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Statistical methods and complexity of data analysis in recent surgical research

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ABSTRACT

To specify the types of statistical methods, currently most influencing high-quality surgical research, we systematically reviewed *original research articles* published in *The American Journal of Transplantation, Annals of Surgery, Liver Transplantation and The American Journal of Surgical Pathology*. We further aimed to determine complexity of data analysis in these journals. Of 518 papers reviewed, 74.7% (95%CI 70.7-78.4) contained methods of inferential statistics. Most frequently used inferential methods among all journals, were basic contingency table analysis, including χ^2-tests and Fisher's exact tests, and methods of survival analysis, with observed frequencies of 39.6% (95%CI 35.3-43.9) and 30.7% (95%CI 26.8-34.9), respectively. Other commonly used procedures were nonparametric techniques and t-tests. Complexity of data analysis was rather sophisticated in *The American Journal of Transplantation, Annals of Surgery* and *Liver Transplantation*, with more than 50% of papers using advanced statistical techniques. However, nearly 65% of papers from *The American Journal of Pathology* were purely descriptive, without any analytical power. Our results indicate that more emphasises should be given to the magnitude of treatment differences and to statistical estimation techniques than to solely rely upon uncritical significance testing. Moreover, authors should be encouraged to further utilize new statistical methodology in their research.

Introduction

The role of statistics as a powerful tool in scientific research is widely accepted and a great increase in the use of statistical methods has been documented for a wide range of medical journals over the past decades [1-4]. Although, favoured by the availability of manifold statistical software packages, a trend towards usage of more sophisticated techniques can be observed, there is also strong evidence, that in particular simple methods, such as t-tests or χ^2-tests remain in common use [4-11].

However, despite a growing body of literature, no comprehensive study to date reported on the use of statistics in top surgical research journals or the types of statistical methods, currently most influencing surgical research. In the present investigation, we therefore reviewed four major surgical journals, currently ranked highest according to the Journal Citation Report 2006 [Institute of Scientific Information, Thompson Corp.] in the category "Surgery", for recent practices regarding their use of statistics. We further aimed to determine complexity of statistical data analysis in these journals. The results of our study allow for the ongoing monitoring of possible trends in statistics usage and may give major implications for further statistical education of practitioners and researchers related to the field.

Materials and Methods

All consecutive original research articles published during the year 2006 in Volume 6, Numbers 4–9 of The American Journal of Transplantation, Volume 243, Numbers 2–6 and Volume 244, Numbers 1–3 of Annals of Surgery, Volume 12, Numbers 1–9 of Liver Transplantation and Volume 30, Numbers 1–9 of The American Journal of Surgical Pathology were included for a bibliometric analysis. Editorials, letters, case reports and review articles were excluded. Additionally, special issues (e.g. conference and congress related issues] of single journals were excluded, in order to avoid bias in terms of the estimated frequencies of applied statistical methods in the journals under investigation.

All papers were manually reviewed for their statistical content by the first and second author [Q.Z. and M.A.]. After critical examination of all sections, tables and figures in a paper, types and frequencies of statistical methods were systematically recorded and classified into 16 categories, similarly used by Emerson and Colditz [5].

Consequently, papers containing statistical analyses beyond descriptive statistics were classified into the categories "Basic Analysis" or "Advanced Analysis" according to sophistication of applied statistical techniques.

Thereby t-tests, simple contingency table analysis (including chi-square- or Fisher's exact test], nonparametric methods, correlation analysis and simple linear regression techniques were considered as Basic Analysis, whereas all papers employing any sophisticated statistical technique beyond those listed above, were classified into the category Advanced Analysis.

Papers containing any method of multivariate analysis (e.g. MANOVA, MANCOVA), statistical modelling, advanced contingency table analysis, epidemiologic statistics, or survival analysis were obligatory categorized as Advanced Analysis. Further, for each paper the number of different statistical techniques uses, was counted in order to determine the amount of various statistical methods involved in each article. Exact 95% confidence intervals were estimated for frequencies of statistical techniques by the Clopper and Pearson method [12].

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Results

There were a total of 124 papers from The American Journal of Transplantation, 130 papers from Annals of Surgery, 128 papers from Liver Transplantation and 136 papers from The American Journal of Surgical Pathology. Table 1 show the types and frequencies of statistical methods in all original research papers of the four journals under investigation. Of all 518 papers reviewed, 74.7% (95%CI 70.7-78.4) contained methods of inferential statistics. Between single journals, these numbers varied substantially and ranged from 35.3% (95%CI 27.3-44.0) for The American Journal of Surgical Pathology to 90.8% (95%CI 84.4-95.1) for Annals of Surgery. Most frequently used inferential statistics among all journals were basic contingency table analysis (χ^2-test and Fisher's exact test) and survival analysis, with observed frequencies corresponding to 39.6% (95%CI 35.3-43.9) and 30.7% (95%CI 26.8-34.9), respectively. Other methods that were frequently identified in more than one quarter of all papers were non-parametric techniques and t-tests. Three papers (0.6%) contained usage of "unidentified tests", as the authors failed to name the statistical procedure employed for generating the presented p-values. Confidence intervals were estimated in approximately one fifth of all research papers, sampled from The American Journal of Transplantation, Annals of Surgery, and Liver Transplantation. However, the corresponding number for The American Journal of Pathology added up to only 7.4%.

Concerning complexity of statistical data analyses, 131 of 518 papers (25.3%, 95%CI 21.6- 29.3), restricted analysis to solely elementary methods as t-tests, chi-square tests, Fisher's exact tests, nonparametric techniques, correlation analysis and simple linear regression analysis, and were therefore categorized as "Basic Analysis" (Table 2). 252 papers (48.6%, 95%CI 44.3-53.1) contained usage of at least one statistical method beyond those listed above and were therefore classified as "Advanced Analysis". Again, between the single journals examined, this proportion differed substantially and was highest for The American Journal of Transplantation (62.9%, 95%CI 53.8-71.4) and lowest for The American Journal of Surgical Pathology (14.0%, 95%CI 8.6-21.0).

Discussion

Our results give up to date evidence for the widespread use of statistics in modern surgical research. As approximately 90% of papers, sampled from The American Journal of Transplantation, Annals of Surgery, and Liver Transplantation were found to have analytical character, using some kind of inferential methods, our findings correspond widely to findings from earlier studies, for a wide range of medical journals from various disciplines [4-11]. However, this does not necessarily hold for papers from The American Journal of Surgical Pathology, as nearly 65% of all papers reviewed from this journal, were purely descriptive, without any analytical power. Thus, it eventually should be reconsidered by the editors, if their possible impact on surgical research justifies their frequency.

Although confidence intervals, by estimating effect sizes, are more likely to provide the information that surgeons and transplant researchers may need, than the single statement of a probability value, they only were identified in a very small proportion of research papers reviewed. This result suggests that in future investigations, more emphasis should be given to the magnitude of treatment differences and to statistical estimation techniques, than to solely rely on uncritical significance testing, as also stressed in an early review from Pocock and colleagues [13].

Finally, we observed that nearly all papers containing methods of inferential statistics, heavily relied upon the application of well-established statistical procedures and seemed to avoid new statistical methodology, although possibly more suitable in single situations. However, on the long run, with the ongoing development of new statistical methods and more user-friendly statistical software packages, also surgical research is likely to pick up the methodological speed in statistical science and will discover new directions in terms of data analysis. In this context, Altman and Goodman [14] suggested that especially methods of Bootstrap, Gibbs sampling, classification and regression trees, random forests, and neural networks are likely to be seen more often in future investigations.

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Table 1. Types and Frequencies of Statistical Methods*

	American Journal of Transplantation	Annals of Surgery	Liver Transplantation	American Journal of Surgical Pathology	All Journals
	n=124	n=130	n=128	n=136	n=518
	n (%)	n (%)	n (%)	n (%)	n (%)
No statistical methods	8 (6.5)	4 (3.1)	2 (1.6)	19 (14.0)	33 (6.4)
Descriptive statistics only	6 (4.8)	8 (6.2)	15 (11.7)	69 (50.7)	98 (18.9)
Inferential methods	110 (88.7)	118 (90.8)	111 (86.7)	48 (35.3)	387 (74.7)
t-tests	44 (35.5)	43 (33.1)	41 (32.0)	10 (7.4)	138 (26.6)
Contingency table analysis					
Basic (χ^2-, Fisher´s Exact test)	49 (39.5)	62 (47.7)	63 (49.2)	31 (22.8)	205 (39.6)
Advanced	2 (1.6)	4 (3.1)	5 (3.9)	0 (0.0)	11 (2.1)
Nonparametric tests	44 (35.5)	39 (30.0)	47 (36.7)	11 (8.1)	141 (27.2)
Analysis of Variance	33 (26.6)	21 (16.2)	19 (14.8)	7 (5.1)	80 (15.4)
Correlation analysis	17 (13.7)	12 (9.2)	19 (14.8)	3 (2.2)	51 (9.8)
Regression analysis					
Basic (Simple linear regression)	9 (7.3)	5 (3.8)	9 (7.0)	2 (1.5)	25 (4.8)
Advanced	19 (15.3)	24 (18.5)	12 (9.4)	2 (1.5)	57 (11.0)
Epidemiologic methods	11 (8.9)	20 (15.4)	4 (3.1)	1 (0.7)	36 (6.9)
Survival analysis	50 (40.3)	42 (32.3)	53 (41.4)	14 (10.3)	159 (30.7)
Other methods	10 (8.1)	11 (8.5)	16 (12.5)	3 (2.2)	40 (7.7)
Unidentified method/test	1 (0.8)	0 (0.0)	0 (0.0)	2 (1.5)	3 (0.6)
Confidence intervals	24 (19.4)	28 (21.5)	29 (22.7)	10 (7.4)	91 (17.6)

*As many papers contained usage of more than one category of statistical methods listed, numbers presented do not add up to the whole of papers reviewed, respectively to 100.0 percent.

A full explanation for the categories listed is given by Emerson/Colditz (1983).

Table 2. Complexity of Statistical Data Analysis

	American Journal of Transplantation	Annals of Surgery	Liver Transplantation	American Journal of Surgical Pathology	All Journals
	n=124	n=130	n=128	n=136	n=518
	n (%)	n (%)	n (%)	n (%)	n (%)
No. of different inferential methods					
Only 1 method	14 (11.3)	9 (6.9)	10 (7.8)	14 (10.3)	47 (9.1)
2 or 3 methods	36 (29.0)	56 (43.1)	47 (36.7)	23 (16.9)	162 (31.3)
4 or 5 methods	32 (25.8)	35 (26.9)	26 (20.3)	3 (2.2)	96 (18.5)
More than 5 methods	27 (21.8)	17 (13.1)	25 (19.5)	6 (4.4)	75 (14.5)
No/descriptive/unidentified methods	15 (12.1)	13 (10.0)	17 (13.3)	90 (66.2)	135 (26.1)
Basic Analysis†	31 (25.0)	36 (27.7)	37 (28.9)	27 (19.9)	131 (25.3)
Advanced Analysis‡	78 (62.9)	81 (62.3)	74 (57.8)	19 (14.0)	252 (48.6)

† t-tests, contingency table analysis basic (chi-square- and Fisher´s exact test), non-parametric techniques, correlation analysis, simple linear regression analysis.

‡Contingency table analysis advanced, ANOVA, Regression analysis advanced, epidemiologic methods, survival analysis, other methods.

If application of even only one of these methods listed could be identified in a paper, classification “Advanced Analysis” was obligatory.