates of 0.80 (95% CI: 0.69 to 0.91) for sensitivity and 0.51 (95% CI: 0.32 to 0.70) for specificity. The corresponding positive and negative likelihood ratio estimates were 1.64 (95% CI: 1.20 to 2.08) and 0.39 (95% CI: 0.28 to 0.50), respectively.

DISCUSSION

In this external validation study, the BAS discriminated mother–infant pairs at higher risk for early breastfeeding cessation consistently with the original derivation sample, as shown by comparable areas under the ROC curve (0.70 vs 0.73). Yet, the rate of early breastfeeding cessation for mothers with a BAS lower than 8 was 9% in the current study as compared with 21% in the original derivation sample, reflecting inadequate calibration.

Overall, the predictive performance of the BAS is supported by its derivation and validation from over 3540 mother–infant pairs enrolled in 5 prospective cohort studies in the United States and Western Europe (France and Italy). The accuracy of this clinical prediction model has been assessed in various settings (23 hospitals or birth centers) and in a broad spectrum of mother–infant pairs (Table 5). However, the clinical usefulness of the BAS may be questioned for several reasons.
First, the BAS yielded moderate sensitivity (0.80) and specificity (0.51) summary estimates, even when restricting our meta-analysis to higher-quality primary studies. The corresponding positive (1.64) and negative (0.39) likelihood ratio estimates failed to achieve thresholds (ie, 10 and 0.1, respectively) that are considered as strong evidence for ruling out or ruling in the event of interest in most clinical circumstances.28 The clinical implications of these findings can be anticipated by deriving posttest probability estimates of early breastfeeding cessation through Bayes’ rule. At a 10% baseline cessation rate, the probability of a mother–infant pair having a BAS lower than 8 would be 0.52, with a 0.15 posttest probability of early breastfeeding cessation (95% CI: 0.12 to 0.19). In contrast, the posttest probability of early breastfeeding cessation would be 0.04 (95% CI: 0.03 to 0.05) for mother–infant pairs with a BAS equal to or higher than 8. These posttest probability estimates indicate that risk stratification on the basis of the BAS may not fully capture the dynamic nature of breastfeeding initiation that makes mothers vulnerable to events during the first 2 weeks postpartum.29 Although the BAS comprises early markers of breastfeeding difficulties (eg, milk supply or neonatal weight loss) and external factors such as support after discharge, it is not calibrated for the use of BAS. Second, miscalibration was another caveat for the use of BAS, undermining its transportability to other countries or settings. Differences in baseline early breastfeeding cessation rates between the original derivation (10.6%) and external validation (5.2%) samples might explain this observation. Yet, calibration could be easily improved by adjusting the (5.2%) samples might explain this observation. Yet, calibration could be easily improved by adjusting the

### TABLE 5 Overview of Primary Studies Included in the Meta-Analysis

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Country</th>
<th>Setting</th>
<th>Enrolment period</th>
<th>Study design</th>
<th>No. participants</th>
<th>Maternal age, mean (SD), y</th>
<th>Primiparous, n (%)</th>
<th>Gestational age, range, wk</th>
<th>Cesarean delivery, n (%)</th>
<th>First time to breastfeed after delivery, mean (SD), h</th>
<th>BAS &lt;8, n (%)</th>
<th>Timing of breastfeeding status assessment, d</th>
<th>Early breastfeeding cessation, n (%)</th>
<th>AUC for the BAS (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall et al 2002</td>
<td>United States</td>
<td>9 suburban hospitals</td>
<td>February–December 2000</td>
<td>Prospective</td>
<td>1075</td>
<td>29 (3.9)</td>
<td>454 (42.2)</td>
<td>35–42</td>
<td>279 (25.9)</td>
<td>2.2 (1.9)</td>
<td>55 (18)</td>
<td>370 (34.4)</td>
<td>114 (10.6)</td>
<td>0.73 (0.70 to 0.76)</td>
</tr>
<tr>
<td>Laborde et al 2007</td>
<td>France</td>
<td>9 hospitals</td>
<td>April–July 2005</td>
<td>Prospective</td>
<td>488</td>
<td>30 (6)</td>
<td>214 (43.9)</td>
<td>37–42</td>
<td>76 (15.6)</td>
<td>1.4 (1.9)</td>
<td>109 (29)</td>
<td>211 (43.2)</td>
<td>13 (2.6)</td>
<td>0.73 (0.68 to 0.76)</td>
</tr>
<tr>
<td>Mercer et al 2010</td>
<td>United States</td>
<td>3 urban hospitals</td>
<td>June 2004–May 2007</td>
<td>Prospective</td>
<td>1182</td>
<td>25 (5.9)</td>
<td>NA</td>
<td>37–42</td>
<td>329 (27.9)</td>
<td>5.6 (8.4)</td>
<td>NA</td>
<td>939 (79.4)</td>
<td>175 (14.6)</td>
<td>0.70 (0.67 to 0.72)</td>
</tr>
<tr>
<td>Zobbi et al 2011</td>
<td>Italy</td>
<td>2 birth centers</td>
<td>July 2008–January 2009</td>
<td>Prospective</td>
<td>368</td>
<td>33 (4.9)</td>
<td>222 (57.5)</td>
<td>35–42</td>
<td>54 (14.0)</td>
<td>≤2 h</td>
<td>79 (17)</td>
<td>119/580 (31.3)</td>
<td>127 (13.3)</td>
<td>0.74 (0.69 to 0.79)</td>
</tr>
<tr>
<td>Present Study</td>
<td>France</td>
<td>8 hospitals</td>
<td>December 2005–February 2006</td>
<td>Prospective</td>
<td>499</td>
<td>30 (4)</td>
<td>231 (46.5)</td>
<td>37–42</td>
<td>77 (15.4)</td>
<td>1.4 (2.1)</td>
<td>110 (26)</td>
<td>188/424 (44.3)</td>
<td>22/424 (5.2)</td>
<td>0.70 (0.65 to 0.74)</td>
</tr>
</tbody>
</table>

AUC, area under the curve; NA, not available from the authors.

*All newborns were breastfed within 2 h of delivery.

b AUC for BAS was computed along with 95% binomial CI on the basis of published data.
original logistic regression intercept to mother–infant pairs in the validation sample (data not presented). Indeed only the calibration intercept differed from 0, whereas the calibration slope remained close to 1. To prevent overfitting, updated BAS should ideally go through external validation, as would a newly derived clinical prediction model. 

Third, the BAS value was undocumented for 15% of mother–infant pairs included in our external validation study. Although this clinical prediction model comprises only 8 predictors, its application may be challenging without training and the use of an electronic or paper-based support tool. It should be emphasized that all predictors are objective measures, with the exception of latching difficulty assessment. Reliability is another important characteristic of the BAS, which still needs to be formally assessed.

Fourth, limited evidence exists on BAS accuracy among late preterm infants, although infants with a gestational age between 35 and 37 weeks are within the scope of this clinical prediction model. Indeed, late preterm infants were eligible in only 2 of the 5 primary studies included in our systematic review, and BAS accuracy estimates were not reported separately for this subgroup. Because of a higher risk for breastfeeding discontinuation after discharge, we cannot exclude that the BAS performs differently in late preterm infants.

According to our findings, mother–infant pairs with BAS equal to or higher than 8 are suitable for standard care, although they are likely to benefit from monitoring through a 1-week postpartum routine visit. More extensive breastfeeding assessment and consultation with lactation specialists has been advocated for mother–infant pairs at higher risk for early cessation as predicted by BAS lower than 8. Yet, neither primary nor meta-analysis of accuracy studies can provide direct evidence on the effectiveness of the BAS for improving breastfeeding-related outcomes. Prospective management studies are needed for establishing the efficacy of BAS in guiding the provision of breastfeeding support to mothers at higher risk for early cessation. Only cluster randomized controlled trials can provide the highest level of evidence on the effectiveness of BAS-based interventions in altering breastfeeding assessment practices at the maternity ward, providing adequate support for at-risk mother–infant pairs, and ultimately decreasing early discontinuation rates.

This meta-analysis totaling 3549 mother–infant pairs enrolled in prospective cohort studies that have been completed since the original derivation of the BAS summarizes the most recent evidence on the accuracy of this clinical prediction model. However, this meta-analysis has several limitations that must be considered.

First, substantial between-study heterogeneity inevitably limited the interpretation of summary accuracy estimates, although we used bivariate mixed-effect regression and performed subgroup analysis of higher-quality studies. The reasons for heterogeneity in estimates related to variations across original studies in terms of setting, mother–infant pair characteristics, baseline early cessation rate, and timing of breastfeeding status assessment.

Second, primary studies were identified by carrying out an extensive literature search and contacting research groups that had derived or validated the BAS. We did not find evidence of selective reporting, although statistical tests and graphical methods for detecting publication bias may be misleading when applied to meta-analyses of diagnostic accuracy studies.

Third, a major methodological concern with primary studies relates to the reference standard for early breastfeeding cessation. Studies that assessed the prevalence of any breastfeeding at fixed time points may have contributed to underestimating breastfeeding duration because some infants who were breastfeeding irregularly may not have been breastfed within the recall period. Other studies that assessed breastfeeding duration retrospectively might be prone to recall bias or imprecision. Although variations in breastfeeding duration estimates have been reported with time of recall, there is limited evidence on the potential for bias over the short-term recall period.

Fourth, 2 of the validation studies, including the present one, had...
a relatively limited effective sample size. Although few data exist on sample size requirements, field experts consider that at least 100 events and 100 nonevents are required for assessing model performance in an external validation sample. Fifth, the primary studies were conducted in the United States or in Western Europe and these findings may not apply to patients from other regions.

CONCLUSIONS

Despite substantial between-study heterogeneity, this meta-analysis confirms that the BAS discriminates mother–infant pairs at higher risk for early breastfeeding cessation with moderate accuracy. Yet, locally recalibrating the BAS is strongly recommended before its implementation. Further study is warranted to determine whether this clinical prediction model can help pediatricians identify mother–infant pairs that may benefit from additional breastfeeding support.

ACKNOWLEDGMENTS

The following persons were responsible for facilitating the conduct of the study at the local hospital level: Isabelle Gothie (Clinique Belledonne, Saint-Martin d’Hères); Catherine Devoldere (General Hospital, Abbeville); Catherine Saliniér (Maison de Santé Protestante Bordeaux Bagatelle, Talence); Florence Roche and Guy Putet (Hospices Civils, Lyon); Muriel Plasse (General Hospital, Albertville), François-Marie Caron (Clinique Sainte-Claire, Amiens); Jean-Pierre Gout (General Hospital, Voiron); Martine Berchateau and François Vie Le Sage (General Hospital, Aix-les-Bains). Ms Fanny Baudino and Maeva Durand conducted follow-up telephone interviews. Ms Linda Northrup, English Solutions (Voiron, France), provided assistance in preparing and editing the manuscript.

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Funded in part by grants from the French Ministry of Health (Programme National Nutrition Santé) and Grenoble University Hospital (Direction de la Recherche Clinique et de l’Innovation).

POTENTIAL CONFLICT OF INTEREST: Dr Gelbert-Baudino is the chairman of the Association Française de Pédiatrie Ambulatoire, which received unrestricted grants from Blédina, Nestlé, Sodilac, and Institut national de prévention et de recherche clinique à l’amélioration de la santé; the other authors have indicated they have no potential conflicts of interest to disclose.

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Pediatrics 2015;135;e1276
DOI: 10.1542/peds.2014-3072 originally published online April 13, 2015;

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