MANY variables (outcome or predictor) in anesthesia are measured on a continuous scale: age, height, weight, body mass index, systolic blood pressure (SBP), and duration of surgery or anesthesia are but a few common examples. However, for routine clinical use and clinical research, continuous variables are often transformed to categorical variables through dichotomization or in some cases the values are converted to more than two categories. For example, body mass index (a continuous variable) is frequently transformed into an ordinal variable using age-specific and sex-specific cut-points in children.1 In some circumstances, cut-points are determined by using arbitrary values to dichotomize continuous variables.2,3

Much has been written on the subject of dichotomization in the statistical literature,4–6 and indeed statisticians are quite vociferous about discouraging the practice of continuous variable dichotomization.6 There is some debate about the wisdom of sacrificing correct statistical practice at the altar of clinical simplicity.7 Clinical sense argues that swaths of our practice involve dichotomous decisions (disease present/disease absent, at risk/not at risk, treat/do not treat). However, some argue that this approach confuses clinical measurement with clinical decision making.8 The logical progression in many situations is that clinical measurements precede decision making. The more precise the clinical measurement, the better decision we can make.8

Common problems associated with continuous variable dichotomization include reduction in the statistical power of the analysis,6 loss of information, and potentially biased effect estimates.3 Investigators in other clinical specialties have addressed the problems associated with continuous variable dichotomization.7–9

However, to our knowledge, no prior such discussions exists in the anesthesia literature. Here, we discuss the clinical and research drawbacks of dichotomizing continuous variables in anesthesia, illustrating these drawbacks with common examples.

Postconceptual Age and Outpatient Surgery
Preterm babies (born before 37 completed weeks of gestation) whose postconceptual age (PCA) is less than 60 weeks at the time of surgery and anesthesia are at increased risk for life-threatening postoperative apnea.10–12 Other investigators have suggested that this risk is highest for infants younger than 44 weeks PCA.13 Although in all these reports PCA was measured as a continuous variable, analysis for risk stratification was dichotomized. The basis for this dichotomy was in many cases unclear, and in some was based on a data frequency criterion.13 Using arbitrary cut-points may lead to inaccurate clinical predictions and unnecessary therapeutic interventions. In the case of PCA at the time of surgery, using a numerical cut-point to categorize risk of postoperative apnea creates a false impression of risk stratification. For example, a scheme that uses 60 weeks PCA as its cut-point assumes that a newborn at 59 weeks and 6 days (baby A) is somehow in a different risk category due to maturity than a baby at 60 weeks plus 1 day (baby B). Similarly, for clinical decision making with regard to postoperative apnea and research data analyses, a baby born at 27 weeks and having surgery at 15 weeks since delivery (42 weeks PCA) will be placed in the same category as baby A from above. Clearly, this is inappropriate from risk estimation perspective.
Intraoperative Hypotension

Commonly, the investigator determines the intraoperative SBP that is most strongly associated with an outcome of interest (perioperative stroke or myocardial infarction). This practice of data-driven dichotomization, that is, searching all points for the largest effect, is strongly discouraged by statisticians because the chosen cut-point significantly affects the strength of the association between a predictor and an outcome variable. It leads to overoptimistic bias or inflation of the odds of an association.

Dichotomization can also produce therapeutic and research dilemmas. For example, consider two 14-year-old boys with intraoperative hypotension, using a threshold for hypotension of SBP less than 95 mmHg. Let us say patient A’s SBP is 65 mmHg while patient B’s SBP is 85 mmHg, each child was treated with appropriate doses of ephedrine, and we repeated their SBP measurement to determine the efficacy of our intervention. If the posttest SBP measurements for patient A was 85 mmHg while for patient B the value was 98 mmHg, the questions we will undoubtedly have to ask is which patient showed greater response to our intervention? Using the clinical cut-point above, child B has improved more because he is no longer hypotensive while child A remains hypotensive and for clinical purposes may receive additional doses of ephedrine or for research purposes may be placed in a multiple hypotension or ephedrine-resistant hypotension group. On the other hand, if we use absolute response to treatment, then patient A has shown more than double the response to our intervention compared with patient B (85–65 = 20 vs. 89–85 = 9).

Implications for Clinical Anesthesia Research

Data interpretation and research conclusions suffer when variables are dichotomized. When continuous variables are dichotomized, they become conventional epidemiologic indicators (i.e., disease present, disease absent). This approach violates a variety of basic statistical principles including reduced reliability of estimates, reduced bivariate correlation between variables, loss of statistical power, and associated inflated type II errors – \[ \text{(power} = 1 - \text{type II error}) \]. In general, the errors increase with the number of variables that are dichotomized.

Dichotomization reduces the bivariate correlation between variables. For example, consider the correlation between duration of postoperative mechanical ventilation (x variable) and hospital length of stay as the y variable. When both x and y variables are treated as continuous, there is a strong positive correlation (\( \rho = 0.63 \)) between the two. Dichotomizing the x variable into prolonged and short ventilation days using 4 days or more as the chosen cut-point is a clinically relevant approach to data interpretation that comes at a price because there is a sharp reduction in the correlation coefficient between the x and y variables (\( \rho = 0.47 \)). Finally, when both x and y are dichotomized, there is further reduction in the correlation coefficient by almost 50% (\( \rho = 0.34 \)).

Dichotomization completely ignores within-category variability and details of the underlying continuous distribution. It assumes a step function relationship, whereas exploring a smoother continuous relationship may be more appropriate and add insight into associations of interest. Dichotomization is an extreme form of “rounding” that is equivalent to losing a third of the data.

Dichotomization and Sample Size Considerations

Dichotomizing variables used for sample size (SS) calculations can lead to wasting of SS for a given power. Suppose we wish to design a study to determine whether a new drug reduces blood pressure from a chosen target definition of hypertension (say SBP > 130 mmHg). Should we power the study for a mean reduction in blood pressure or a proportionate reduction in the probability of hypertension? Assume that SBP is normally distributed in each group (A and B) with the same SDs (i.e., \( \sigma_A = \sigma_B = 20 \text{ mmHg} \)). If sample A has a mean SBP = 130 mmHg and sample B has a mean SBP = 140 mmHg, using our target definition of hypertension, the prevalence of hypertension is 0.5 in sample A and 0.69 in sample B, for a difference in proportions of 0.69 - 0.50 = 0.19. Detecting a difference in proportions of 0.19 requires 278 patients, but detecting a difference in mean SBP of 10 mmHg between the two samples requires only 172 patients (both with \( \alpha = 0.05 \) and 90% power). Using a test of proportions in this instance is associated with a 62% increase in the sample size compared with the sample size needed = 86 patients (both with 90% power). Using a test of proportion for SS estimation in this instance is associated with a 62% increase in the SS compared with the SS needed for comparing the mean difference in SBP. Using too many subjects in a study is expensive and unnecessarily exposes study subjects to potentially harmful therapy or intervention.

Final Remarks

As previously noted, many of the perceived advantages of dichotomizing continuous variables are illusory and are generally not supported by statistical principles. The practice of “forcing” individuals into groups may simplify the statistical analysis and interpretation of results; however, this comes with a hefty price with regard to the robustness of the analysis and the conclusions drawn from the study. Therefore, what is sensible in a clinical setting may not be relevant to correct statistical analysis.

Through this report, we encourage anesthesiology practitioners and researchers to consider the many limitations associated with variable dichotomization and to analyze and report continuous variables as such. In the long run, this would
improve the quality and validity of conclusions drawn from anesthesia research and should improve patient care.

Acknowledgments
Supported by the National Institute of General Medical Sciences (NIGMS) of the National Institutes of Health (Bethesda, Maryland) (grant no. K23 GM104354 to Dr. Nafiu).

Competing Interests
The authors are not supported by, nor maintain any financial interest in, any commercial activity that may be associated with the topic of this article.

Correspondence
Address correspondence to Dr. Nafiu: onafiu@med.umich.edu

References