

Anatomy of a Research Paper

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Summary

Writing, editing, and publishing the paper is the last step in the research process. The paper tells the story of the project from inception, through the data-collection process, statistical analysis, and discussion of the results. Novice authors often struggle with writing and often find themselves with either nothing on paper or a weighty version of random thoughts. The process of writing the paper should be analogous to the research process. This article describes and provides a template for the essential sections and features of a scientific report (structured abstract, introduction, hypothesis, methods, results, discussion, and conclusions), describes authorship guidelines that have been established by professional societies, and discusses the importance of adequate and correct references. *Key words: research; scientific method; writing; publication; manuscripts, medical.* [Respir Care 2004;49(10):1222–1228. © 2004 Daedalus Enterprises]

Introduction

Writing is a skill born from practice. The first step to becoming a good writer is becoming an avid and careful

reader. A researcher's early experiments in writing should include multiple rewrites, with constructive criticism from a mentor. Imitating a writing style that feels comfortable

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Richard D Branson MSc RRT FAARC presented a version of this article at the RESPIRATORY CARE Journal symposium, "Anatomy of a Research

Paper: Science Writing 101" at the 48th International Respiratory Congress, held October 5–8, 2002, in Tampa, Florida.

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and reaches your intended audience may be a good way to begin.

Publishing a paper is the logical result of any research project. After all the effort required for design, implementation, data collection, and data analysis, publication is the crucial end point. Publishing serves to share important information with the scientific community and results in personal satisfaction and professional advancement. An author who routinely submits only abstracts without follow-up publication is revealing either a lack of commitment or lack of confidence in study design or results.

An important part of the publication process is scrutiny of the design, methods, data collection, and statistical analysis used in the study. Careful review of the study leads the investigator to discover flaws in the process and clarify the original thought process. It is better to identify shortcomings yourself than to have them pointed out for you by a peer-reviewer pre-publication or in a letter to the editor post-publication.

The mechanics of writing a paper are typically spelled out by each individual journal. *RESPIRATORY CARE* offers an author's guide online.¹ In addition to helping authors meet the journal's formatting requirements, the author's guide also serves as a rough outline for the paper. Using an outline to write a paper may seem like an undergraduate exercise, but the outline is an important tool for organizing your thoughts.

This article describes the anatomy of a research paper, discusses common mistakes, reviews some science-writing rules, and provides some science-writing tips.

The Title Page

The Title

A good title is important for several reasons. The title alerts the reader to the topic of your paper. A well written or phrased title creates curiosity and draws readers to investigate the substance of your paper. However, the main function of the title is to describe your research. Titles should describe the research succinctly; long titles provide no advantage. The title should avoid overstating what resides within and of course should avoid marketing themes.

As with any part of the research paper, research and read other titles on a similar topic. Make note of the wording, length, and syntax. Be specific! The title should let the reader know if your paper is a human, animal, or bench study. As an example, if your title is "Moisture Output of 2 Humidification Systems," it is incomplete. Give more information; for example, "Moisture Output of 2 Humidification Systems for Use With Mechanically Ventilated Patients," or "Comparison of the Moisture Output of 2 Humidification Systems With a Lung Model." The title

tells the reader what to expect in the paper and thus whether the paper really pertains to his literature-search. If you are looking for data on humidification studies with mechanically ventilated patients, the first title is more germane to your topic. Respect the reader: briefly, but clearly, explain the paper's content in the title.

Authors

It may seem self-evident who the authors of a paper are, but authorship has become an issue of concern in recent years.²⁻¹⁰ Part of the issue is the complexity of medicine and technology; completing a research project often requires experts from several fields. Research across disciplines has become a funding priority and also leads to one paper having numerous authors. Unfortunately, politics also appears to play a major role.

In 1997 the International Committee of Medical Editors published guidelines for authorship,¹¹ which were recently extensively revised:

Authorship credit should be based on 1) substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published. Authors should meet conditions 1, 2, and 3.

Interestingly, Durack found that 98% of papers published in the *Boston Medical and Surgical Journal* (predecessor of *The New England Journal of Medicine*) had only one author. This contrasts sharply with today's statistics, wherein only 5% of papers have only one author.² The original articles section of *The New England Journal of Medicine* averages 6 authors per article.³

Huth⁵ provided authorship guidelines that are based on the contribution of the individual investigators. In that system individuals responsible for data collection are not justifiable authors. Many respiratory therapists begin their forays into research as data collectors, and this can be the start of a publishing career. Individuals who collect data can earn authorship by participating in one of the other 4 activities in the aforementioned guidelines. Table 1 describes the principles and rationale for authorship.

From a practical standpoint, most papers are written by 1 or 2 primary authors. The remaining authors have reviewed the work and/or aided in study design or data analysis. Frequently, other members of a research group are included as authors because of their positions and the pressure to publish in pursuit of promotion and tenure. It is a good habit to agree to authorship only if you have met

Table 1. Principles and Rationale for Authorship

Principle	Rationale
1. Each author must have participated sufficiently in the research represented by the report to take public responsibility for the content.	An author must be able to defend the content of the report, including the data and other evidence and the conclusions based on them. The author must also be willing to publicly concede errors of fact or interpretation discovered after publication of the report and state the reason for the error.
2. Participation must include 3 steps: (1) conception or design of the research and/or analysis and interpretation of the data; (2) drafting the report or revising it for critically important content; and (3) final approval of the published version.	Authors cannot publicly defend the intellectual content of the report unless they understand its origins (conception) and can testify to the validity of its argument (critical analysis of evidence). Authors must have sufficient involvement in writing the report to be able to defend it as an accurate report of the research that led to it.
3. Participation solely in the collection of data (or other evidence) does not justify authorship.	Data and other evidence may be gathered by persons who know little or nothing of the steps critical to the main intellectual substance. Such persons cannot take public responsibility for the main elements of a report; they could testify only to the validity of elements of evidence and not to how those elements support the report's arguments and conclusions. Persons for whom authorship is not justified may be named in the report's acknowledgements section.
4. Each part of the report that is critical to its main conclusions and each step in the research that led to its publication must be attributable to at least one author.	Each element of the report that is vital to its conclusions must be publicly defensible or the report's validity is open to question. Therefore, the authorship of a report must include one or more persons able to defend any of its critical vital elements.
5. Persons who have contributed intellectually to the report but whose contribution does not justify authorship may be named in the acknowledgements section and their contributions described. You must obtain permission from persons you wish to mention in the acknowledgements section.	Unless solely responsible for all the report represents, authors should indicate who provided intellectual assistance and the nature of that assistance. Technical assistance includes building equipment, collecting data, locating and abstracting literature, and work in preparing the manuscript that is not intellectual work on its scientific content.

(Adapted from Reference 4)

the principles in Table 1. It is also a good habit to ask only co-authors who have met those standards.

Determining the order in which to list the authors may be simple or complex.⁶ Generally speaking, the individual responsible for the majority of the work is the first author. Authors are then listed in order of contribution. The exception to that rule is the last author listed; in many instances the senior author is listed last. The senior author is often the most experienced member of the group, the administrative leader, and/or the person who directs or is responsible for funding at the facility where the research was done.

Key Words

The key words cannot be picked simply at the author's discretion; instead, they must be terms that appear in the National Library of Medicine's list of Medical Subject Headings (at <http://www.nlm.nih.gov/mesh/MBrowser.html>). However, in the near future it is likely that few journals will list key words, because when conducting a MEDLINE literature search, it is necessary to search all fields (ie, the titles, abstracts, journal names, journal volumes/numbers/page numbers) in order not to miss documents of interest, and since (1) all the key words appear in the title and

abstract and (2) the Medical Subject Headings list is very incomplete, the key words are superfluous.

Corresponding Author

The title page should give the full name and affiliation of each author and specify which is the corresponding author; the corresponding author is the primary contact for the journal's editorial office and the contact person for individuals who have questions about the research. If the corresponding author is at a hospital or an academic institution, list his or her full name (including middle initial), professional or postgraduate degree (eg, "MD"), title, department, hospital, university (if applicable), mailing address, telephone number, assistant's name and telephone number, facsimile number, pager number, and e-mail address. If the corresponding author is at a company, list his or her full name (including middle initial), professional or postgraduate degree (eg, "MD"), title, department (if applicable), company name, mailing address, telephone number, assistant's name and telephone number, facsimile number, pager number, and e-mail address.

Financial and Equipment Support

The title page should also list specific information about organizations, agencies, or companies that supported the

research, either financially or by providing equipment, services, or personnel. If the research was supported by a grant, give the grant number.

Conflicts of Interest

The title page should also list and explain conflicts of interest. The most common conflict of interest is that one of the authors has a financial affiliation with a company that produces one of the products tested or discussed in the research. Explicitly state any affiliations or interests that could be perceived as creating a conflict of interest. However, if there are no such affiliations or interests, there is no need to include a general statement of “innocence” such as, “The authors have no financial affiliation with any of the organizations or products mentioned in this report.”

The Abstract

Nearly all journals require that research papers include abstracts. The abstract appears following the title page. Recently, the *structured abstract* (ie, an abstract that has 5 sections: introduction, objective, methods, results, and conclusions) has become the standard for most research articles (whereas reviews, case reports, and certain other types of special articles have nonstructured abstracts). The abstract must accurately reflect the content of the paper; nothing can be included in the abstract that does not appear in the body of the paper. Therefore, it is best to write the abstract *after* you have written and carefully edited your paper. The abstract is a synopsis of the paper, and many readers will never read any more than the abstract, so it is very important that the abstract be absolutely accurate and concisely convey the paper’s most important data and conclusions. If the journal that publishes your paper is indexed by *Index Medicus* (MEDLINE), the paper will be locatable via the National Library of Medicine’s PubMed search engine (at <http://www.pubmed.gov>) and the abstract will be viewable at that Web site. MEDLINE’s size limit for abstracts is 4,096 characters (approximately 600 words), but most journals prefer their abstracts to be ≤ 300 words.

The structured abstract demands the author be concise. Do not include background information, do not use abbreviations or acronyms (unless the acronym will appear ≥ 4 times in the abstract), and delete any word that is not necessary to convey information. Don’t go too far, however, and eliminate the essential structure and elements that make a complete sentence. Also, don’t use phrases such as “Results will be provided,” when you could write a phrase that describes a key finding, such as “The treatment group had significantly lower mortality.” Don’t spec-

ulate or include opinion in the abstract. The abstract is a “just the facts” presentation of your research.

The abstract’s major emphasis should be the methods and the main results. The introduction or purpose can often be stated in a single sentence. The objective should be stated in one imperative-style sentence; for example: “Objective: Compare the moisture output of 2 humidification systems, using a lung model.” For the abstract that is plenty. Describe the methods and the main results in 3–4 sentences each. Carefully select the most important data and statistics to show and/or describe in the results section. Just state the main results. The conclusion, like the introduction can typically be handled in 1 or 2 sentences. Try summing up the findings in the first sentence and then make a conclusion in the second. For our example, “Moisture output from these 2 humidification systems was not statistically different. Both systems meet the standards for humidifiers used during mechanical ventilation.” In that example, the objective and conclusions are stated in only 35 words. That leaves well over 200 words to describe your methods and results.

The Introduction Section

The introduction section (in some journals this section is called “background”) lays the foundation for the paper. Some authors write long, heavily referenced introductions, but most authors save the heavy detail and description of previous related research for the discussion section. The classic introduction is 2 or 3 paragraphs. The first paragraph provides the background information, with a few seminal references. It’s not necessary to introduce every paper on the topic in the introduction. Mention the most important references and state the research problem. The second paragraph can elaborate on the importance of the problem and list unresolved issues. The final paragraph describes the rationale for the current study and should contain the *research question* and the *hypothesis*. A common error of novice authors is to forget to include the hypothesis.

Of course, you should have a hypothesis prior to starting a study. Keep the hypothesis in mind as you write the paper. Those who review the paper will ask, “Will the chosen methods adequately answer the research question? Do the results definitively refute or support the hypothesis? Is the conclusion (based on the hypothesis) supported by the results?”

In the introduction you can include more background information if you think it is imperative to educate the reader, but remember, the reader is busy too, and a long introduction may turn readers away. As a rule, keep the introduction to 3 paragraphs, with the following information:

1. What is the problem or issue? Mention 3–5 of the most important references.
2. What is the importance of the problem or issue? You can include a few recent references here to demonstrate that research is active on the subject.
3. State your research question and hypothesis.

The Methods Section

The methods section should describe in detail how the study was performed. Ideally, after reading your methods section another researcher could duplicate your study. Remember when writing the methods section, it should be clear how your methods will answer the research question and refute or support your hypothesis.

Structured methods sections (ie, with subheadings such as “subjects,” “treatment protocol,” and “statistical methods”) are popular, and some prestigious journals, which have limited print space, provide an expanded, online methods section. The number of subheadings in the methods section depends on the type of paper. A study that involves human subjects should include the subheading/section “subjects.” An equipment evaluation should include a subheading/section entitled “equipment.” The most common methods subheadings are discussed below.

Subjects

Describe the study subjects (ie, normal volunteers, patients, or animals). If you have a control group, describe those subjects as well. Describe how the subjects were recruited and selected. Describe the inclusion and exclusion criteria. In a small study it may be helpful to include a table that lists the relevant characteristics (eg, age, sex, treatment group, diagnosis) of each patient. In larger trials, the paper should include a table that summarizes the demographic data of the study groups.

If your study involved human subjects, you must include a statement that you obtained approval from your institutional review board, and you should describe, in a general way, how you obtained informed consent from the study subjects. Indicate who signed the consent form: the subjects or their legal representatives (which is common in critical care). As an example, “The protocol was approved by the University of Cincinnati Institutional Review Board, and informed consent was obtained from the subjects’ next of kin.” If the institutional review board waived the requirement to obtain consent, state why it was waived. Institutional review board approval is absolutely required to conduct studies with human subjects, so if your research did not have approval, your paper will be returned without review.

Equipment

Describe the equipment used in the study. Be sure to describe how the equipment was calibrated and, if necessary, validated. Validation is different than calibration. As an example, you may calibrate a flow-measurement device using the manufacturer’s suggested technique (eg, using a super syringe). You can then validate the flow-measurement device by comparing it to measurements from the type of device that is used to obtain the accepted standard measurement (eg, rotameter). If your study is an equipment evaluation, give detailed descriptions of the devices. Equipment evaluations should also include data related to costs.

Some journals require a “product sources” page (at the end of the paper) that lists (in alphabetical order), for each device or supply used in the study, the name/model, manufacturer, and city and state of the manufacturer. Conversely, some journals state that information parenthetically at first mention of each device or supply. For example, “We used the same type of ventilator (Veolar, Hamilton Medical, Reno, Nevada) with both study groups.” Remember, one goal of the methods sections is to allow another investigator to reproduce your results. If someone wants to reproduce your results, they must know what equipment was used and how it was calibrated.

Interventions or Study Procedures

This section describes what clinical procedures or interventions were done and what data were collected. Depending on the type of study, this section may include a description of the experimental protocol and a timeline for procedures and measurements. It is important to provide thorough details. A diagram of the study protocol along a timeline, showing the timing of interventions and the time of measurements, can be particularly instructive. Use of high-quality figures can reduce the length of the methods section and make your methods easier to understand.

Data Analysis

Data analysis is another part of research where novice authors often stumble. First, be clear that even some of the most prolific authors are “statistically challenged.” Get help from a mentor regarding statistics before you finish the protocol and meet with them regarding data collection. Consulting a statistician early is well worth the time and expense. The data analysis section should describe how data were handled, what statistical tests were done, and what p value was deemed to indicate a statistically significant difference. If necessary, explain why the statistical tests you selected were appropriate. Citing a reference for

the appropriate statistical test is a good idea, if one is available, as it helps limit questions from the reviewers.

The Results Section

Though it may seem self-explanatory that the results section should include *only* the results, many authors place opinion and discussion in the results. The results section should simply state the findings, without bias or interpretation. If the methods section has listed experiments in order, the results section should follow the same sequence. At the very least the results should be provided in a logical sequence, often along the time line of the study. For instance, the results of the baseline measurement period should be presented prior to the results obtained after the intervention.

The results section lends itself to any number of potential constructs. Use tables or graphs to represent large volumes of data. If you use a table or graph, don't repeat the information in the paragraph. Paragraphs that include large volumes of data read like the *Book of Numbers*.¹² After the fourth generation, the reader can't remember which result matches which experiment, and loses interest. A table can be as onerous as the paragraph form if the table is allowed to "grow unchecked." Try to keep tables to a single page. If that is not possible, consider dividing up the data among multiple tables (split along the experimental time line) or using graphs.

The results section should be written in the past tense. For example, "Moisture output was greater with system A than with system B." This may seem confusing to novice authors and readers, but the rationale is sound. If you were to write, "Moisture output *is* greater," it would imply a generalizability to situations outside of the experiment. In *your* experiment the moisture was greater with system A under the conditions studied, but that does not imply that the moisture would be greater with system A under all other conditions in which the devices might be used. This is a subtle but important point; use the past tense form in the results section.

Chatburn made the important observation that the results of a study do not prove anything.¹³ Research results can only confirm or reject a hypothesis. Each individual study adds to the collective understanding of the problem and adds evidence to support or refute a given interpretation.

Major faux pas in the results section include: failure to provide the data that is critical to answering the research question; adding interpretation to the findings; and failure to address the statistics. If in the methods section you listed the statistical tests and the p value that was deemed to indicate a statistically significant difference, don't forget to address those in the results section.

The Discussion Section

When starting the discussion consider the research question first. You posed the research question, explained your

methods for answering it, and provided the results; now answer the question. The discussion is the place for interpreting the results. Use the statistical results to make conclusions regarding the research question. In other words, if the hypothesis is statistically confirmed by the results, what does that mean?

The discussion is usually the easiest section to write, and there is no "magic formula." From my standpoint, if you are having trouble with the discussion, you can use the simple construct in Table 2. The most common mistake in the discussion section is overstating the findings. For instance, if you found that high-frequency ventilation improved oxygenation, you cannot infer that other outcomes (eg, mortality) are also improved. If a new bronchodilator reduces airway resistance faster than the old one, you cannot infer that patients will come off the ventilator faster. That type of unjustified inference appears to indicate that the authors knew what they wanted the results to be prior to the study and that they set out to *prove* that the new treatment is better, not to *find out* whether the new treatment is better. Such bias is apparent in phrases such as "We have demonstrated that. . . ."

The reader should easily follow the research question through the methods, results, discussion, and to the conclusion. As a good test, read your hypothesis and conclusion out loud. If you do not see an obvious logical connection between the two, there is a problem.

The preponderance of references should be cited in the discussion section. A few historical references may be helpful for perspective. Most of the references should be recent and aid in the interpretation of your results. If a report you cited disagrees with your findings, clearly explain why.

The discussion section is your chance to review the current knowledge and explain how your study's findings add to the body of knowledge. You can provide opinion as long as you identify it as such.

The Conclusions Section

Many journals require a conclusions section. State your conclusions in clear, simple language. Do not reiterate the data or the discussion. Then you can state your hunches and inferences, making very clear that they are speculation only (eg, "Though the difference between the treatment groups was statistically significant, we suspect that the difference will not influence hospital mortality."). Finally, in the conclusions section you should indicate what research questions should be answered next (eg, "We are currently designing a study to determine whether the statistically significant difference identified in the present study significantly affects hospital mortality.").

Table 2. Generic Construct for Writing the Discussion Section

Paragraph	Objectives	Example Sentence
1	Describe the major findings of the report Answer the research question Don't make conclusions	"The main finding of our research is that, with our lung model, the moisture outputs of device A and device B were not different."
2	Interpret your findings Explain what you believe the major findings mean Don't over-interpret	"During mechanical ventilation both systems provided a moisture output that exceeds current standards."
3-5	Compare your results to the current literature on the same or similar topics Use references to support your interpretation of your findings and the current literature Make sure to discuss the literature that conflicts with your data and explain why the reports conflict	"Pierson et al found that device A was superior to device B in an animal study under uncontrolled conditions. Our findings were obtained under controlled laboratory conditions."
6	List the limitations of your study Describe the generalizability of your results to other situations Describe problems you encountered in the methods	"The duration of our experiment was 4 hours. Performance of these devices beyond that time frame is unknown."
7	List unanswered questions Propose further research that should be undertaken	"Further studies using small tidal volumes are necessary before pediatric use can be recommended."
8	Conclusion Answer the research question and explain your interpretation of the findings Don't make conclusions not supported by the results	YES: "We found no difference in the moisture outputs of system A and system B. Both systems can be used to provide humidification during short-term mechanical ventilation of adults." NO: "Moisture output of system A was significantly greater than system B. System A may improve mucociliary function, enhance secretion clearance, and reduce the incidence of ventilator-associated pneumonia."

Acknowledgements

The acknowledgements section names people who contributed to the work but did not contribute sufficiently to earn authorship. Such individuals may include an in-house reviewer, data-collection personnel, statistical consultant, or typist. You must have permission from any individuals mentioned in the acknowledgements section. Do not make long dedications; keep acknowledgements short and to the point (eg, "Thanks to Jane Smith PhD, of the Respiratory Care Department, University of California at San Francisco, for her assistance with statistical analysis."). Statements about financial support of the research and conflicts of interest should *not* be mentioned in the acknowledgements section, but on the title page.

Summary

Writing a research paper requires patience and practice. There are some simple rules that can assist the novice author in constructing a paper, and there are common pitfalls to be avoided. I would caution that the proper planning of a study is the best way to avoid problems at the writing stage. No amount of clever writing can cover for poor study design or execution.

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