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CLINICAL ARTICLE

Predicting postoperative day 1 hematocrit levels after uncomplicated hysterectomy

Carolyn W. Swenson *, Michael S. Lanham, Daniel M. Morgan, Mitchell B. Berger

Department of Obstetrics and Gynecology, University of Michigan, Ann Arbor, MI, USA

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ABSTRACT

Objective: To develop a model for predicting postoperative hematocrit levels after uncomplicated hysterectomy. *Methods:* In a retrospective study, data were analyzed from the Michigan Surgery Quality Collaborative for non-emergent hysterectomies performed for benign indications among women aged at least 18 years between January 1, 2012, and April 4, 2014. Linear mixed models were used for univariate and multivariate analyses. *Results:* The model was developed with data from 4747 hysterectomies and validated on 1184 cases. In the mixed multivariate analysis, higher postoperative day 1 (POD1) hematocrit levels were associated with higher weight ($B = 0.03222$, $P < 0.001$), higher preoperative hematocrit ($B = 0.6587$, $P < 0.001$), and non-vaginal hysterectomy ($B = 0.2815$, $P = 0.0055$). Lower POD1 hematocrit was associated with higher preoperative platelet count ($B = -0.00457$, $P < 0.001$), greater estimated blood loss ($B = -0.00652$, $P < 0.001$), and larger intraoperative crystalloid volume ($B = -0.3303$, $P < 0.001$). The final model predicted POD1 hematocrit within 4% points of the actual value for 91.7% of cases in the validation set. *Conclusion:* Use of the model after uncomplicated hysterectomy might help to support the practice of selectively conducting postoperative hematocrit tests after hysterectomy in a clinically thoughtful and cost-effective manner.

1. Introduction

Hysterectomy is the most common major gynecologic surgery performed in the USA, and the second most common surgery performed for women of reproductive age (after cesarean delivery) [1]. Evidence-based guidelines exist for preoperative management, including prophylaxis against surgical-site infections and venous thromboembolism [2]. By contrast, postoperative protocols are largely determined by historical practices and expert opinion rather than by scientific evidence. Although numerous textbooks recommend blood tests—including a complete blood count—as part of the routine postoperative evaluation of a patient, several studies suggest that such routine laboratory testing rarely results in meaningful differences in clinical outcomes [3,4].

Studies have also attempted to identify factors that predict blood counts. One looking at patients undergoing cardiopulmonary bypass surgery [5] identified various factors including older age, female sex, Hispanic or non-white ethnic origins, lower body surface area, and high creatinine as independent predictors of a hematocrit level of 21.9% or lower. Petersen et al. [6] looked at predictors of postpartum hematocrit after vaginal delivery and found that an estimated blood loss of more than 500 mL, Hispanic ethnic origin, and third- or fourth-degree perineal laceration were objective predictors of a hematocrit level of less than 26% [6]. The aim of these previous studies was to be able to predict which patients would have hematocrit values at or below a certain threshold; however, few studies have provided a model capable of accurately predicting a postoperative blood count value. To our knowledge, the only published study has been based on orthopedic procedures with a study sample of which less than 40% were women [7].

Given the lack of evidence supporting routine postoperative laboratory tests after benign gynecologic surgery, the aim of the present study was to develop a mathematical model that can accurately predict postoperative hematocrit level after hysterectomy for benign indications. Such a model might not only limit the number of unindicated procedures that patients undergo after hysterectomy, but also decrease unnecessary resource utilization.

2. Materials and methods

In a retrospective study, data were analyzed from the Michigan Surgical Quality Collaborative (MSQC) [8] for hysterectomies performed across the state of Michigan, USA, between January 1, 2012, and April 4, 2014. Informed consent was not required because the MSQC database contains de-identified data. The University of Michigan Institutional Review Board granted "Not Regulated" status to the present study j(HUM00073978).

* Corresponding author at: University of Michigan, Department of Obstetrics and Gynecology, L4000 Women's Hospital, 1500 E. Medical Center Dr., SPC 5276, Ann Arbor, MI 48109–5276, USA. Tel.: +1 734 764 8429; fax: +1 734 647 9727.
E-mail address: scarolyn@med.umich.edu (C.W. Swenson).

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The MSQC is an ongoing collaboration involving academic and community hospitals across Michigan and is funded by the Blue Cross Blue Shield of Michigan/Blue Care Network. Trained nurse data abstractors prospectively collate data on patient characteristics, intraoperative processes of care, and 30-day postoperative outcomes, from patients undergoing surgery at participating hospitals.

For the present study, data were reviewed from all women aged 18 years or older who underwent a hysterectomy during the study period at an MSQC member hospital. To model postoperative hematocrit levels after uncomplicated hysterectomies performed for benign indications, only patients with current procedural terminology codes and International Classification of Diseases, Clinical Modification 9 codes consistent with benign, non-emergent hysterectomy for a non-obstetric indication were considered for the analysis. The inclusion criteria were a preoperative hematocrit level greater than or equal to 20%, postoperative day 1 (POD1) hematocrit greater than or equal to 15%, intraoperative crystalloid infusion less than 5 L, no intraoperative colloid infusion, estimated blood loss (EBL) of 10–500 mL, operative duration greater than or equal to 15 minutes, preoperative platelet count greater than or equal to 100 000/μL, body mass index (calculated as weight in kilograms divided by the square of height in meters) greater than or equal to 15, and an American Society for Anesthesiologists physical status classification of 1 (normal, healthy patient), 2 (mild systemic disease), or 3 (severe systemic disease). Patients were excluded if they had a diagnosis of cancer as a result of the surgery, cancer as an indication for the surgery, preoperative sepsis, other concomitant major surgeries (e.g. colectomy, or liver or kidney surgery), or red-blood-cell or platelet transfusion preoperatively, intraoperatively, or postoperatively.

To build and test the hematocrit prediction model, the study sample was randomly divided into a model development subset and a validation subset, respectively. Modeling and statistical analyses were done via SAS version 9.4 (SAS Institute, Cary, NC, USA) using "proc mixed," "proc reg" with "vif" and "collin" options, "proc anova," and "proc freq" with "chisq" option, as appropriate. Comparisons of continuous and categorical variables between the two subsets were done via one-way analysis of variance and χ^2 tests, respectively.

To derive the model, patient demographics and preoperative, intraoperative, and postoperative characteristics associated with blood loss and fluid balance were selected as the independent variables (Box 1). Univariate associations between independent variables and the postoperative hematocrit level were analyzed, and variables that were significant at an α level of 0.10 or less were entered into a multivariable linear mixed model, with random site effects to account for clustered data. This multivariable linear mixed model was subjected to stepwise selection to identify a subset of significant model variables with a P value of less than 0.05 in a type III test of fixed effects. The fixed effects were retained only if their addition to the model significantly improved model fit (i.e. decreased the Akaike information criterion by a value consistent with a P value of less than 0.05 for a χ^2 distribution with 1 degree of freedom). The retained variables were analyzed for collinearity.

Predicted hematocrit levels were calculated for the randomly selected validation subset, which comprised 20% of the eligible hysterectomy cases and did not include any data used in the model development subset. The predicted value for each patient was compared with the actual postoperative hematocrit level for that patient, and the difference between the two values was calculated to assess the accuracy of the model for the purposes of prediction.

3. Results

Demographic and perioperative data were obtained for 13 745 women who underwent hysterectomy at 50 hospitals participating in the MSQC during the study period. After excluding complicated hysterectomies, 9172 (66.7%) cases were identified as uncomplicated hysterectomies. Of the uncomplicated hysterectomies, 1818 (19.8%) had no postoperative hematocrit value in the database, and 1420 (15.5%) had their lowest postoperative hematocrit in the database recorded on a date that was not POD1. As a result, 5934 (64.7%) uncomplicated hysterectomies were eligible for analysis, 4750 (80.0%) of which were randomly allocated into a model development dataset and 1184 (20.0%) to a validation dataset. Three cases were subsequently found to lack preoperative body weight; as a result, the final number in the model development dataset was 4747.

The subsets were similar in terms of patient age, body mass index, ethnic origin, and smoking status (Table 1). The difference in distribution of route of hysterectomy between subsets reached statistical significance ($P = 0.05$) with a slightly lower proportion of abdominal hysterectomies and greater proportion of vaginal hysterectomies in the model validation subset than in the model development subset.

In the mixed multivariable linear regression, factors associated with a higher POD1 hematocrit included higher weight, higher preoperative hematocrit, and non-vaginal hysterectomy route. Variables associated with a lower POD1 hematocrit value included higher preoperative platelet count, higher EBL, and larger volume of intraoperative crystalloid infusion (Table 2). Analysis of the variables included in the final model revealed no significant collinearity (data not shown).

For purposes of validation, the ability of the model to predict POD1 hematocrit to a value within 1% to within 5% points was tested (Table 3). The model predicted the POD1 hematocrit level to ±5% points for 100%, ±4% points for 91.7%, ±3% points for 81.2%, ±2% points for 62.9%, and ±1% points for 34.8% of cases. The squared correlation coefficient (R^2) of the model (calculated for the whole study sample including the validation subset) was 0.53.

Given the finding that a vaginal hysterectomy route was associated with lower POD1 hematocrit, the change in hematocrit (measured as the difference between POD1 hematocrit and preoperative hematocrit) was analyzed by route of hysterectomy. The mean change in hematocrit was significantly greater for cases of vaginal hysterectomy versus other routes of hysterectomy (−6.40% ± 2.93% vs −5.82% ± 2.92%; $P < 0.001$). By route of hysterectomy, overall mean EBL was highest for abdominal (201.2 ± 128.0 mL), followed by vaginal (141.0 ± 102.2 mL), laparoscopic-assisted vaginal hysterectomy (130.5 ± 105.8 mL), and then laparoscopic hysterectomy (91.3 ± 78.5 mL). However, vaginal hysterectomy had significantly greater EBL as compared with all other routes (141.0 ± 102.2 mL vs 126.9 ± 108.4 mL; $P < 0.001$).

4. Discussion

In the present study, a mathematical model has been developed to predict POD1 hematocrit levels after hysterectomy for benign disease.

Box 1
Variables analyzed within the linear mixed model.

Demographic characteristics	Preoperative	Intraoperative	Postoperative
Age [a], ethnic origin [a], body mass index [a], height, weight [a], diabetes, smoking status [a], ASA class, functional status	Hematocrit [a], platelet count [a]	Route of hysterectomy [a], type of anesthesia, temperature [a], intraoperative crystalloid volume [a], EBL [a], urine output [a], surgical time [a]	Temperature

Abbreviations: ASA, American Society of Anesthesiologists; EBL, estimated blood loss.
[a]Variables independently predictive of postoperative day 1 hematocrit levels when analyzed by bivariate logistic regression.