

# Statistics for Anesthesia

## Using [OnlineStatBook.com](http://OnlineStatBook.com)



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# Using Slides

- For educational principles and integration with course's interactive Excel spreadsheets see
  - Dexter et al. [Application of an online reference for reviewing basic statistical principles of operating room management.](#) *Journal of Statistics Education* 18(3), 2010



# Using Slides

- Topics selected are those needed for study of anesthesia group and OR management
  - © 2009 Franklin Dexter
  - Last updated 09/06/11
- Rice University's Online Statistics Interactive Multimedia Course contains three modes
  - Standard, if you prefer to read content
  - Multimedia, if you prefer to listen to lectures
  - Condensed, which does not apply to our use



# Probability Distribution

- Probability distribution
  - Review learning objectives at top of page
  - Answer the questions at bottom
    - Check your answers by clicking the OK
  - Surgical case durations and time from end of surgery to extubation follow right-skewed distributions
  - Birth weight, ejection fractions, and  $S_aO_2$  on room air follow left-skewed distributions



# Probability Distribution

- Cumulative frequency curve
  - Answer the questions at the bottom of the web page and review answers
  - Proportions of physiologically complex pediatric procedures performed at different hospitals in a region can be viewed with cumulative frequency curve



# Central Tendency

- What is central tendency?
  - Since total cost for caring for a population of patients equals the mean multiplied by the number of patients, knowing the “central tendency” of a probability distribution is important to cost accounting for anesthesia



# Central Tendency

- Difference between mean and median
  - Follow web site's steps since they have been shown in studies to enhance learning
    - Take the pretest
    - Do the simulations
    - Do the post test



# Central Tendency

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- Absolute deviations
  - As for all future simulations, follow web site's steps to enhance learning
    - Take the pretest
    - Do the simulations
    - Do the post test
  - Absolute deviations are often used to assess the magnitude of differences between scheduled and actual OR times

# Central Tendency

- Mean
  - Mean and median rarely are the same for historical OR times of similar cases, but often are the same for total hours of cases and turnovers of a specialty in an OR on a weekday
  - When considering costs, the mean OR time is economically relevant, being proportional to the total OR time used



# Central Tendency

- Median
  - Median is useful when analyzing OR times because it is unaffected by very long cases



# Central Tendency

- Trimmed mean
  - Trimmed mean is at bottom of web page
  - Many commercial products suggest OR case scheduling using trimmed mean of historical OR times of recent, similar cases



# Variability

- Percentiles
  - Do not worry about different ways to calculate percentiles, just that there are different ways
  - The longest and shortest amounts of time to complete cases are often estimated by using the 5<sup>th</sup> and 90<sup>th</sup> percentiles of historical OR times of similar cases
    - They are about 1/3<sup>rd</sup> less and 1/3<sup>rd</sup> more than the median, respectively



# Variability

- Variance and standard deviation
  - Standard deviation among days in the total hours of cases including turnovers affects how often anesthesiologists work later than average
  - Although standard deviation can be used to assess lability in hemodynamic parameters during an anesthetic, estimates can be sensitive to artifacts (i.e., extreme outliers)



# Variability

- Standard deviation and mean
  - Focus on how large standard deviations reflect large absolute deviations from the mean
    - Not same as large range
    - Not same as equally spread out
    - Not increased by large mean



# Correlation

- Positive and negative correlation
  - Reimbursement and total costs are positively correlated
  - Patient age and endotracheal tube size are positively correlated
  - Average pain score and satisfaction are negatively correlated



# Correlation

- Linear correlation
  - Professional fee charges for anesthesia care and anesthesia time are linearly correlated
  - Height and weight are not linearly correlated
  - Altitude and hemoglobin saturation are not linearly correlated



# Correlation

- Strength of correlation
  - Propofol induction dose is strongly correlated with weight among patients of all ages
  - Surgical time is very weakly correlated to anesthesia induction and emergence times



# Probability

- Basic concepts
  - Probability of a single event
    - Surgeon #1 finishes case #1 with the surgical microscope within 3 hr
  - Probability of pair of events
    - Surgeon #1 finishes his case #1 with the surgical microscope within 3 hr
    - Surgeon #2 finishes her case #1 without the microscope more than 3 hr after start, and only then will need the microscope for her case #2



# Probability

- Conditional probability
  - Probability that a case will finish within the next 1 hr is conditional on its having been on-going for the past 2 hr
  - Probability that mean arterial pressure will drop 10 mmHg within 10 min is conditional on its having already dropped 20 mmHg



# Probability

- Statistical independence
  - Consider the probability that General Surgery has been busier than average every Monday for the past 8 weeks and yet there is in fact no overall positive trend in its workload



# Probability

- Prior probability
  - Calculate the probability that a case that the surgeon has never scheduled before at the facility will take  $> 1$  hr longer than scheduled
    - Depends on prior probabilities
    - Frequent problem with add-on cases done in afternoons keeping people working late in ORs



# Probability

- Bayes' theorem
  - If temperature of child undergoing mastoidectomy has increased from  $36.5^{\circ}\text{C}$  to  $38.3^{\circ}\text{C}$  over the past 2 hr, consider malignant hyperthermia or remove blankets?



# Normal Distributions

- Basic features

- May plan staffing at 66<sup>th</sup> percentile of workload if 2 × as expensive to work overtime as during regularly scheduled hours
  - Close to 1 standard deviation above mean
- May reduce staffing to save money while assuring that at least 95% of urgent cases start within 4 hr of submission
  - Close to 2 standard deviations above mean



# Normal Distributions

- Area under normal curve
  - Area under curve from far left to  $X$  is useful for calculating probability that a case will take at most  $X$  hours
    - Also useful for probability that all the cases in an OR will finish by 4:00 PM



# Normal Distributions

- Differences among normal distributions
  - If you answer all of the pretest questions correctly, you may want to skip the simulation
  - Comparison of 2 normal distributions is central to understanding Student's  $t$ -test comparison of means of 2 normal distributions



# Normal Distributions

- Standard normal distribution
  - Questions at bottom of web page are especially practical for future content
  - If the total hours of cases including turnover times in an OR has a mean of 7 hr and a standard deviation of 0.5 hr, on what percentage of days will there be overtime payment for work  $> 8$  hr?



# Sampling Distributions

- Introduction

- After answering questions at bottom of web page, consider the following:

- Sampling distribution of maximum number of patients present simultaneously in the phase I post anesthesia care unit each day
- Sampling distribution of minimum mean arterial pressure after induction of anesthesia



# Sampling Distributions

- Sample size
  - When calculating mean variable costs per hour of OR time among all of a surgeon's cases, typically sample size  $(N) > 200$  cases
  - When calculating mean OR time of historical cases of a certain combination of surgeon and scheduled procedure, the most common sample size at a tertiary suite is  $N = 0$  cases and the second most common is  $N = 1$  case



# Sampling Distributions

- Central limit theorem
  - When finished simulation, consider that for total hours of cases including turnovers, sample sizes are generally  $N > 30$  weeks and staffing is planned for slightly more than average workload
    - From central limit theorem, basing staffing on a normal distribution is often reasonable



# Estimating Population Parameters

- Parameters and statistics
  - To estimate how much longer one anesthetist takes to do a lumbar (labor) epidural than another, you might calculate a 95% confidence interval for the difference in their mean times



# Estimating Population Parameters

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- Degrees of freedom
  - Our examples are less interesting than the heights of Martians on the web page



# Estimating Population Parameters

- Bias
  - Questions at the bottom of the web page are especially useful for OR management, because bias in case duration prediction is a common concern
  - If a group of surgeons consistently underestimates OR times to get cases onto an OR schedule, then there is *bias*



# Estimating Population Parameters

- Sampling variability
  - As you answer the pretest questions, consider that the probability distributions of OR times for similar cases are often right-skewed and that the median of historical OR times is useful since it excludes outliers



# Confidence Intervals

- Introduction

- Useful to estimate the 95% lower confidence limit for the cancellation rate of each specialty at a facility and to compare that value to a threshold for being unacceptable



# Confidence Intervals

- Confidence interval for mean
  - Calculate 95% two-sided confidence interval for the average reimbursement per American Society of Anesthesiologists' Relative Value Guide billing unit of different payers contracting with an anesthesia group



# Confidence Intervals

- Student  $t$ -distribution
  - Important to understand that even if you sample from a normal distribution, the mean follows a Student's  $t$ -distribution
  - For OR times, the sample sizes are often very small (e.g.,  $N = 3$ ), and thus the difference between Student's  $t$ -distribution and a normal distribution is important practically



# Hypothesis Testing

- Probability values
  - Emphasis on difference between small  $p$ -value and large effect is important
    - When testing if diversity of types of procedures performed by one anesthesia group differs from another, routinely  $N > 10,000$  for both causing  $p < 0.000001$  even when differences are practically irrelevant clinically
      - Confidence intervals are more useful



# Hypothesis Testing

- One-tailed tests
  - One-tailed tests are often practical for managerial questions
    - When evaluating the probability that a case will fit within a hole in the OR schedule, all that is of interest is whether its OR time will be less than or equal to some threshold



# Student's $t$ -Test

- Testing a single mean
  - Test whether a payer's reimbursement per American Society of Anesthesiologists Relative Value Guide unit is significantly different from the national survey value



# Student's $t$ -Test

- Student's  $t$ -distribution
  - Characteristics of tails of the distribution are important, because we rely on the 5<sup>th</sup> percentile and the 90<sup>th</sup> percentile for the shortest and longest times that cases take



# Student's $t$ -Test

- Difference of two means
  - Test whether two surgeons take different amounts of time to complete a procedure



# Additional Education in Operating Room Management

- [www.FranklinDexter.net/education.htm](http://www.FranklinDexter.net/education.htm)
  - Course in OR management by web, onsite or at the University of Iowa (3.5 days)
  - Lectures on day of surgery decision making, PACU staffing, OR allocation and staffing, anesthesia staffing, financial analyses, comparing surgical services among hospitals, strategic decision making, and drug costs
- [www.FranklinDexter.net](http://www.FranklinDexter.net)
  - Comprehensive bibliography of peer reviewed articles in operating room and anesthesia group management