EDUCATION

Applied statistics in vascular surgery Part 1: Choosing between parametric and non-parametric tests

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Abstract:

The interest for studying and performing surgical research has grown during the last decades. Among its fundamental principles is the understanding of statistical tools that will allow an appropriate analysis and interpretation of the data. The aim of our study is to present the basic concepts of parametric and non-parametric statistical tests for assessing differences when comparing two or more groups. A basic understanding of normal vs non-normal distribution is presented, along with definitions of the most appropriate statistical test to be used based on the type of the variables, the data distribution, the number of groups and the independence between groups.

INTRODUCTION

The interest in surgical research has vastly increased over the last 30 years, accounting for an increasing number in published articles, conference presentations and citations counts in peer reviewed journals [1]. Among the integral parts of surgical research is the appropriate statistical analysis. As a result, it is of utmost importance, especially for young surgeons to properly work on statistics when performing their research or studying the work of other colleagues. However, a surgeon may often feel overwhelmed when trying to decide which statistical method to use when conducting a research. Currently, there are statistical teams that work on medical data, however it is recommended that surgeons may also have to acquire some level of statistical understanding. Determining what type of data to collect and what hypothesis test to formulate is among the fundamental principles of surgical research. The aim of this article is to present a general understanding of the basic statistical concepts when facing the dilemma of which statistical test to use.

Data distribution and samples' independence

Collecting data for all patients who ever had a vascular operation is time consuming and usually not feasible. For that reason, we often pick up a representative study sample and formulate a hypothesis. The *a priori* hypothesis is the null hypothesis (H_o), which assumes that no significant difference is expected between specified populations. For example, when comparing the age of patients treated with endovascular and open repair of abdominal aneurysms, the null hypothesis assumes that there is no statistically significant difference. If the null hypothesis is rejected, then the alternative hypothesis (H_1) is true and thus, there is difference in the age of patients treated with the two techniques. The first step when analysing data is to decide whether it is continuous or categorical. In our case, age of study participants can take all values within a measurement scale and thus it can be considered as a continuous variable. On the contrary, categorical variables contain a finite number of categories or distinct groups (e.g. gender). When dealing with variables, in general, the researcher should firstly apply descriptive techniques, namely frequency distributions and graphical displays (Figure 1) in order to get acquainted with the data.

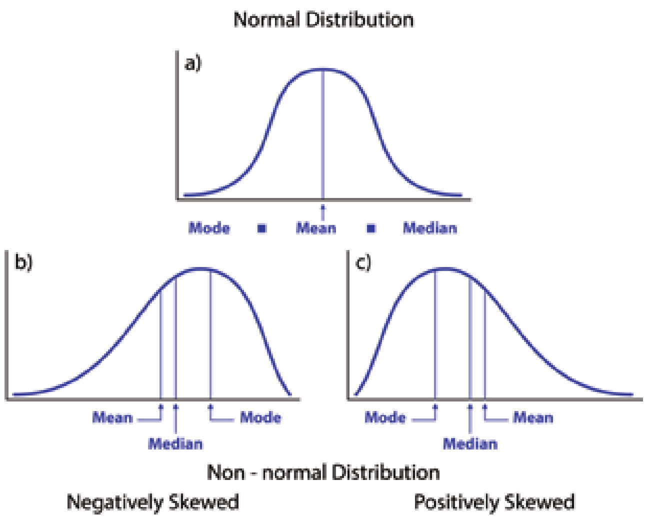

Figure 1. Examples of normal and non-normal distributions: a) the upper curve represents a symmetrical, bell shaped (normal) distribution, in which mean = median = mode, b) the left curve represents a negatively skewed distribution with mean ≤ median ≤ mode and shows an elongated tail at its left, in which more observations are present compared to normal distribution curve, c) the right curve represent a positively skewed distribution with mean ≥ median ≥ mode and shows an elongated tail at its right, in which more observations are present compared to normal distribution curve.

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In case of a continuous variable, the next step is to decide about the distribution of the data. When data follow a symmetric and bell-shaped curve around the mean value then a parametric test can be used. Parametric are methods that use distributional assumptions, they assume that the data follow a normal distribution and also that the spread of the data (variance) is uniform either between groups or across the range being studied [2]. On the contrary, the non-parametric tests do not require the data to follow a particular distribution and they apply by using the rank order of observations rather than the measurements themselves [2,3]. As it is important to clearly assess whether data come from a normal distribution or not, the researcher can apply a more mathematical way, which is the "*Kolmogorov-Smirnov goodness-of-fit test*". After assessing the normality of study variables, the researcher should assess samples' independence. Two or more samples/groups are independent if the values of one sample/group do not depend on the values of the other sample/group. In our case patients who were treated with endovascular repair are different from those who were treated with open repair and as a result samples are independent.

Choosing the appropriate statistical test

Appropriateness of a statistical test when examining for difference of a continuous variable (i.e. age of participants) among different groups (i.e. endovascular and open repair) depends on the variables' distribution (normal vs. non-normal) and the independence of groups. In case of normal distribution, mean and standard deviation (SD) should be reported, while in case of skewed distribution, median with inter-quartile range is appropriate for reporting the average of the continuous variable. A statistical algorithm depicting which statistical test to use when dealing with data based on the type of the variable, the distribution, the number of groups and the independence between groups is shown in Table 1. It should be highlighted that using a parametric test when the data deviate strongly from normal distribution, could lead to incorrect conclusions. Furthermore, when analyzing small study samples (n<30 patients), the parametric assumption of normality is particularly worrisome and non-parametric tests should be used instead. On the contrary, if data are not skewed, use of non-parametric procedures will have generally less power to detect statistically significant difference for the same samples[4].

When dealing with categorical data (e.g. gender) *chi-square test* is used if the sample size contains more than 20 observations in total and more than five observations in each group. In case of small study sample, *Fisher's exact test* is used instead, while *McNemar's test* can be used for paired categorical data [5]. Dealing with the statistical tests can be performed by using many different commercially available statistical packages with various specifications and costs, such as SPSS (IBM), STATA (StataCorp), SAS (SAS Institute), R (R Core Team), Minitab (Minitab Inc.) and others.

In conclusion, research in vascular surgery has expanded together with rapid advances in endovascular technology and increasing complexity of patient's care. To support this demand, the vascular researcher should make proper use of statistical techniques to analyze primary data in order to correctly drive decision-making.

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TYPE OF VARIABLE	Continuous										Categorical	
DISTRIBUTION	Normal distribution					Skewed distribution						
No of GROUPS	1 group	2 groups		>2 groups		1 group	2 groups		>2 groups			
Independence between GROUPS		Independent	Dependent	Independent	Dependent		Independent	Dependent	Independent	Dependent	Independent	Dependent
STATISTICAL TEST	1-sample t-test	Independent sample t-test	Paired sample t-test	ANOVA	Repeated-measures ANOVA	Sign test, Wilcoxon signed ranks test	Mann-Whitney U test	Sign test, Wilcoxon signed ranks test	Kruskal-Wallis H test	Friedman test	Chi-square test, Fischer exact test	McNemar's test
EXAMPLE	Mean age of all patients with AAA	Mean age of AAA patients treated with OSR vs. EVAR	Difference in aortic diameter in patients before vs. after EVAR	Mean age of AAA patients treated with OSR vs. EVAR vs. conservative treatment	Difference in aortic diameter in patients before vs. after 6 months vs. after 1 year of EVAR	Mean age of all patients with AAA	Mean age of AAA patients treated with OSR vs. EVAR	Difference in aortic diameter in patients before vs. after EVAR	Mean age of AAA patients treated with OSR vs. EVAR vs. conservative treatment	Difference in aortic diameter in patients before vs. after 6 months vs. after 1 year of EVAR	Difference in males/ females among patients treated with OSR vs. EVAR	Difference in number of patients with excluded/ non-excluded aneurysmal sac after 6 months vs. after 1 year of EVAR

Table 1. A statistical algorithm depicting which test to use, based on the type of variable, data distribution, number of groups and independence between groups

Abbreviations: AAA: Abdominal Aortic Aneurysm, ANOVA: Analysis of Variance, EVAR: Endovascular Aortic Repair, OSR: Open Surgical Repair