Published in final edited form as:

Anesthesiology. 2015 September ; 123(3): 504–506. doi:10.1097/ALN.0000000000000745.

Continuous variable transformation in anesthesia: useful clinical shorthand, but threat to research

Olubukola O. Nafiu, MD, FRCA, MS, Brenda W Gillespie, PhD*, and Alex Tsodikov, PhD*

Department of Anesthesiology, Section of Pediatric Anesthesiology, University of Michigan, Ann Arbor, Michigan, USA

*Department of Biostatistics, University of Michigan, Ann Arbor, Michigan, USA

Introduction

Many variables (outcome or predictor) in anesthesia are measured on a continuous scale: age, height, weight, body mass index (BMI), systolic blood pressure (SBP), 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, BMI (a continuous variable) is frequently transformed into an ordinal variable using age 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 argue that swaths of our practice involve dichotomous decisions (disease present/disease absent, at risk/not at risk, treat/do not treat). On the other hand, 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 (5). 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.

Address correspondence and request for reprints to: Olubukola O. Nafiu (MD, FRCA, MS). 1500 East Medical Centre Drive, University of Michigan Health System, Room UH 1H247, Ann Arbor, Michigan 48109-0048. Phone: 734-936-4280. Fax: 734-936-9091. onafiu@med.umich.edu.

No other conflicts of interest declared by any of the authors on this manuscript.

Post-conceptual age and outpatient surgery

Preterm babies (born before 37 completed weeks of gestation) whose post-conceptual age (PCA) is <60wk 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 44wk 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, in some the cutoff 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 60wk PCA as its cut-point assumes that a newborn at 59wk and 6days (baby A) is somehow in a different risk category due to maturity than a baby at 60wk plus one day (baby B). Similarly, for clinical decision-making with regard to postoperative apnea and research data analyses, a baby born at 27wk and having surgery at 15wk since delivery (42wk 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 lowest intraoperative systolic blood pressure (SBP) that is associated with an outcome of interest (perioperative stroke or myocardial infarction) (14). This practice of data-driven dichotomization, i.e. 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 (5, 6). 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 14yr old boys with intraoperative hypotension, using a threshold for hypotension of SBP <95mmHg. Let's say patient A's SBP is 65mmHg while patient B's SBP is 85mmHg, each child was treated with appropriate doses of ephedrine and we repeated their SBP measurement to determine the efficacy of our intervention. If the post-test SBP measurements for patient A was 85mmHg while for patient B the value was 98mmHg, 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 to patient B ($85-65 = 20$ vs. $98-85 = 13$).

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 (7), reduced bivariate correlation between variables (9), loss of statistical power and associated inflated type II errors – *power = 1 - type II error* (6, 8). In general, the errors increase with the number of variables that are dichotomized (9).

Dichotomization reduces the bivariate correlation between variables (9). For example, consider the correlation between duration of postoperative mechanical ventilation (*x-variable*) and hospital length of stay (LOS) 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 4d 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% ($\rho=0.34$).

Furthermore, dichotomization completely ignores within-category variability and assumes a monotonic relationship between groups. Also, dichotomization discards all details about the underlying distribution of a continuous variable. Dichotomization is an extreme form of “rounding” that is equivalent to losing a third of the data (5).

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 BP from a chosen target definition of hypertension (say systolic BP > 130mmHg). Should we power the study for a mean reduction in BP or a proportionate reduction in the probability of hypertension? Assume that SBP is normally distributed between two samples (A and B) with the same standard deviations (i.e. $\sigma_A = \sigma_B = 20\text{mmHg}$). If sample A has a mean SBP = 130mmHg and sample B a mean SBP = 140mmHg, using our target definition of hypertension, the prevalence of HT in sample A, $P(\text{HTN})_A = 0.5$, while for sample B the prevalence $P(\text{HTN})_B = 0.69$. The mean difference for these two samples is $(\mu_B - \mu_A) = 0.69 - 0.50 = 0.19$. The sample size needed for detecting a 19% difference in proportions = 139 patients, vs. a 10mmHg difference in mean SBP between the two samples when the sample size needed = 86 patients (both with 90% power). Using a test of proportion for sample size estimation in this instance is associated with a 62% increase in the sample size compared to the sample size 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 regards 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 anesthesia 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

National Institute of General Medical Sciences (NIGMS) of the National Institute of Health, grant number K23 GM104354 supported Dr. Nafiu's work.

References

1. Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003–2006. *JAMA*. 2008; 299:2401–2405. [PubMed: 18505949]
2. Montan S. Increased risk in the elderly parturient. *Curr Opin Obstet Gynecol*. 2007; 19:110–112. [PubMed: 17353677]
3. Nyberg DA, Souter VL, El-Bastawissi A, Young S, Luthhardt F, Luthy DA. Isolated sonographic markers for detection of fetal Down syndrome in the second trimester of pregnancy. *J Ultrasound Med*. 2001; 20:1053–1063. [PubMed: 11587012]
4. Weinberg CR. How bad is categorization? *Epidemiology*. 1995; 6:345–347. [PubMed: 7548338]
5. Dawson NV, Weiss R. Dichotomizing continuous variables in statistical analysis: a practice to avoid. *Med Decis Making*. 2012; 32(2):225–6. [PubMed: 22457338]
6. Selvin S. Two issues concerning the analysis of grouped data. *Eur J Epidemiol*. 1987; 3:284–287. [PubMed: 3653356]
7. Vintzileos AM, Oyelese Y, Ananth CV. The “anathema” of arbitrary categorization of continuous predictors. *Am J Obstet Gynecol*. 210(3):200–3. [PubMed: 24096179]
8. Streiner DL. Breaking up is hard to do: the heartbreak of dichotomizing continuous data. *Can J Psychiatry*. 2002; 47(3):262–6. [PubMed: 11987478]
9. MacCallum RC, Zhang S, Preacher KJ, Rucker DD. On the practice of dichotomization of quantitative variables. *Psychological Methods*. 2002; 7:19–40. [PubMed: 11928888]
10. Rossavik IK, Fishburne JI. Conceptional age, menstrual age, and ultrasound age: a second-trimester comparison of pregnancies dated of known conception date with pregnancies dated from last menstrual period. *Obstet Gynecol*. 1989; 73:243–249. [PubMed: 2643067]
11. Coté CJ, Zaslavsky A, Downes JJ, Kurth CD, Welborn LG, Warner LO, Malviya SV. Postoperative apnea in former preterm infants after inguinal herniorrhaphy. A combined analysis. *Anesthesiology*. 1995; 82(4):809–22. [PubMed: 7717551]
12. Allen GS, Cox CS Jr, White N, Khalil S, Rabb M, Lally KP. Postoperative respiratory complications in ex-premature infants after inguinal herniorrhaphy. *J Pediatr Surg*. 1998; 33:1095–8. [PubMed: 9694101]
13. Malviya S, Swartz J, Lerman J. Are all preterm infants younger than 60 weeks postconceptual age at risk for postanesthetic apnea? *Anesthesiology*. 1993; 78(6):1076–81. [PubMed: 8512100]
14. Bijker JB, van Klei WA, Kappen TH, van Wolfswinkel L, Moons KG, Kalkman CJ. Incidence of intraoperative hypotension as a function of the chosen definition: literature definitions applied to a retrospective cohort using automated data collection. *Anesthesiology*. 2007; 107(2):213–20. [PubMed: 17667564]