# Organizing the Biomedical Paper

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The preparation of a scientific paper has less to do with literary skill than with organization (Lang, 1987). Authors of biomedical manuscripts want to organize each manuscript so that readers will be able to follow a sequence of events and understand the message. The editor (or the peer reviewer) of a biomedical manuscript reads it to discern (among other things) whether the author has organized the manuscript successfully and, if not, whether a specific rearrangement might make the manuscript more understandable to readers. Readers of a biomedical paper are usually physicians or scientists; they read a paper because they are interested in the message. If a paper is difficult to follow, such readers probably will not be interested in trying to understand it. In some cases, they will read the abstract, but seldom will that be enough to present the author's conclusions effectively. For the manuscript to be effective, it must be written with a specific plan in mind.

The organization of a medical or scientific paper mirrors the sequence of events detailed and discussed in the paper. The author-researcher begins by asking a question (in the Introduction), then undertakes the activities required to find an answer (described in the Materials and Methods), obtains and compiles the data (described in the Results), and answers the question (in the Discussion). Other important elements of the biomedical paper that require specific organization include the title and references. This chapter will briefly discuss each of these elements. Writing the abstract is covered in this book (see "Writing Abstracts," p. 92), and determining authorship is discussed in a chapter in *Essays for Biomedical Communicators: Volume 2 of Selected AMWA Workshops* (Witte, 1997).

Update of Iles RL. Organizing the scientific journal paper. In Minick P, ed. *Biomedical Communication: Selected AMWA Workshops*. Bethesda, Md: American Medical Writers Association; 1994:133-138.

## Begin at the Beginning

Do not overlook the obvious. Begin by thinking about the journal to which the paper will be submitted. Get a copy of the journal, read it, and familiarize yourself with its style and format. Make sure that your article is suitable for the intended journal. In the journal's "Instructions to Authors," the editor should describe acceptable types of manuscripts and give guidelines for submitting manuscripts, including the format for references. For example, some journals no longer accept case reports, and most journals have space limitations. Knowing the desired format before you start will make your paper easier to write and keep you from having to reformat it later. When you are reporting a clinical trial, remember to use the CONSORT guidelines (Moher et al, 2001) for structuring your manuscript. These guidelines are discussed in the AMWA workshop *Reporting the Results of Randomized Controlled Clinical Trials*.

When writing an investigative biomedical paper, you can begin with any section, but it is often easiest to start with the Methods section, which details the steps taken to prove the hypothesis; then move to the Results section. For the purposes of this chapter, however, the sections of the paper will be discussed in sequential order.

### *The Title*

Most authors do not realize the importance of the title. They concentrate on the text, completely overlooking the title until the paper is finished, and then quickly write a title as an afterthought. However, your title is your first chance to hook your reader or reviewer. Your title will be read by far more people than will your paper, and, often, the title will determine whether your paper is read at all. Reviewers will use your title and key words to index your work.

Your title should accurately, specifically, and completely identify the central topic of the paper. The title should be structured like other titles in the journal but should also be creative. If you use a subtitle, the title should state the general topic of the manuscript; and the subtitle, the specific topic: eg,

> Local Paclitaxel Delivery for the Prevention of Restenosis: Biological Effects and Efficacy In Vivo [Herdeg et al, 2000, p. 1969]

Stating the specific topic creatively in the subtitle might pique your readers' curiosity:

> Device-Supported Myocardial Revascularization: Safe Help for Sick Hearts [Sweeney & Frazier, 1992, p. 1065]

Often, however, subtitles just add unnecessary words. For instance,

> Third Coronary Artery Bypass Operations: Risks and Costs [Lytle et al, 1997, p. 1287]

could easily have been

> Risks and Costs of Third Coronary Artery Bypass Operations

which is simpler and more specific.

## Main Title

Most journals prefer titles with 100 or fewer character spaces. Begin the title with an important word to attract your intended readers, and remember to use the same key terms as in your hypothesis (the question at the end of the Introduction) and in your Conclusions (in the Discussion). Often, you can just insert an adjective before the dependent variable to make your point.

> *Impaired* Chronotropic Response to Exercise Stress Testing as a Predictor of Mortality [Lauer et al, 1999, p. 524; italics mine]

If your study includes an independent and a dependent variable, list both. If the study was not conducted in humans, name the species at the end of the title.

> Adenovirus-Mediated Insulin Gene Transfer Improves Nutritional and Post-Hepatectomized Conditions in Diabetic Rats [Yamaguchi et al, 2000, p. 670]

If the study is a randomized trial, identify it as such. Other examples of good titles include these:

> Coronary Flow Reserve as a Physiologic Measure of Stenosis Severity [Gould et al, 1990, p. 459]

> Effect of Hemodialysis on Plasma Nitric Oxide Levels [Hon et al, 2000, p. 387]

> Acute Myocardial Infarction after the Use of Sildenafil [Arora et al, 1999, p. 700]

In titles, avoid

- Noun clusters or too many nouns

> Academic Health Systems Management: The Rationale Behind Capitated Contracts [Taheri et al, 2000, p. 849]

> Subacute Stent Thrombosis in the Era of Intravascular Ultrasound-guided Coronary Stenting without Anticoagulation: Frequency, Predictors, and Clinical Outcome [Moussa et al, 1997, p. 6]

- Words ending in *-tion* and *-ment*, which should be verbs

> Surgical *Management* of Anatomical *Variations* of the Right Lobe in Living Donor Liver Transplantation [Marcos et al, 2000, p. 824; italics mine]

- Nonstandard abbreviations

- *The* at the beginning of and within the title; just delete *the*

> *The* Use of Subcutaneous Erythropoietin and Intravenous Iron for *the* Treatment of *the* Anemia Caused by Severe, Resistant Congestive Heart Failure Improves Cardiac and Renal Function and Functional Cardiac Class, and Markedly Reduces Hospitalization [Silverberg et al, 2000, p. 1737; italics mine]

Complete sentences can be used as titles when your point is especially strong or when the journal routinely uses complete sentences.

> Gender and Carotid Endarterectomy: Does it Matter? [Akbari et al, 2000, p. 1103]

> Growth Hormone Enhances Amino Acid Uptake by the Human Small Intestine [Inoue et al, 1994, p. 715]

And finally, proofread for misplaced or poorly placed modifiers. Can you find them in the following titles?

> Ceftriaxone-Resistant Salmonella Infection Acquired by a Child from Cattle [Fey et al, 2000, 1242]

Factors Influencing HLA Sensitization in Implantable LVAD Recipients [Massad et al, 1997, 1120]

### Running Title

The journal will usually ask for a shorter version of the title, to be used as a "running title" or "running head" on subsequent pages of the manuscript. The running title is typed on the manuscript's title page and is generally limited to 40 character spaces. Remember to include all of the main words from the title, specifying the independent and dependent variables whenever possible. For the running title, you can omit the species. For example, shorten

Dexamethasone Alone or in Combination with Ondansetron for the Prevention of Delayed Nausea and Vomiting Induced by Chemotherapy

to

Prevention of Delayed Nausea and Vomiting Induced by Chemotherapy [The Italian Group for Antiemetic Research, 2000, p. 1555]

Or shorten

Association Between Method of Delivery and Maternal Rehospitalization

to

Delivery Method and Postpartum Rehospitalization [Lydon-Rochelle et al, 2000, p. 1574]

## IMRAD

IMRAD stands for Introduction, Methods (and Materials), Results, and Discussion. Together, these sections constitute a scientific manuscript. The IMRAD system for writing a scientific paper originated with Pasteur, although he did not use the now-standard headings (Day, 1988). In 1972, the American Standards Institute decided to standardize all the headings used in investigative scientific papers. Thus, the IMRAD system was born. Although IMRAD is a useful organizational format, there is no absolute formula for writing; every paper is different and has, as Zeiger (2000, p. 8) says, "its own story to tell and its own organizational challenge." And, you want the story to be complete. Although each section should focus on its specific part of the process, keep the main question and answer of the study in mind as you write.

## Introduction

*What question was studied? The answer is in the Introduction.*

The Introduction creates the expectation that is fulfilled by the rest of the paper. Structure the Introduction like a funnel; ie, begin with what is known about the subject, move to what is unknown, and end with the question your study answers. You can also think about this as progressing from the general to the specific. Begin with a background statement or two describing the nature and scope of the study. A good Introduction gives readers enough background to understand the problem but not so much as to overwhelm them and detract from the research question. Also, make sure that the background statement relates only to the specific subject of the paper. For example, if you are writing about the effectiveness of the different immunosuppressants used to treat patients who have undergone transplantation, start your Introduction with background on immunosuppressants, not with information about the first transplantation procedures.

Next, explain why the study is necessary: what "gap" does it fill? In this section, preliminary reports or abstracts can be cited, as can closely related, previously published work. However, avoid using the names of investigators in the Introduction; remember, the Introduction is intended to hook your reader into reading the paper. Mentioning others by name (rather than by contributions) takes the spotlight away from your work.

Discussion of the gap should lead directly into the specific research question. If your work added nothing to the known literature (even a different interpretation), it would be of no value to the field, so make sure that the unknown element is obvious to the reader. At the end of the Introduction, clearly state the research question; precede it with a phrase that signals that the answer is coming. Examples of signal phrases include "To determine whether . . . ," "The purpose of this study was . . . ," "Therefore, in this study, we asked whether . . . ," and "The current study was, therefore, designed to determine whether . . . ."

The question should repeat the key terms of the title and the Introduction as well as the objectives, the independent and dependent variables, the species, and, when necessary, the groups. You can include a short statement of results in the Introduction, but this is unnecessary if the journal requires an abstract, which would state your conclusions. The importance of the study may also be briefly stated in the final sentence of the Introduction.

Keep the Introduction short: one or two typed pages. You want to catch and hold your readers' attention, not overwhelm them. Write verbs in present

tense for the question and for what is known and in past tense for previous findings. And remember to use transitions.

The following brief Introduction follows the format nicely. I have italicized repeated key words and transitions, all of which make the paragraph flow well.

### General Area

*Restenosis* after an initially *successful percutaneous transluminal coronary angioplasty* remains an important *unsolved problem* with this *promising revascularization technique*. *Retrospective studies have found* that several clinical, angiographic, and procedural *variables* are important *predictors* of *restenosis*.[xx-xx]

### Gap or General Problem

There is considerable variation *among the studies, however*, and the *results* are often difficult to interpret. *Prospective trials* are *clearly needed* to confirm the *observations* made in *retrospective studies* and to assess whether the risk of *restenosis* can be *predicted accurately* in specific patients.

### Previous Findings

*Several studies* have reported high rates of *restenosis among patients* with *coronary vasospasm*, such as Prinzmetal's angina,[xx-xx] as well as *among those* with coronary lesions susceptible to *abnormal vasoconstriction* during provocative *testing*.[xx]

### Hypothesis or Research Question

We designed a *prospective* trial to *test* whether *abnormal coronary vasoconstriction*, detected by hyperventilation testing before *angioplasty*, *increases the likelihood of restenosis*. A *test* that could *accurately identify* patients at high risk of *restenosis* might influence management.

This Introduction reads well. Note the repetition of key words and phrases, which also serve as transitions for the reader. With the first word, you know the subject of the paper, "restenosis," which is followed almost immediately by the narrowed subject, "predictors of restenosis." The author then discusses the shortcomings of the available retrospective studies and addresses the need for a prospective study. His hypothesis, "We designed a prospective trial . . ." follows obviously from the gap in knowledge. The author's final statement informs the reader of the importance of this work to patient care.

## *Materials and Methods*

*How was the problem studied? The answer is given in Materials and Methods.*

The Materials and Methods section should read like a cookbook recipe and is usually arranged chronologically. The Methods section should be thorough enough for someone else to be able to reproduce the experiment. Because this section is usually the easiest to write, many authors begin with it. In Methods, describe what was done to answer the research question, clearly stating the study design and detailing the chosen methodology (materials, subjects, populations).

### Study Design

Begin with a brief statement of the study design (use a header), which should include a sentence about Institutional Review Board approval, the process of informed consent, and compliance with the Animal Welfare Act and Good Laboratory Practices. For example,

> The EXCITE study was a double-blind, randomized, parallel design, placebo-controlled, international multicenter trial designed to compare the efficacy and safety of xemilofiban to placebo when administered to patients prior to and for up to 6 months after PTCR [percutaneous coronary revascularization] [O'Neill et al, 1999, p. 110)].

> The protocol was approved by the institutional review board of each participating hospital, and all patients gave written informed consent before they were involved in the study [O'Neill et al, 2000, p. 1317].

### Study Protocol

The detail of the protocol comes next. Start by repeating your research question:

> We tested the efficacy of xemilofiban administered orally in a dose of 10 or 20 mg given three times daily for up to six months [O'Neill et al, 2000, p. 1317].

If the purpose of the procedure is not clear, explain it to the reader. Repeat the description of the study population, as well as the inclusion and exclusion criteria, unless these elements have been previously detailed in a readily obtainable journal. (If this is the case, refer to the previous study: "The protocol for the trial has been explained elsewhere.[xx]")

> Patients with angiographic evidence of clinically significant coronary artery disease necessitating PTCR were eligible for the study. Patients at high risk for ischemic events were sought in order to maximize the event rate and thus increase the opportunity to demonstrate a therapeutic effect. Patients who had received abciximab before PTCR were not eligible for enrollment [O'Neill et al, 2000, pp. 1316-1317].

At this point, you should explain how the study was randomized, if it was a randomized trial (eg, geographically or individually); how the allocation schedule was generated and how and when the allocation was done; and how the person generating the assignment was separated from the person executing the assignment. After describing the randomization, list the precautions taken to mask (or blind) the trial: eg, capsules and tablets; the location of the code during the trial and when the code was broken; and evidence of successful blinding among the participants, interventionalists, the outcome assessors, and the data analysts (Moher et al, 2001).

> After the diagnostic angiogram had been obtained and before PTCR was performed, patients were randomly assigned to one of three regimens: a single oral dose of 20 mg xemilofiban administered before PTCR . . . or placebo administered both before and after the procedure. The random assignments were made by telephone with the use of an interactive voice-response computer system and were stratified according to the study center. . . . Patients were evaluated 10 to 21 days and 60 days after PTCR. Subsequent monitoring for cardiac events, safety, laboratory values, concurrent medications, and compliance was performed monthly by telephone or by site visits. . . . [O'Neill et al, 2000, p. 1317].

Explain how you projected the target sample size, and include primary and secondary outcome measures, such as study end points:

> There were two primary end points. The first was event-free survival at 182 days, with an event defined as death or nonfatal myocardial infarction. . . . Secondary end points included . . . [O'Neill et al, 2000, p. 1317].

As you complete the description of the protocol, make sure that you have accounted for all of the materials used, including drugs, culture media, buffers, gases, and subjects (human or animal) with inclusion and exclusion criteria for the study. Give exact names, manufacturers, and manufacturers' addresses for the materials you used (some journals require only the city and state for the address).

> After the assessment of blood pressure and habitus, technicians affixed polysomnography leads to each participant and performed calibrations. An 18-channel polysomnographic recording system (model 78, Grass Instruments, Quincy, Mass.) was used to assess sleep state and respiratory and cardiac variables. . . . Arterial oxyhemoglobin saturation, oral and nasal airflow, nasal air pressure, and ribcage and abdominal respiratory motion were used to assess episodes of sleep-disordered breathing. Oxyhemoglobin saturation was continuously recorded with a pulse oximeter (model 3740, Ohmeda, Englewood, Colo.) [Peppard et al, 2000, p. 1379].

Give all of the details necessary for understanding the study and all of the details that affected the study. If a questionnaire was administered, make sure that you have told the reader how it was administered and by whom (see above). If a method is not well established and has not been published or is fairly complex, do not refer to the reference without describing the method completely in the paper. Methods that failed to lead to your study's desired conclusion must be included. To avoid interrupting the flow of the manuscript, place details in parentheses.

> The growth hormone group received a loading dose of 5 mg of growth hormone (somatropin, Humatrope, Eli Lilly, Indianapolis) per day subcutaneously for the first week (for example, a 70-kg patient received 0.5 mg per kilogram of body weight per week), followed by a maintenance dose of 1.5 mg per day for the remaining 16 weeks of the study (for example, a 70-kg patient received 0.15 mg per kilogram per week) [Slonim et al, 2000, p. 1633].

Results should be included in the Methods section ONLY if they are specifically pertinent to the protocol.

> For simplicity, and because so few women in this cohort drank heavily (1.2 percent reported drinking more than 45 g of alcohol per day), we did not define an upper limit for alcohol consumption, although clearly this would be necessary in establishing public health guidelines [Stampfer et al, 2000, p. 17].

Visual elements work well in Methods. In fact, using an illustration is the best way to help the reader understand your protocol (Figure 1). In an illustration, you can easily define participant flow numbers and timing of randomization; assignment, interventions, and measurements for each randomized group; time lengths; arms of the study; and patient designations. Patient characteristics can often be best presented in a table (Table 1 [The Italian Group for Antiemetic Research, 2000, p. 1556]). In a paper with a

complicated Methods section, like a surgical paper, always include an illustration that shows exactly how the procedure was done (Figure 2).

Explain anything that would make your reader ask "why?"—including dead-end methods and study limitations. Explain the limitations of the study methods in a matter-of-fact way. The limitations need to be addressed, but keep the statements short and simple. You do not want to overwhelm the reader with possibly negative implications.

## Dead-end method

> To reduce concern about observer error and the ability to validate temperature measurements, the analysis included only the initial temperature determinations for children evaluated at Children's Hospital and Regional Medical Center in Seattle. The laboratory data that were analyzed consisted of white-cell counts and serum urea nitrogen and creatinine concentrations. Only the initial laboratory test result for each child was analyzed as a potential risk factor for the development of the hemolytic-uremic syndrome [Wong et al, 2000, p. 1931].

## Limitation of Study Methods

> We excluded years before 1939 because the cause-of-death portion of the death certificate was substantially different in earlier years. Data on the cause of death were available for more than 99 percent of all deaths in the United States, except for 1972, when a 50 percent sample was used to estimate the number of deaths [Dowell et al, 2000, p. 1399].

## Statistical Analysis

The last paragraph(s) of Methods should state the analytical procedures that you used to determine the significance of your Conclusions. State the procedures used to analyze each set of data and the software used for analysis. Include your rationale, detailing the main comparative analyses used. Explain whether the analyses were completed on an intention-to-treat basis. The following excerpt is a small portion of a three-paragraph description of statistical analyses for a randomized trial.

> The trial was designed to have 90 percent power to detect a 25 percent reduction in the composite end point of death, nonfatal myocardial infarction, or urgent revascularization in pairwise comparisons of each xemilofiban treatment group with placebo, with a two-sided type I error of 0.025, assuming an event rate of 17.6 percent in the placebo group. . . . For the final analysis, the level of significance was 0.02 for the first primary end point and 0.01 for the second primary end point. . . . Cumulative event rates for each end point were estimated with the use of the Kaplan-Meier method; . . . . Analyses of cardiac end points were performed on an intention-to-treat basis and included all patients according to the assigned treatment and all adjudicated cardiac end points during the designated follow-up period [O'Neill et al, 2000, p. 1317].

In the Methods section, subheadings should be used whenever possible, especially when the section is long and complicated, and always for clinical trials. Sample subheadings include "Study Design," "Enrollment of Patients," "Study Protocol," "Study End Points," and "Statistical Analyses."

Because the Methods section describes work already completed, write it in past tense, in either passive or active voice. Although the active voice is more interesting to read, frequent use of "I" may seem

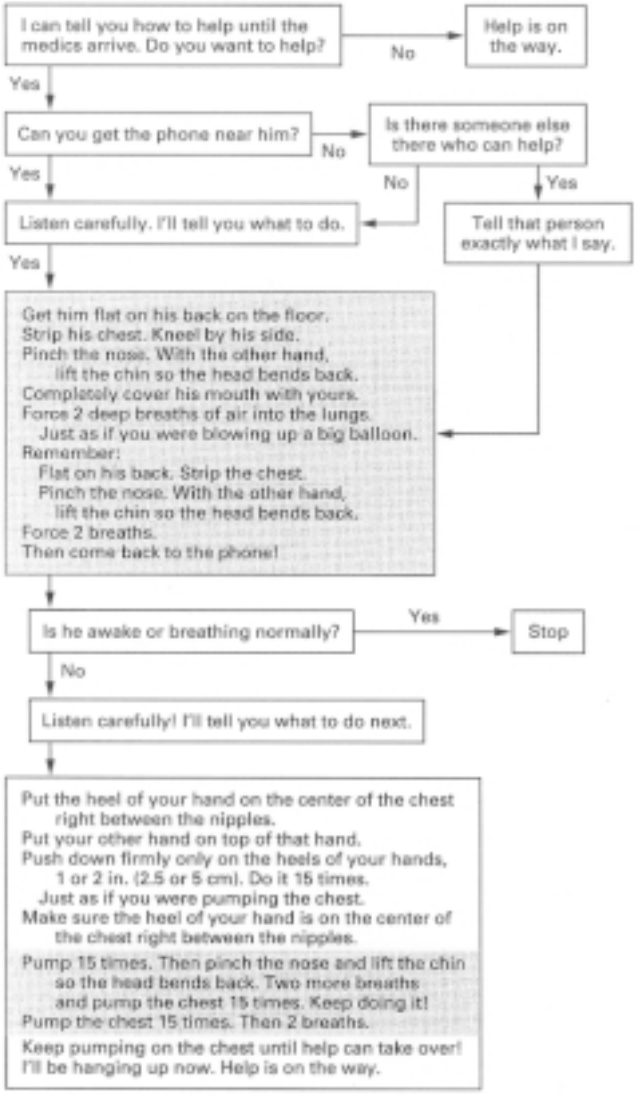


***Figure 1.*** *Study protocol (Hallstrom, p. 1548). An outline of this type makes understanding the protocol simple.* [Editors' note: All figures are reprinted with permission.]

egotistical, so passive is often used in this section. Remember, however, that you can mix the voice and tense in scientific manuscripts, so you can change from active to passive, using active when you want more emphasis.

## Results

*What were the findings? The answer is in the Results section.*

The Results section, which logically answers the research question, should correlate directly with the Methods section. For every method, there should be a result. When possible, use the same order and subheadings that you used in Methods so that the correlations will be easy for the reader to follow. For example, in a manuscript called "Administration of Wine and Grape Juice Inhibits In Vivo Platelet Activity and Thrombosis in Stenosed Canine Coronary Arteries" (Demrow et al, 1995), the subheadings used by the authors in the Methods section are

- Group 1: Red Wine
- Group 2: White Wine
- Group 3: Grape Juice
- High-Performance Liquid Chromatography Analysis

Likewise, the Results section has the same headers.

Although not all headers from the two sections must mirror each other, try to keep them as closely related as possible. Another example comes from "Hemodynamic Effects of Sildenafil in Men with Severe Coronary Artery Disease" (Herrmann et al, 2000). Headers used in Methods are

- Study Subjects
- Study Protocol
- Calculations
- Statistical Analysis

whereas headers in Results are

- Clinical Characteristics
- Systemic and Pulmonary Hemodynamic Effects
- Coronary Hemodynamic Effects
- Adverse Effects

Begin each paragraph by stating a result. Do not begin by restating your methods. Cite data that establish the similarities between the treatment groups first, and then present the results of the treatment. State the effect of the intervention on the primary and secondary outcome measures in the trial and include the confidence level. Remember to use data from only

CHARACTERISTICS OF THE PATIENTS.*

| CHARACTERISTIC | LOW-RISK GROUP | | | HIGH-RISK GROUP | |
|---|---|---|---|---|---|
| | PLACEBO (N=203) | DEXAMETHASONE (N=207) | ONDANSETRON PLUS DEXAMETHASONE (N=208) | DEXAMETHASONE (N=43) | ONDANSETRON PLUS DEXAMETHASONE (N=44) |
| | number of patients (percent) | | | | |
| Sex | | | | | |
| Male | 11 (5.4) | 18 (8.7) | 8 (3.8) | 0 | 1 (2.3) |
| Female | 192 (94.6) | 189 (91.3) | 200 (96.2) | 43 (100) | 43 (97.7) |
| Age | | | | | |
| <50 yr | 82 (40.4) | 82 (39.6) | 86 (41.3) | 29 (67.4) | 35 (79.5) |
| 50–64 yr | 78 (38.4) | 84 (40.6) | 76 (36.5) | 8 (18.6) | 8 (18.2) |
| ≥65 yr | 43 (21.2) | 41 (19.8) | 46 (22.1) | 6 (14.0) | 1 (2.3) |
| Median | 53 | 53 | 51 | 45 | 42 |
| Motion sickness | | | | | |
| No | 173 (85.2) | 179 (86.5) | 170 (81.7) | 28 (65.1) | 32 (72.7) |
| Yes | 30 (14.8) | 28 (13.5) | 38 (18.3) | 15 (34.9) | 12 (27.3) |
| Use of alcohol | | | | | |
| No | 161 (79.3) | 153 (73.9) | 159 (76.4) | 40 (93.0) | 38 (86.4) |
| Yes | 42 (20.7) | 54 (26.1) | 49 (23.6) | 3 (7.0) | 6 (13.6) |
| Karnofsky score | | | | | |
| ≤80 | 10 (4.9) | 17 (8.2) | 8 (3.8) | 3 (7.0) | 3 (6.8) |
| 90 or 100 | 193 (95.1) | 190 (91.8) | 200 (96.2) | 40 (93.0) | 41 (93.2) |
| Treatment setting | | | | | |
| Outpatient | 188 (92.6) | 190 (91.8) | 197 (94.7) | 40 (93.0) | 41 (93.2) |
| Inpatient | 15 (7.4) | 17 (8.2) | 11 (5.3) | 3 (7.0) | 3 (6.8) |
| Primary site of tumor | | | | | |
| Breast | 189 (93.1) | 182 (87.9) | 194 (93.3) | 42 (97.7) | 41 (93.2) |
| Other | 14 (6.9) | 25 (12.1) | 14 (6.7) | 1 (2.3) | 3 (6.8) |
| Chemotherapy | | | | | |
| Cyclophosphamide | 105 (51.7) | 94 (45.4) | 104 (50.0) | 9 (20.9) | 8 (18.2) |
| Doxorubicin | 43 (21.2) | 47 (22.7) | 51 (24.5) | 15 (34.9) | 20 (45.5) |
| Epirubicin | 43 (21.2) | 50 (24.2) | 42 (20.2) | 18 (41.9) | 15 (34.1) |
| Carboplatin | 12 (5.9) | 16 (7.7) | 11 (5.3) | 1 (2.3) | 1 (2.3) |
| Full dose of chemotherapy received | | | | | |
| Yes | 105 (51.7) | 118 (57.0) | 110 (52.9) | 25 (58.1) | 28 (63.6) |
| No | 98 (48.3) | 89 (43.0) | 98 (47.1) | 18 (41.9) | 16 (36.4) |

*Because of rounding, not all percentages total 100.

***Table 1.***

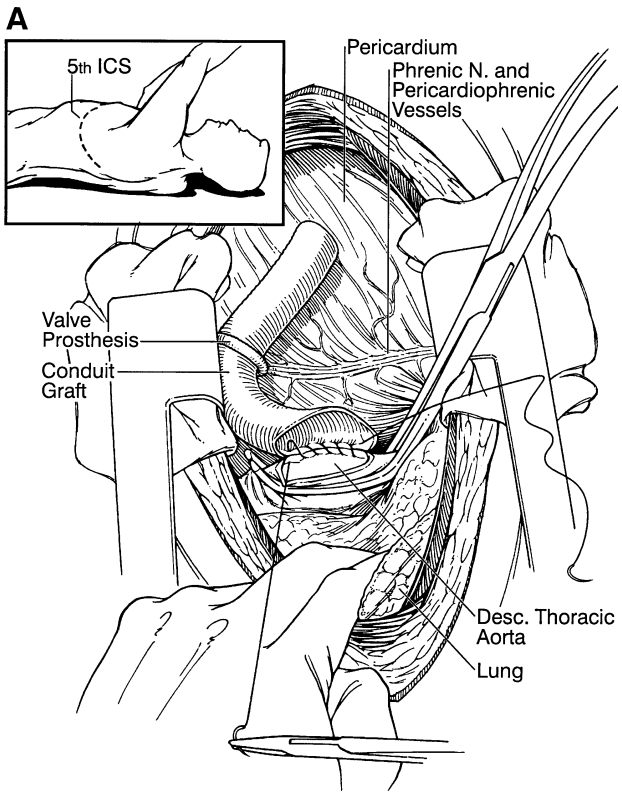


***Figure 2.*** *A step-by-step procedure is best shown in an illustration.*

the study being reported. If necessary, describe a previous study in the Introduction and discuss its relevance in the Discussion, but do not include any previous work in Results. Only in certain scientific fields (eg, biochemistry) would the methods and results be reported together. In some scientific studies, in which multiple experiments lead to a final result, each experiment may be reported with its result, the paper being organized chronologically by experiment.

Also remember that the Results section is another appropriate place for tables and figures, which are perfect for presenting detailed data (Table 2 [Moynihan et al, 2000, p. 1648], Figure 3). No one wants to read strings of data written into sentences. By using illustrations, you can keep written data to a minimum. Charts make protocol results easier to understand (Figures 4 and 5). A response to treatment can be shown graphically with a line drawing (Figure 6). Bar graphs show changes better than tables (Figure 7) and can be used for more complex data to show comparisons (Figures 8 and 9). Diagrammatic illustrations can also be used to enhance figures that show the results of diagnostic tests and surgical procedures (Figure 10) and to simplify complex scientific concepts (Figure 11). Never repeat textual information in the tables or graphs. The text should supplement or highlight, rather than repeat, the graphical data. And, remember, always make sure that the numbers in the Results match the numbers in the Abstract and Discussion.

When results are expressed in words, put data in parentheses after the result:

> When data on all 893 follow-up studies were analyzed, there was a decrease in mean blood pressure from base line to follow-up (from 125/82 mmHg to 123/79 mmHg) and an increase in the prevalence of stage 1 or worse hypertension (from 28 to 31 percent) [Peppard et al, 2000, p. 1380].

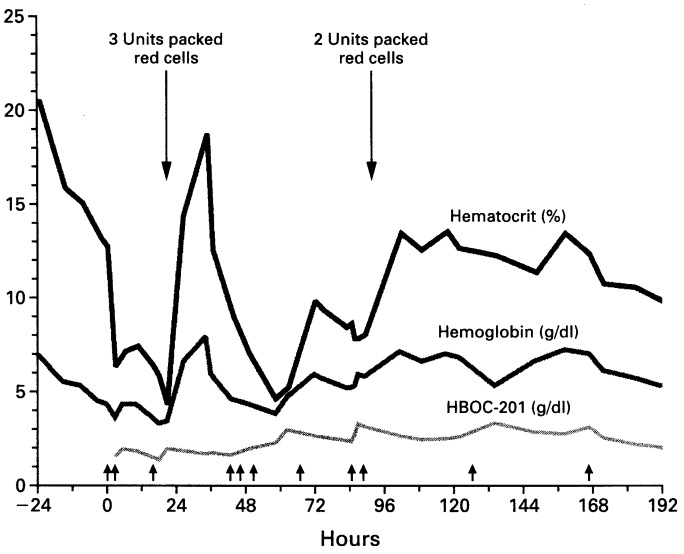


***Figure 3.*** *Hematocrit, hemoglobin, and calculated HBOC-201 levels, presented graphically (Mullon et al, 2000, p. 1641). These data would be impossible to present in the text.*

QUANTIFICATION OF BENEFITS, COVERAGE OF ADVERSE EFFECTS AND COSTS, AND DISCLOSURE OF TIES WITH INDUSTRY IN MEDIA STORIES, ACCORDING TO DRUG.*

| CHARACTERISTIC OF STORY | TOTAL | | ALENDRONATE | | PRAVASTATIN | | ASPIRIN | |
|---|---|---|---|---|---|---|---|---|
| | % (no./total no.) | 95% CI | % (no./total no.) | 95% CI | % (no./total no.) | 95% CI | % (no./total no.) | 95% CI |
| Did not quantify benefits | 40 (83/207) | 33–47 | 57 (40/70) | 45–69 | 13 (9/70) | 6–23 | 51 (34/67) | 38–63 |
| Quantified benefits | | | | | | | | |
| Only relative benefits | 83 (103/124) | 75–89 | 87 (26/30) | 69–96 | 80 (49/61) | 68–89 | 85 (28/33) | 68–95 |
| Only absolute benefits | 2 (3/124) | 1–7 | 0 (0/30) | 0–12† | 0 (0/61) | 0–6† | 9 (3/33) | 2–24 |
| Relative and absolute benefits | 15 (18/124) | 9–22 | 13 (4/30) | 4–31 | 20 (12/61) | 4–32 | 6 (2/33) | 1–20 |
| Adverse effects and costs | | | | | | | | |
| Adverse effects mentioned | 47 (98/207) | 40–54 | 53 (37/70) | 41–65 | 31 (22/70) | 21–44 | 58 (39/67) | 46–70 |
| Costs mentioned | 30 (63/207) | 24–37 | 21 (15/70) | 12–33 | 30 (21/70) | 20–42 | 40 (27/67) | 28–53 |
| Ties with industry | | | | | | | | |
| Cited expert or study | 82 (170/207) | 76–87 | 83 (58/70) | 72–91 | 87 (61/70) | 77–94 | 76 (51/67) | 64–86 |
| Cited expert or study with tie‡ | 50 (85/170) | 42–58 | 71 (41/58) | 57–82 | 70 (43/61) | 57–82 | 2 (1/51) | 0–10 |
| Disclosed tie§ | 39 (33/85) | 28–50 | 32 (13/41) | 18–48 | 47 (20/43) | 27–66 | 0 (0/1) | |

*CI denotes confidence interval.

†The one-sided 97.5 percent confidence interval is given because the percentage is zero.

‡The story quoted at least one expert or study-group member with a tie, as determined by a search of the published scientific literature.

§The tie was also disclosed in the media story.

***Table 2.***

In addition to reporting percentages, include absolute numbers in parentheses when feasible:

> There was no significant difference in the incidence of hospitalization for congestive heart failure between the two groups; the annual rates were 3.5 percent among the patients with a ventricular pacemaker and 3.1 percent among those with a physiologic pacemaker (reduction in relative risk, 7.9 percent; 95 percent confidence interval, -18.5 to 28.3 percent; P = 0.52) [Connolly et al, 2000, p. 1389].

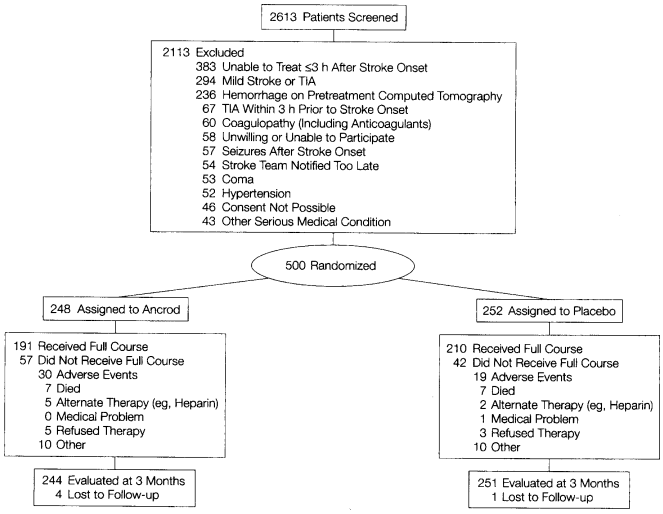


***Figure 4.*** *Trial profile (Sherman et al, 2000, p. 2398) that shows patient assignment to the different arms of the study.*

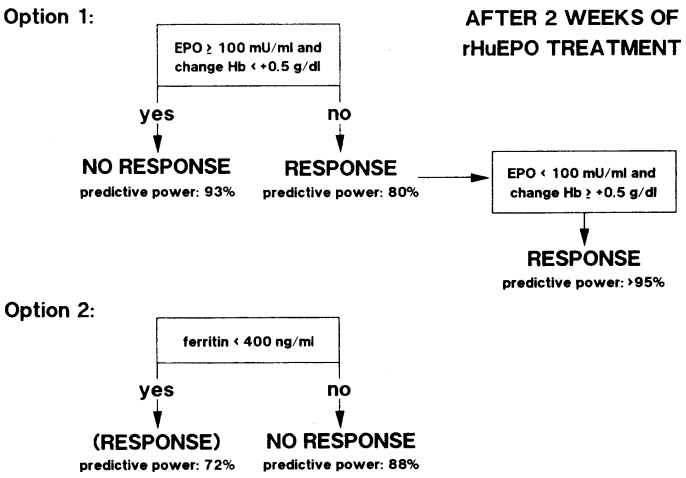


***Figure 5.*** *Algorithm to predict response or unresponsiveness to rHuEPO therapy in chronic anemia of cancer (Ludwig et al, 1994, p. 1059).*

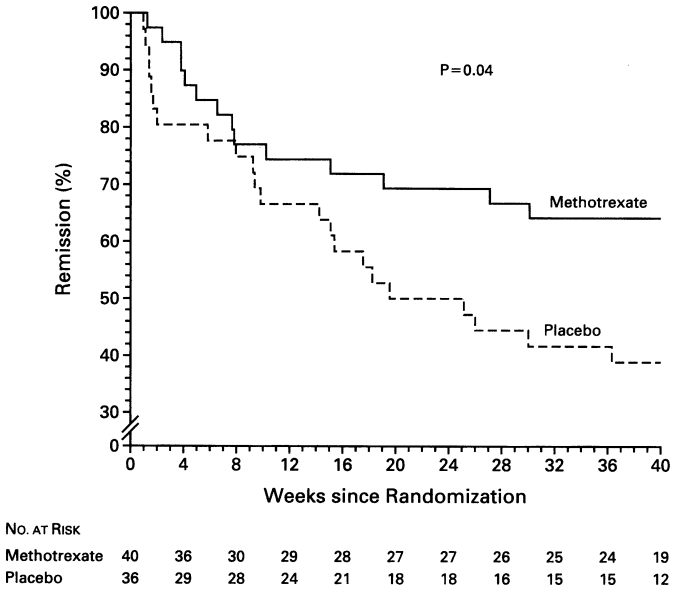


***Figure 6.*** *Kaplan-Meier estimates of the time to relapse in patients given methotrexate and placebo (Feagan et al, 2000, p. 1630), shown in a line drawing.*

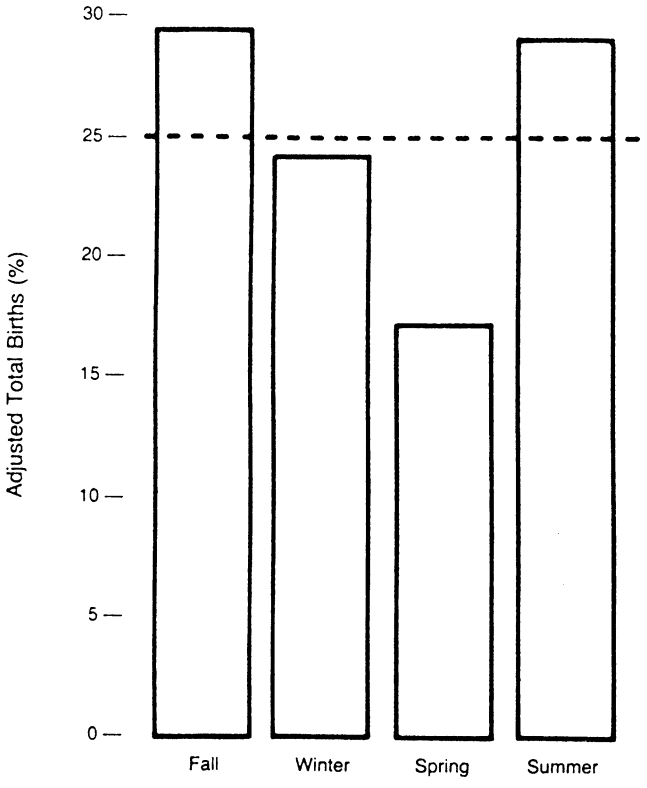


***Figure 7.*** *Adjusted births by season, as a percentage of adjusted total births in all seasons (Levine et al, 1990, p. 15), shown by a bar graph.*

Remember that good writing keeps the reader from having to guess the author's meaning. Whenever you use the word *significant*, report confidence intervals, standard deviations, and *P* values. Many journals now require exact *P* values, even for studied data sets for which the results are not significant.

Always state your data clearly and simply, and write in the past tense because you are describing what you have already done. If there were any deviations from the study as stated in the protocol, describe them, along with the reasons for the deviations.

## *Discussion*

*What do your findings mean? The answer is provided by the Discussion.*

The purpose of the Discussion is to explain the principles, relationships, and generalizations implied by the Results. You should discuss—not recapitulate—the results, and you need to be persuasive. Write in the present tense, except when describing results; then write in the past tense.

Every Discussion should have a beginning, middle, and end. The first sentence of the Discussion should clearly answer the research question by using the same key terms that were used in the statement of the question at the end of the Introduction. Readers should not have to guess at your answer. In the following example, note the repetition of key words and phrases.

### Ending of the Introduction

. . . to test whether *abnormal coronary vasoconstriction detected by hyperventilation testing before angioplasty increases the likelihood of restenosis*.

### Beginning of the Discussion

. . . The presence of *abnormal coronary vasoconstriction, detected on hyperventilation testing before angioplasty*, was associated with *an increased likelihood of restenosis* in patients with unstable angina and single-vessel coronary disease.

Follow this statement with your Conclusions, based on the Results, presenting your strongest evidence first.

Another example follows:

The EXCITE trial tested the hypothesis that in patients treated with PTCR, long-term oral administration of xemilofiban, after an initial dose given before the procedure, would extend the clinical benefit of short-term glycoprotein IIb/IIIa receptor blockade previously demonstrated with abciximab, tirofiban, and eptifibatide. Our finding that treatment with xemilofiban did not improve the long-term outcome after PTCR has two possible explanations. First, this short-acting oral agent may not have had sufficient efficacy in the short term. Second, long-term use of the agent may not have had sufficient . . . [O'Neill et al, 2000, pp. 1320-1321].

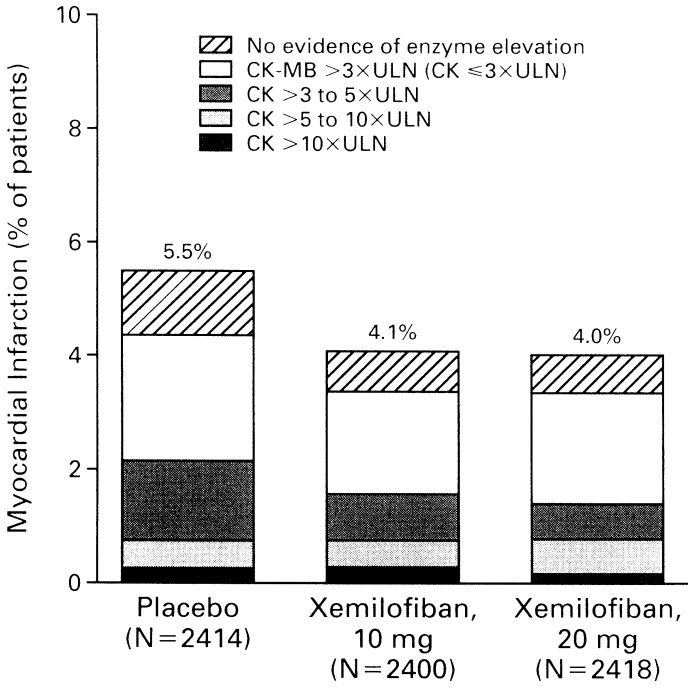


***Figure 8.*** *Myocardial infarctions occurring within one day after randomization of the index revascularization, according to creatine kinase level (O'Neill et al, 2000), shown by a bar graph.*

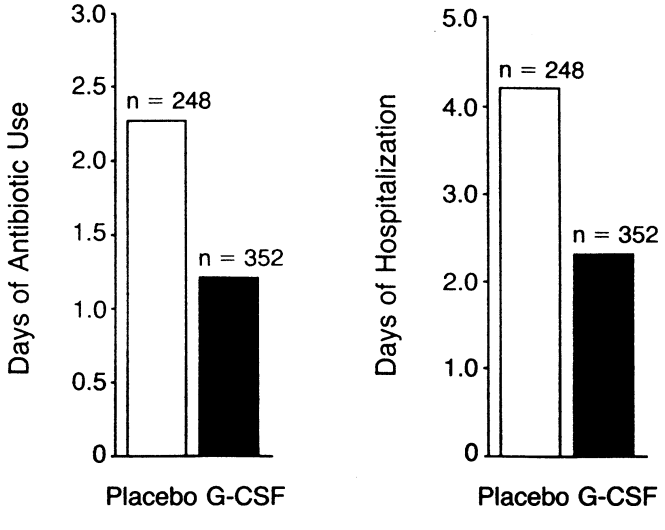


***Figure 9.*** *Secondary clinical end points in the study groups (Crawford et al, 1991), shown by comparative bar graphs.*

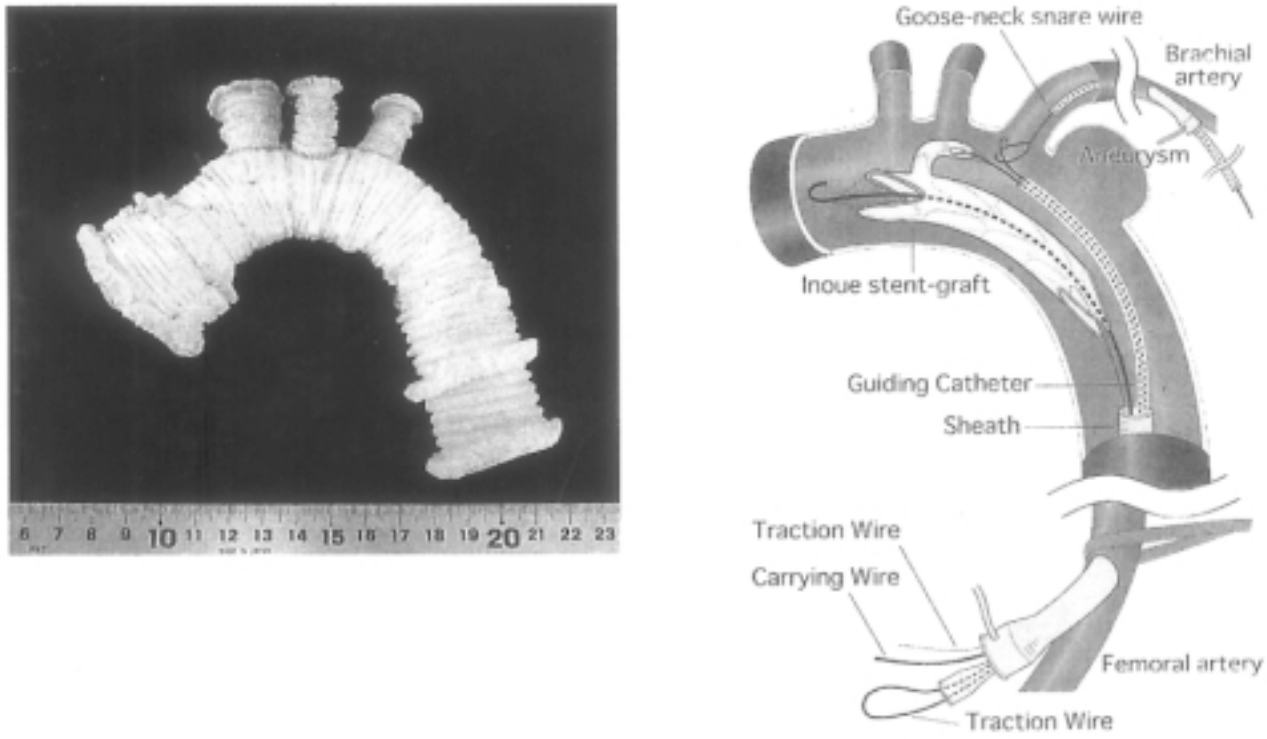


***Figure 10.*** *Aortic arch reconstruction with endovascular branched stent graft (Inoue et al, 1999, p. II-317). The side-by-side photo and illustration allow the reader to see the device as well as the technique used to insert it.*

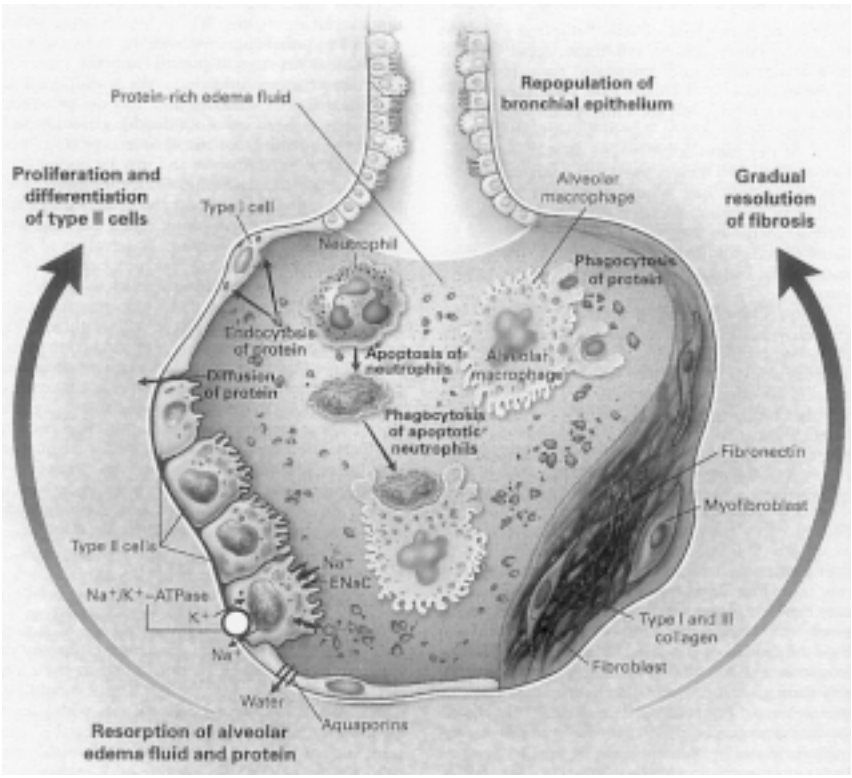


*Figure 11. Mechanisms important in the resolution of acute lung injury and acute respiratory distress syndrome (Ware and Matthay, 2000, p. 1342). Use of a drawing makes this scientific concept easier to understand.*

Never begin the Discussion with background information, and never repeat information stated in the Introduction. Background material should be found only in the Introduction.

In the middle of the Discussion, interpret your results and show how they support your answer. Topics should be discussed in descending order of their importance to the answer. Use comparisons to other studies to explain how the results fit in with existing knowledge. You can do this in several ways:

## Introduce Points with Your Own Findings

> Our data show that oral sildenafil does not adversely affect coronary blood flow, coronary vascular resistance, or coronary flow reserve. On the basis of the decrease in the heart rate–systolic blood pressure double product (a surrogate measure of myocardial oxygen demand), we might have expected a parallel decrease in coronary blood flow due to autoregulation. The absence of such a finding in our study may reflect the inaccuracy of the double product as a true measure of myocardial demand, variations in the calculated values for coronary blood flow and resistance, or a vasodilatory effect of sildenafil that blunts the expected reduction in coronary blood flow [Herrmann et al, 2000, p. 1625].

> Our study did not address the mechanism for the previously reported adverse cardiovascular events after the use of sildenafil, but our results do suggest that this mechanism is not the result of an adverse effect on coronary hemodynamics. Others have speculated that cardiac events may be due to interactions with other drugs . . . [Herrmann et al, 2000, p. 1625].

## Comparison with Earlier Work (Use Your Work to Support Previous Studies)

> The fact that our study was prospective lends support to the evidence of a causal role of sleep-disordered breathing in hypertension. We found that the presence of sleep-disordered breathing was predictive of hypertension four years later [Peppard et al, 2000, p. 1382].

> It is noteworthy that high percentages of the patients at low risk who were given placebo did not have delayed vomiting (87.2 percent) or moderate-to-severe nausea (81.8 percent). These percentages are similar to those we found in a previous study of patients who received neither prophylaxis nor placebo against delayed emesis, in which the same regimen for prophylaxis against emesis during the first 24 hours was used [The Italian Group for Antiemetic Research, 2000, p. 1559].

## Comparison with Earlier Work (Use Others' Work to Support Your Study)

> Previous studies of the hemodynamic effects of intravenous and oral sildenafil in normal men and men with stable ischemic heart disease have demonstrated a small but consistent decrease in systemic and pulmonary blood pressure after administration of the drug.[xx] The results of the present study confirm these findings in men with anatomically severe coronary disease. In addition, we investigated the effects of sildenafil on coronary hemodynamics [Herrmann et al, 2000, p. 1625].

> The increase in insulin-like growth factor in patients in the growth hormone group was consistent with that seen in adults with other diseases that are treated with growth hormone.[xx] However, our findings do not support the possibility that the beneficial effect of growth hormone is due to the action of insulin-like growth factor I on the bowel, since the degree of clinical improvement in individual patients was not correlated with their levels of insulin-like growth factor I [Slonim et al, 2000, p. 1637].

Ambiguous results and any discrepancies between your work and that of others should also be presented in the middle of the Discussion. These are your least impressive results, so present them objectively and bury them. The middle of the discussion is the place to explain any limitations of the study (methods, validity of assumptions, study design, and bias) or unexpected findings. The following paragraph is the sixth in a 10-paragraph Discussion:

> We did not have data that could be used to model the dynamic relation between sleep-disordered breathing, habitus, and hypertension. For example, although there have been few relevant studies, there has been speculation that sleep-disordered breathing has a causal role in obesity.[xx] If this is the case, then our efforts to control for confounding by including measures of obesity in our models may have led to a partial overadjustment of the association between sleep-disordered breathing and hypertension and thus to an underestimate of the association [Peppard et al, 2000, pp. 1382-1383].

The following paragraph was also buried:

> Our study has several limitations. The Doppler guidewire was carefully placed to optimize signal strength and to ensure an accurate measurement of peak velocity. Nevertheless, this method assumes a time-averaged parabolic flow velocity, negates the effects of vessel tortuosity on alterations in pulsatility . . . [Herrmann et al, 2000, pp. 1625-1626].

## The Ending

Make the ending of your Conclusion section strong. The concluding paragraph should restate the answer to the research question. Begin with a signal, such as "In conclusion" or "In summary," so your readers will know that this is the answer. After stating the Conclusion, you can briefly mention possible applications, implications, or speculations.

### Application

> Our findings support the statement of the American College of Cardiology and the American Heart Association that "primary PTCA should be used as an alternative to thrombolytic therapy only if performed in a timely fashion . . ." [Canto et al, 2000, p. 1579].

### Implication

> Because sleep-disordered breathing is highly prevalent, afflicting as many as 9 percent of women and 24 percent of men in the United States,[xx] a causal association could be responsible for a substantial number of cases of hypertension and its sequelae, such as cardiovascular and cerebrovascular morbidity and mortality [Peppard et al, 2000, p. 1383].

### Speculation

> The presence of elevated cardiac troponin I levels immediately after transplantation in cardiac transplant recipients suggests the need for intervention before transplantation to protect the microvasculature within the donor hearts, perhaps by improving the preservation of the donor organs or preparing the recipient in advance to prevent damage during the reperfusion period [Labarrere et al, 2000, p. 463].

Suggest future work, if necessary.

> A larger multicenter study should be conducted to confirm these results and to address many issues, including the best dose of growth hormone and the length and frequency of therapy that are necessary to produce and maintain clinical remission [Slonim et al, 2000, p. 1637].

In summary, keep the Discussion as short as possible, so that your reader grasps the take-home message. Authors most often err by including too much information in the Discussion without including transitions between paragraphs. Do, however, thoroughly discuss the answer to your research question, beginning with the strongest result from your study. Minor points should be presented in the middle of the section and treated briefly. Any conflicting data should be presented objectively, and speculations and opinions must be clearly distinguished from facts.

## In General

As in anything you write,

- Include only one thought per sentence; one idea per paragraph.
- Use the active voice whenever possible.
- Use simple words. Scientific words are complicated enough. Don't subject your readers (even if they are brilliant) to every four- or five-syllable word you know. Long words make a paper very hard to read.
- Keep the sections as short and simple as possible.
- Use transitions and key words throughout your manuscript.
- Write an outline for each section before you begin writing.
- Consult a statistician before you plan a study.
- Make sure that every word you write relates directly to your thesis. Keep your question in mind as you write.

## Acknowledgments

Not everyone should be listed as an author. Use the guidelines suggested in the Uniform Requirements for Authors of Biomedical Journals (International Committee of Medical Journal Editors, 1997) to determine the criteria for authorship and the order in which to list authors. Names of those who participated in the study but who do not meet the criteria for authorship should be listed in the Acknowledgments if the journal permits this section. Acknowledge intellectual assistance, technical help, gifts of special equipment or materials, and outside financial assistance (grants, contracts, fellowships, cash support). Remember, everyone whom you thank must give signed permission to be acknowledged and should see a copy of the final draft. A sample Acknowledgment follows:

> The STAT investigators and coordinators acknowledge with thanks the cooperation of the patients and their families who participated in this study. Contributions to this report from the following individuals at Knoll Pharmaceutical Co. are gratefully acknowledged: Gerry Fava, Shi-Yun Shen, members of the Biostatistics and Data Management Department, for guidance with statistical analysis; and Thomas Zimmerman and Kenneth Kashkin of the Clinical Development Department for suggestions in manuscript preparation [Sherman et al, 2000, p. 2403].

## *References*

Before beginning to format your references, make sure that you have checked the target journal's Instructions for Authors, because reference style varies from journal to journal. Always get a copy of the journal to check for reference style also; occasionally, the samples given in the Instructions for Authors will differ from the style actually printed in the journal. In that case, use the printed style.

Include among your references only published works. Whenever possible, cite experts and the most important works in the field—those that are readily available to the reader. Reference numbers are placed according to how the citation is written. If an author is mentioned, place the reference number after the author's name. If you cite more than one author, write "Cooley and colleagues[xx]" or "Cooley et al,[xx]" depending on journal style. If you cite only two authors, write "Cooley and Brown.[xx]" If ideas are referenced, place reference numbers at the end of the statement of each idea, unless all of the references refer to all of the ideas. For example,

> Lower mortality rates have been associated with higher volumes of elective procedures in studies of percutaneous transluminal coronary angioplasty (PTCA),[xx-xx] coronary stenting,[xx] and coronary-artery bypass grafting.[xx,xx]"

But

> Although ancrod does not directly affect any other coagulation factors or hematological components, rapid defibrinogenation does[xx-xx]" [Sherman et al, 2000, p. 2395].

If more than one reference is needed for an idea, cite the references in chronological order within the group. In a table or figure, number the reference according to where the table or figure is first cited in the text.

### Unpublished Data

References to unpublished data are listed in the text within parentheses: eg, "(unpublished data, with permission, D. Cooley)." In these cases, a signed statement that the reference is correct should be obtained from the person giving the reference; this statement must be enclosed with your manuscript when it is submitted. Articles in press can be listed in the references, but a copy of the acceptance letter should be enclosed with the submitted manuscript.

Make sure that there is a reference for every citation, and always check the original source. Although it may seem easier to copy a reference from another manuscript's reference list, that author might have placed or typed the reference incorrectly. Reference citations are easy to check on the Internet, and the full text of many articles can be found online. Until the manuscript is published, it is wise to keep a copy of each article cited.

## Styling Your Manuscript

When you think you have finished writing or editing, go back and verify that you have carefully followed the journal's Instructions to Authors. If there is a word limit, adhere to it. Look at the target journal to make sure that your manuscript is typed exactly as it would be typeset in the journal. If the journal uses a flush-left, bold title, type yours in the same fashion. Use the same wording for the "Address reprint requests to . . . " line. Believe me, whatever you can do to make less work for the journal will be appreciated. Make sure that your title page includes all the information requested by the journal and that everything is packaged and labeled neatly. If you have any questions, call the managing editor.

Your manuscript should make a good visual impression. The originality and significance of the work are certainly most important, but reviewers will also note poor organization, formatting, and writing. Reviewers in our institution often tell me that when papers they review are poorly written, they decrease the score they give the manuscript or ask for editorial revisions.

## And Now, Get Organized

If you want to write (or edit) a good biomedical paper, get organized. Organization is the key to success. The best research in the world can be hidden in a poorly written paper. Even if the paper is published, a reader may not take the time to ferret out the message. And in some cases, the paper won't get published. Some editors do not even review poorly written manuscripts because they believe that a sloppy manuscript signals sloppy science.

Knowing the formula for writing a biomedical paper will make the writing and editing process much easier. Just as solving an algebraic problem becomes easier with a formula, writing a biomedical paper requires an understanding of the IMRAD system and a willingness to take the time to apply that system to your work.

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# About the Author

Marianne Mallia has worked as a medical editor and writer for 25 years. She is currently senior medical writer and manager in the Section of Scientific Publications at the Texas Heart Institute in Houston, Texas. Mallia has edited and written more than 1600 scientific articles, speeches, and books, including *Surgical Treatment of Aortic Aneurysms*, by Denton A. Cooley, MD; *Reflections and Observations: Essays of Denton A. Cooley*; *A History of the Texas Heart Institute*; and the *Heart Owner's Handbook*. For many years she served as a consultant to the *Texas Heart Institute Journal*. Mallia has served on various committees of the American Medical Writers Association (AMWA), both in the Southwest Chapter and at the national level. For more than 15 years, she has led workshops throughout the Texas Medical Center and Houston, at other institutions around the country, and at chapter and Annual Conferences for AMWA. Mallia's AMWA workshops include *Organizing the Biomedical Paper*, *Medical Manuscripts Other Than the Biomedical Paper*, *How to Organize and Run Medical Writing Internships*, and *Advanced Writing*. In 1996 she was named an AMWA Fellow, and in 1998 she received the Golden Apple Award for outstanding workshop leadership. Mallia was workshop coordinator for the 1997 and 1998 Annual Conferences, was Annual Conference Chair in 1999, and currently serves as Administrator of Education.