In the United States, postpartum hemorrhage is a leading preventable cause of maternal mortality and morbidity. To reduce morbidity from postpartum hemorrhage, risk assessment is an important starting point for informing decisions about risk management and hemorrhage prevention. Current perinatal care guidelines from the Joint Commission recommend that all patients undergo postpartum hemorrhage risk assessment at admission and after delivery. Three maternal health organizations—the California Maternal Quality Care Collaborative, AWHONN, and the American College of Obstetricians and Gynecologists’ Safe Motherhood Initiative—have developed postpartum hemorrhage risk-assessment tools for clinical use. Based on the presence of risk factors, each organization categorizes patients as low-, medium-, or high-risk, and ties pretransfusion testing recommendations to these categorizations. However, the accuracy of these tools’ risk categorizations has come under increasing scrutiny. Given their low positive predictive value, the value proposition of pretransfusion testing in all patients classified as medium- and high-risk is low. Further, 40% of all postpartum hemorrhage events occur in low-risk patients, emphasizing the need for early vigilance and treatment regardless of categorization. We recommend that maternal health organizations consider alternatives to category-based risk tools for evaluating postpartum hemorrhage risk before delivery.

(Obstet Gynecol 2021;138:924–30)
DOI: 10.1097/AOG.0000000000004579
risk assessment is an essential starting point for informing decisions about risk management. Once at-risk patients are identified, the effect of postpartum hemorrhage risk assessment is indirect and contingent on the effectiveness of primary and secondary postpartum hemorrhage prevention practices. Primary prevention can be defined as anticipatory planning for postpartum hemorrhage. Examples of anticipatory planning measures include: postpartum hemorrhage risk factor modification; transfer of high-risk patients (e.g., those with placenta accreta spectrum disorders) to specialized centers;49 and mobilization of experienced staff, resources, and blood products in anticipation of postpartum hemorrhage. Secondary prevention comprises practices that reduce the effect of postpartum hemorrhage on the risk of morbidity. For example, the close monitoring of high-risk patients at and after delivery to enable the early detection and treatment of postpartum hemorrhage.

OPERATIONALIZING POSTPARTUM HEMORRHAGE RISK ASSESSMENT

Limited evidence is available that describes how postpartum hemorrhage risk assessment can be operationalized across one or more maternity units. Information about patients’ postpartum hemorrhage risk can be accessed by staff in a number of ways, such as medical record review, physical or electronic display boards, and person-to-person handovers, huddles, or rounds. However, individual patient risk assessment and manual data entry of risk information into medical records are time consuming processes. Embedding a postpartum hemorrhage prediction platform in patients’ electronic health records can reduce the time spent by staff performing a manual assessment. Additionally, automated systems can display risk information as visual alerts, provide user-centered decision support, and link to guideline-informed evidence-based education. Although data from a systemic review of randomized trials in the nonobstetric literature suggest that mortality outcomes are similar with or without clinical decision support,10 pragmatic trials are needed to evaluate the effect of postpartum hemorrhage clinical decision support linked to automated postpartum hemorrhage risk assessment from electronic clinical data capture.

CURRENT CATEGORY-BASED RISK-ASSESSMENT TOOLS

Three maternal health organizations—the California Maternal Quality Care Collaborative, AWHONN, and the American College of Obstetricians and Gynecologists’ Safe Motherhood Initiative—have developed postpartum hemorrhage risk assessment-tools for clinical use.5,11,12 Each organization categorized at-risk patients into medium-risk or high-risk groups and assigned patient-level risk factors into each risk category (Appendix 1, available online at http://links.lww.com/AOG/C468). The selection and assignment of risk factors into each category were based on expert opinion only.

Medium-risk and high-risk are classified differently by the California Maternal Quality Care Collaborative, AWHONN, and the Safe Motherhood Initiative. For example, only the Safe Motherhood Initiative includes body mass index (BMI, calculated as weight in kilograms divided by height in meters squared) higher than 40 and estimated fetal weight greater than 4,000 g as risk factors in the medium-risk group, and patients with two or more medium risk factors are classified as high risk only in the AWHONN and Safe Motherhood Initiative tools. The lack of uniformity is problematic because hospital administrators and staff may be uncertain about what tool to incorporate into clinical practice. Additionally, none of the organizations provide detailed information related to the development, validation, and accuracy of their tool.

ACCURACY OF CATEGORY-BASED RISK-ASSESSMENT TOOLS

To compare and contrast the predictive validity of currently used California Maternal Quality Care Collaborative, AWHONN, and Safe Motherhood Initiative risk-assessment tools, we identified five studies that report accuracy data.13–17 Details of our search strategy for identifying relevant publications are presented in Appendix 2, available online at http://links.lww.com/AOG/C468. In four studies, data were sourced from single obstetric centers,13,14,16,17 and one study sourced data from a large network of hospitals in Northern California.15 Four studies included data from patients who underwent vaginal and cesarean births,13,15–17 and one study examined only cesarean births.14 We abstracted postpartum hemorrhage prevalence and accuracy data (sensitivity, specificity, positive, and negative predictive values) from these studies (Table 1). Of note, these studies used different postpartum hemorrhage definitions, specifically: estimated blood loss,15–17 transfusion of at least 1 unit of packed red blood cells (RBCs),13,14,16,17 or at least 4 units of RBCs,14 or a composite outcome of postpartum hemorrhage–related morbidity.15

Despite the variability in postpartum hemorrhage definitions, positive predictive values were very low...
(less than 10%) in nearly all cohorts of medium and high-risk patients (Table 1), indicating that, in the majority of cases, a positive result (ie, classifying a woman as medium-risk or high-risk) can be interpreted as a false-positive (with the possible exception of patients with conditions associated with a very high risk of postpartum hemorrhage, such as placenta previa and accreta).18,19 It is likely that the low positive predictive values are due to the low postpartum hemorrhage prevalence in these cohorts, which may be related to improved postpartum hemorrhage management as a consequence of bundle implementation. However, in the absence of high-quality data, it is unclear what aspects of bundle implementation are associated with a lower likelihood of postpartum hemorrhage and whether health care professionals manage postpartum hemorrhage differently according to patients’ risk category. Perhaps equally as important, in four of the five studies, more than 40% of postpartum hemorrhages occurred in low-risk patients with no risk factors.13,15–17 Therefore, current risk-assessment tools are failing to assign elevated risk categories to a large proportion of women who ultimately experience postpartum hemorrhage.

### Table 1. Accuracy Data for Postpartum Hemorrhage Risk-Assessment Tools

<table>
<thead>
<tr>
<th>Definition of PPH</th>
<th>PPH Prevalence</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AWHONN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium risk</td>
<td>2.8</td>
<td>96</td>
<td>9</td>
<td>7</td>
<td>97</td>
</tr>
<tr>
<td>Transfusion of 1 or more units pRBC&lt;sup&gt;14&lt;/sup&gt;</td>
<td>0.4</td>
<td>97</td>
<td>8</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>High risk</td>
<td>9.2</td>
<td>83</td>
<td>41</td>
<td>9</td>
<td>97</td>
</tr>
<tr>
<td>Transfusion of 1 or more units pRBC&lt;sup&gt;14&lt;/sup&gt;</td>
<td>1.8</td>
<td>88</td>
<td>40</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td><strong>CMQCC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium risk</td>
<td>9.0</td>
<td>57</td>
<td>69</td>
<td>12</td>
<td>96</td>
</tr>
<tr>
<td>Blood loss of 500 mL or greater VD or 1,000 mL or greater CD&lt;sup&gt;17&lt;/sup&gt;</td>
<td>10.5</td>
<td>57</td>
<td>73</td>
<td>10</td>
<td>97</td>
</tr>
<tr>
<td>Blood loss of 1,000 mL or greater&lt;sup&gt;15&lt;/sup&gt;</td>
<td>2.0</td>
<td>57</td>
<td>72</td>
<td>3</td>
<td>99</td>
</tr>
<tr>
<td>Transfusion of 1 or more units pRBC&lt;sup&gt;14&lt;/sup&gt;</td>
<td>4.5</td>
<td>65</td>
<td>69</td>
<td>8</td>
<td>98</td>
</tr>
<tr>
<td>Transfusion of 1 or more units pRBC&lt;sup&gt;14&lt;/sup&gt;</td>
<td>4.0</td>
<td>83</td>
<td>26</td>
<td>7</td>
<td>96</td>
</tr>
<tr>
<td>Transfusion of 4 or more units pRBC&lt;sup&gt;14&lt;/sup&gt;</td>
<td>0.6</td>
<td>91</td>
<td>26</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Severe PPH*&lt;sup&gt;15&lt;/sup&gt;</td>
<td>0.5</td>
<td>59</td>
<td>71</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td><strong>ACOG’s Safe Motherhood Initiative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium risk</td>
<td>23.4</td>
<td>22</td>
<td>95</td>
<td>23</td>
<td>94</td>
</tr>
<tr>
<td>Blood loss of 1,000 mL or more&lt;sup&gt;15&lt;/sup&gt;</td>
<td>10.2</td>
<td>10</td>
<td>95</td>
<td>10</td>
<td>95</td>
</tr>
<tr>
<td>Transfusion of 1 or more units pRBC&lt;sup&gt;14&lt;/sup&gt;</td>
<td>7.3</td>
<td>22</td>
<td>96</td>
<td>7</td>
<td>99</td>
</tr>
<tr>
<td>Transfusion of 1 or more units pRBC&lt;sup&gt;14&lt;/sup&gt;</td>
<td>22.6</td>
<td>36</td>
<td>95</td>
<td>23</td>
<td>97</td>
</tr>
<tr>
<td>Transfusion of 4 or more units pRBC&lt;sup&gt;14&lt;/sup&gt;</td>
<td>22.2</td>
<td>46</td>
<td>88</td>
<td>22</td>
<td>96</td>
</tr>
<tr>
<td>Severe PPH*&lt;sup&gt;15&lt;/sup&gt;</td>
<td>5.1</td>
<td>59</td>
<td>87</td>
<td>5</td>
<td>99</td>
</tr>
</tbody>
</table>
| **PPH, postpartum hemorrhage; PPV, positive predictive value; NPV, negative predictive value; pRBC, packed red blood cells; CMQCC, California Maternal Quality Care Collaborative; VD, vaginal delivery; CD, cesarean delivery; ACOG, American College of Obstetricians and Gynecologists.**

Data are %.

Accuracy data for medium risk categories were calculated using a composite of medium-risk and high-risk outcomes, compared with those in the low-risk group. For high-risk categories, outcomes were compared with those of medium risk or low risk.

* Ruppel et al define severe postpartum hemorrhage as 1) transfusion of at least 4 units red blood cells or 2) transfusion 1–3 units of red blood cells with a hematocrit below 18% or 3) blood loss greater than 1,500 mL with a hematocrit below 18%.

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PREDICTIVE MODELING FOR POSTPARTUM HEMORRHAGE RISK ASSESSMENT

Given the poor performance of category-based tools, investigators are now focused on developing clinical prediction models that can use values or levels of multiple predictors to provide individualized probabilities of postpartum hemorrhage risk. A recent systematic review identified 14 such models, eight for use in the general obstetric population and six for use in patients with placenta previa or placenta accreta spectrum disorder. Results showed that studies of prediction models are relatively few, suffer from low sample sizes and high risk of bias, and have not undergone robust external validation.

Machine learning and artificial intelligence have also been explored as potential methods for postpartum hemorrhage risk assessment, with recently published studies reporting excellent predictive performance in machine learning models. However, these models have not been externally validated, and no studies have assessed the effects of these models on clinical decision-making and subsequent maternal outcomes. As a consequence, no published prediction models for postpartum hemorrhage are ready for clinical use.

CLINICAL IMPLICATIONS

Transfusion Preparedness

The California Maternal Quality Care Collaborative, AWHONN, and Safe Motherhood Initiative risk-assessment tools all tie pretransfusion testing recommendations to postpartum hemorrhage risk categorizations. Specifically, a type and screen is recommended for medium-risk and a type and cross for high-risk patients. These recommendations were based on expert opinion.

To determine whether these pretransfusion testing recommendations are justified, it is worth examining validation study data, including proportions of patients classified as medium and high-risk by these tools and frequency of transfusion in these groups (Tables 1 and 2). Overall, proportions varied considerably across studies, with 18–60% of patients classified as medium risk and 4–60% classified as high risk. The rate of RBC transfusion was low in medium-risk patients (2.0–4.5%) and was low-to-moderate in high-risk patients (7.3–22.6%). Taken together, these findings raise questions about the necessity of these blood ordering recommendations for all medium-risk and high-risk patients. Future studies should examine transfusion service quality indicators (such as the crossmatch-to-transfusion and crossmatch-to-issue ratio).

It is possible that the implementation of less stringent blood ordering recommendations may result in more frequent use of emergency-release blood products and, secondarily, recipient alloimmunization. However, the transfusion rate of emergency-release blood products from a massive transfusion protocol in obstetrics is extremely low (0.09–0.21%). For those who develop major or life-threatening postpartum hemorrhage, the availability of a type and screen or type and cross does not necessarily obviate the need for emergency-release blood products. Furthermore, in patients with negative antibody screens, RBCs are not routinely matched by blood banks for antigens other than ABO and RhD. Therefore, compared with crossmatched RBCs, uncrossmatched Rh-negative RBCs may not result in an increased risk of alloimmunization in the recipient.

Support this assertion, new antierthrocyte antibodies have been identified in only 1.8–3% of patients who receive uncrossmatched RBC

Table 2. Proportion of Women Classified as Low, Medium, and High Risk for Postpartum Hemorrhage

<table>
<thead>
<tr>
<th>Category</th>
<th>Dilla et al\textsuperscript{14}</th>
<th>Kawakita et al\textsuperscript{14,}*</th>
<th>Ruppel et al\textsuperscript{15}</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWHONN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low risk</td>
<td>NA</td>
<td>8.3</td>
<td>NA</td>
</tr>
<tr>
<td>Medium risk</td>
<td>NA</td>
<td>31.2</td>
<td>NA</td>
</tr>
<tr>
<td>High risk</td>
<td>NA</td>
<td>60.5</td>
<td>NA</td>
</tr>
<tr>
<td>CMQCC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low risk</td>
<td>71.6</td>
<td>25.6</td>
<td>71.1</td>
</tr>
<tr>
<td>Medium risk</td>
<td>24.3</td>
<td>60.3</td>
<td>23.6</td>
</tr>
<tr>
<td>High risk</td>
<td>4.1</td>
<td>14.1</td>
<td>5.3</td>
</tr>
<tr>
<td>SMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low risk</td>
<td>NA</td>
<td>24.4</td>
<td>NA</td>
</tr>
<tr>
<td>Medium risk</td>
<td>NA</td>
<td>38.9</td>
<td>NA</td>
</tr>
<tr>
<td>High risk</td>
<td>NA</td>
<td>36.7</td>
<td>NA</td>
</tr>
</tbody>
</table>

NA, not applicable; CMQCC, California Maternal Quality Care Collaborative; SMI, Safe Motherhood Initiative.

Data are %.

* Included only cesarean deliveries.
transfusions,²⁹ which is comparable with the incidence with crossmatched RBCs in the general population.³⁰,³¹ Additionally, the majority of cases of severe hemolytic disease of the fetus or newborn are due to prior pregnancy (83%), with only a small minority (3%) caused by prior exposure to transfusion.³²

False-Positives
There are important clinical implications for patients categorized to medium-risk or high-risk groups who do not experience postpartum hemorrhage (ie, false-positive cases). Although false-positive cases may not experience direct harm from overdiagnosis, investing in the implementation of a risk-assessment tool can come at the cost of other health services that may have been used for postpartum hemorrhage treatment; these are commonly referred to as opportunity costs. For example, in a simulation of 10,000 deliveries that assumed an overall transfusion rate of 1.6%, Einerson et al estimated that the total cost of a type and cross for high-risk patients and a universal type and screen for other patients was $958,984, a universal type and screen policy was $913,161, and a selective type and screen in high-risk patients only was $347,208.³³ Further cost-effectiveness analyses would help evaluate these and other clinical and economic costs related to postpartum hemorrhage risk classification. Those who are false-positives may also experience unnecessary emotional or psychological distress from being categorized as medium or high-risk before delivery. These patients shoulder the burden of risk for others who are true-positives who cannot receive postpartum hemorrhage risk management without false-positives also receiving the same interventions.

False-Negatives
As cited previously, multiple validation cohorts demonstrate that more than 40% of postpartum hemorrhage events occur in low-risk patients.¹³,¹⁵,¹⁷ This finding is consistent with data from a large population-wide study in which nearly 40% of those with severe postpartum hemorrhage requiring transfusions had no postpartum hemorrhage–related risk factors.³⁴ Therefore, maternity staff should not over-rely on risk-assessment tools for predicting postpartum hemorrhage risk nor lessen their vigilance for postpartum hemorrhage when caring for low-risk patients.

IS IT TIME TO STOP USING RISK-ASSESSMENT TOOLS?
Although hemorrhage bundles have been associated with reduced morbidity related to postpartum hemorrhage, individual components of those bundles, including risk assessment, have not been directly linked to improved patient outcomes. However, current risk-assessment tools could be used as cognitive aids to ensure that key postpartum hemorrhage risk factors are identified and can stimulate discussion among maternity staff and administrators about postpartum hemorrhage risk reduction strategies. It is these discussions that should drive postpartum hemorrhage risk management decision-making as opposed to specific outputs from risk-assessment tools. In the absence of accurate postpartum hemorrhage prediction models, risk-assessment tools may have value in informing, but not driving, clinical decision-making.

FUTURE DIRECTIONS
The future of postpartum hemorrhage risk stratification hinges on two important facets—improved predictive ability and a better understanding of how to practically use predictive outputs, including the development of evidence-based recommendations. Clinical prediction models that provide individual probabilities of postpartum hemorrhage risk may eventually replace the current category-based risk tools. Development of these models should follow the Transparent Reporting of a Multivariable Prediction Model for Individual Progress or Diagnosis’ guidelines³⁵,³⁶ and should include internal validation followed by external validation of the desired outcome in the population of interest.³⁷ Health economic analysis will help to establish risk thresholds based on each model’s predictive performance, pretransfusion testing recommendations, available health care resources, postpartum hemorrhage prevalence, and harms compared with benefits of decisions.³⁸ Clinicians also will need evidence-based recommendations on how to practically use predictive outputs. Given the high probability of false categorization using current risk-assessment tools, anticipatory planning measures for postpartum hemorrhage should be restricted to those that are inexpensive and beneficial to most patients, such as multidisciplinary team huddles for communicating risk and the close monitoring of vital signs after delivery. Given the relatively low transfusion rates in those classified as medium-risk or high-risk, current recommendations for transfusion preparedness that are tied to risk management tools need to be reevaluated. Further, it is unclear whether all hospitals have a sufficient blood bank inventory to allow blood products to be sequenced for all high-risk patients, especially during times when demand for blood products is high across an entire hospital system. Future effect studies are
needed to determine whether other anticipatory care planning interventions (such as early second-line uterotonic use or tranexamic acid administration) focused on patients at high-risk of postpartum hemorrhage are effective at reducing rates of postpartum hemorrhage-related morbidity.

CONCLUSION
Overall, there remains significant room for improvement in the practice of postpartum hemorrhage risk assessment. Although postpartum hemorrhage risk assessment is a key starting point for postpartum hemorrhage risk management, existing validation data do not support current pretransfusion testing recommendations tied to postpartum hemorrhage risk categorization. Instead, large scale population-based studies are needed to develop accurate prediction models that provide individual probabilities of postpartum hemorrhage risk. This information, coupled with more nuanced approaches to anticipatory planning, has the potential for positively influencing clinical decision-making and improving maternal outcomes.

REFERENCES
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