Appendix 2. Cumulative Summation Analysis

The standard cumulative summation chart was constructed by defining 4 parameters: acceptable outcome rate (p_0), unacceptable outcome rate (p_1), and probabilities of type I and type II errors. Based on published complication rates of abdominal hysterectomy, the acceptable outcome rate for intraoperative complications was set at 5.7% and the acceptable outcome rate for any intraoperative or postoperative complications was set at 36% (14,15). The unacceptable outcome rate was set at twice the acceptable rate for intraoperative complications (ie, 11.4%) and at 50% for any intraoperative or postoperative complications. The probability of type I and type II errors was each set at 0.1. A score (*s*) was calculated after each procedure as a function of parameters p_0 and p_1 (16). The cumulative summation score began at 0 and was cumulatively recalculated for each procedure in chronological order. The cumulative summation score was decreased by *s* for each procedure without a complication and increased by $1-s$ for each procedure with a complication. A cumulative summation curve was created by plotting the cumulative summation scores vs procedure order. Upper (H_1) and lower (H_0) control limits for this score were calculated as functions of the 4 parameters mentioned in the first sentence (16). When the cumulative summation curve for a particular surgeon rises above the upper control limit, the surgeon's complication rate is considered poorer than the unacceptable rate. When the cumulative summation curve for a particular surgeon drops below the lower control limit, the surgeon's complication rate is considered to be as low as or lower than the acceptable rate. As outlined in the paper by Komatsu et al (16), the average number of attempts needed in order to cross the acceptable limit can be derived solely from the parameters specified a priori for the cumulative summation analysis (p_0, p_1, type I and II error rates).

Risk-adjusted cumulative summation curves were constructed using the observed minus expected cumulative summation method. First, a complication risk score (*r*) was estimated for each patient based on fitting a logistic regression model to predict complications as a function

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of patient risk factors. The risk-adjusted cumulative summation score began at 0 and was cumulatively recalculated for each procedure in chronological order. The risk-adjusted cumulative summation score was decreased by r for each procedure without a complication, and increased by $1-r$ for each procedure with a complication. If the complications are occurring as expected as estimated from the risk model, the risk-adjusted cumulative summation curve will be relatively flat around the reference line of 0. The risk-adjusted cumulative summation curve for a particular surgeon will rise above the reference line if the surgeon's complication rate is worse than expected, given their patient's risk factors.

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