

EDITORIAL

Towards clearer writing

M. Zeiger

Can the quality of writing in journal articles be improved? The editors of The European Respiratory Journal believe the answer is "yes", so they have included some suggestions on writing in their revised Instructions to Authors (January 1993). These suggestions are based on the notion that a scientific paper should tell a clear story from beginning to end. This editorial explains these suggestions, which are quoted below, and presents brief examples, adapted from papers published in the Journal, to illustrate them.

Introduction

State the question you asked (= hypothesis tested) and the considerations leading you to formulate this question. Give only pertinent references.

Why should the question be stated? The reason is that the question is the anchor of the paper. For the story to be clear, every sentence in the paper should relate to the question. Thus, Methods tells what was done to answer the question; Results tells what was found that answers the question; and Discussion states and explains the answer to the question. If the question is not stated, readers have no clear idea of what the story will be about, or what kind of answer to expect.

To give readers the clearest idea of the kind of answer to expect, the question should be stated specifically. A vaguely stated question is less useful. For example, "In this study, respiratory function was measured in polio survivors with acute respiratory muscle involvement, those with only limb involvement, those with bulbar involvement, and healthy age-matched controls, during wakefulness and during sleep" [1]. This statement tells what the authors did, not what they were asking. A specific question is clearer: "In this study, we asked whether respiratory function during either wakefulness or sleep is impaired differently in polio survivors with acute respiratory muscle involvement, those with only limb involvement, and those with bulbar involvement". From this question, we expect the answer to be either yes, respiratory function is impaired differently in these groups, or no, it is not. The key element is the verb ("is differently impaired").

The question can be introduced with a question word, such as "whether", as in "we asked whether..." or as a

hypothesis to be tested: "In this study we tested the hypothesis that...".

The question is not the first statement in the Introduction. Before stating the question, the Introduction should lead readers to the question, by telling the story of what is known about the topic of the research and what is not yet known. In addition, if previous work suggested a possible answer to the question, that work can also be included before the question is stated. Finally, after the question, the experimental approach used to answer the question may need to be stated.

The Introduction should be as brief as possible. Its purpose is to lead to the question, not to provide a complete review of the topic.

Example 1: Introduction [2]

^A Inhalation of hypertonic saline aerosol induces bronchoconstriction in many asthmatic patients¹. ^B In some patients, bronchoconstriction is followed by a refractory period, during which a second hypertonic saline challenge elicits much less bronchoconstriction². ^C The cause of this refractory period has not been determined. ^D Previous studies have suggested that the refractoriness after hypertonic saline challenge cannot be attributed to protective catecholamines³, reduction in nonspecific airway responsiveness after the first challenge⁴, or depletion of mediators from airway mast cells^{3,5}.

^E Another possibility is that cyclooxygenase products such as prostaglandins D₂ and F_{2α} and thromboxane A₂ are responsible for the refractoriness. ^F This possibility is suggested by previous studies showing that refractoriness after exercise⁶, or after ultrasonically nebulized distilled water challenge⁷, can be reduced by pre-administration of the prostaglandin synthesis blocker indomethacin. ^G We therefore asked whether cyclooxygenase products contribute to the refractoriness that occurs after bronchoconstriction induced by hypertonic saline aerosol. ^H To answer this question, we investigated the effects of indomethacin on the development of refractoriness to hypertonic saline in a group of nine asthmatic subjects.

This Introduction tells a story that leads to the question. Sentences **A** and **B** state what is known about the topic of the research. **C** states what is unknown. **D** supports **C** by mentioning possible answers that have been rejected. **E** states another possible answer, which implies the question. **F** supports **E** by mentioning previous work

that suggested this possible answer. **G** states the question. **H** states the experimental approach.

Materials and methods

Study design

Provide a brief overview of the tests or experiments, that is, the strategy for answering the question(s). In this subsection, include the independent variable(s) manipulated, the dependent variable(s) measured and all controls. Do not include details of methods.

The study design subsection is the part of the Material and Methods section that continues the story started in the Introduction. This subsection tells the strategy of what was done to answer the question, without the "cookbook" details. "What was done" includes the independent variable(s) manipulated, the dependent variable(s) observed or measured, and all controls. It also indicates what one experiment consisted of, and states when, and for how long, each manipulation or measurement was made. For studies that include several experiments, the order in which the experiments were performed should also be stated. The total number of experiments can be included in the study design subsection, although alternatively, the number can be stated in the preparation subsection (if the same number holds for all experiments), or in the data analysis subsection.

The study design subsection may also be called "Experimental protocol". For studies that are purely descriptive, a study design subsection may not be needed. For these studies, the experimental approach at the end of the Introduction is usually sufficient to give an overview of the experiments.

Example 2: Study design subsection [3]

^A To determine whether superoxide anion production induced by platelet-activating factor is increased in human alveolar macrophages from smokers, ^B we incubated alveolar macrophages from each of 30 smokers and 18 nonsmokers separately in increasing concentrations of platelet-activating factor, and ^C assessed production of superoxide anions by measuring reduction of ferricytochrome C. ^D Incubation at each concentration lasted for 120 min. ^E Production was measured at 0, 10, 30, 60, 90, and 120 min. ^F As controls, we assessed spontaneous production of superoxide anions in unstimulated alveolar macrophages (no platelet-activating factor) from the same subjects and production of superoxide anions in alveolar macrophages incubated with the inactive precursor lyso-platelet-activating factor.

This study design subsection begins by repeating the question the paper asked (**A**), thus continuing the story by linking "what was done" with the question. Repeating the question is especially useful in papers that have two

or more questions. Next comes an overview of what was done: the independent variables studied (smoking group *versus* nonsmoking group, platelet-activating factor) (**B**) and the dependent variable measured (production of superoxide anions) (**C**). **B** also includes the numbers of experiments performed (30 for smokers, 18 for nonsmokers). Next, **D** states what one experiment consisted of and how long each incubation lasted. **E** tells when measurements were made. Finally, **F** describes two controls: spontaneous production (essentially a baseline), and incubation with the inactive precursor (a control for platelet-activating factor).

What is not included in the study design subsection is the cookbook details of how the experiments were performed. For example, details of how the study subjects were selected, how the macrophages were collected and incubated, how production was assessed, and how production from smokers and nonsmokers was compared are given in separate subsections elsewhere in the Methods section (Study subjects, Preparation of alveolar macrophages, Superoxide anion assay, and Data analysis, respectively). Thus, the Methods section includes a certain amount of repetition: the dependent and sometimes the independent variables are mentioned both in the study design and in the cookbook subsections.

The study design subsection should be as brief as possible, without sacrificing completeness. In particular, repetition of steps within the study design subsection should be avoided. For example, if each experiment is repeated several times, each time with a different stimulus, the steps of the experiment should be named once, and then a statement can be added saying, "This experiment was performed *n* times, each time using a different stimulus. The stimuli used were...".

Results

Include only important results, i.e. results that help answer the question. Present most data in figures or tables, not in the text. Describe the prestudy condition of study subjects or animals in Methods, not in Results. Keep the Results section brief.

For the story begun in the Introduction and Methods to continue in the Results section, important results, *i.e.* the results that help answer the question, should be placed at the beginnings of paragraphs, as in Example 3 below (sentence **A**). Supporting details (**B**), if needed, and control results (**C**) can be stated after the important results.

Example 3: Beginning of a Results section [3]

^A Stimulating alveolar macrophages with platelet-activating factor caused a greater dose-dependent increase in superoxide anion production in alveolar macrophages from smokers than in alveolar macrophages from nonsmokers, figure 1. ^B The increase was greater at concentrations of platelet-activating factor above 10^{-10} M,

figure 1, and at all time points measured, figure 2. ^C In contrast to platelet-activating factor, the inactive precursor lyso-platelet-activating factor did not alter the production of superoxide anions from smokers' or nonsmokers' alveolar macrophages.

Figure legends, description of methods, and control results should not appear at the beginnings of paragraphs, because they do not tell the story. Thus, Example 3 above should not begin by saying, "Superoxide anion production in alveolar macrophages from smokers and nonsmokers is shown in figure 1" (figure legend), or "Superoxide anion production was measured in alveolar macrophages from smokers and nonsmokers" (methods), or "The inactive precursor lyso-platelet-activating factor did not alter the production of superoxide anions from smokers' or nonsmokers' alveolar macrophages" (control result).

Data should be presented in figures or tables, where they are easy to read. Data in the Results section make the text unnecessarily long, and do not tell the story. Therefore, instead of "The total number of cells·ml⁻¹ bronchoalveolar lavage fluid was 35.4±5.8×10⁴ in smokers compared to 10.8±2.9×10⁴ in nonsmokers (p < 0.05), table 2", this sentence can say, "The total number of cells·ml⁻¹ bronchoalveolar lavage fluid was greater in smokers than in nonsmokers, table 2".

The pre-study condition of the study subjects is not a result, and thus belongs in the Methods section, not in Results. Thus, the following sentences should be omitted from the beginning of the Results section and added to the subsection of Methods that describes the study subjects: "The 18 nonsmoking and 30 smoking subjects studied had a wide variety of diseases, table 1. All had clearly localized lung disease, except for eight who had no sign of lung disease after intensive diagnostic procedures. The two groups had no differences other than their smoking habits, table 2".

The Results section should be as brief as possible, so that the readers can find and focus on the important results easily. "The more noise, the less message".

Discussion

At the beginning of the Discussion, state the answer to the question asked in the Introduction (check that the answer responds to the question), and briefly support the answer with relevant results. Then, as necessary, explain or defend the answer, explain contradictory or unexpected results and discrepancies with previous findings, describe limitations of the methods and discuss possible implications. Emphasize the new and important aspects of the study.

The clearest way to finish the story started in the Introduction and continued in the study design subsection of Methods and in Results is to state the answer to the question at the beginning of the Discussion, as in sentence A of Example 4 below. The beginning is the most

prominent position, so putting the answer at the beginning ensures that readers will see it. The answer should be identified, for example as in the first six words of sentence A, so that readers do not think the answer is something previously known.

Example 4: Beginning of a Discussion [4]

^A **This study in dogs shows that rapid rewarming of peripheral airways, in itself, does not exacerbate airway obstruction induced by cool dry air challenge.** ^B In the seven dogs studied, the increase in peripheral airway resistance after cool dry air challenge was not different when the airways were exposed to warm humid air rather than cool dry air during recovery, ...etc.

In addition, the answer should be supported briefly with relevant results, as in sentence B. Summarizing relevant results pulls the story of the paper together for the reader, especially in papers that have more than one question. Thus, readers do not have to re-read the Results section, or look back at the figures or tables, to find out which results support the answer.

It is important that the answer responds to the question asked in the Introduction. If the question and answer are different, the story of the paper is not clear (and the author appears not to understand the paper). In Example 4 the question was "whether rapid rewarming of peripheral airways exacerbates airway obstruction induced by challenge with cool dry air".

In the middle of the Discussion, topics should be organized in a logical progression, beginning with topics most closely related to the answer. The logic of the organization should be indicated at the beginning of the paragraph. Thus, readers can read the first sentence of every paragraph in the Discussion and follow the story.

In the Discussion started in Example 4 above, the authors went on to explain a discrepancy with previous findings on the same topic (C, etc.). Then they discussed implications for humans (D, E, etc.). Finally, they applied the findings to a related topic (F, G, etc.). This progression is indicated at the beginning of the paragraphs (Example 5).

Example 5: Middle of a Discussion [4]

^C The exacerbated airway obstruction during warm humid air recovery reported by others^{16, 17} might be explained by differences in experimental design, ...etc.

^D It is possible that the airways of asthmatic subjects are rewarmed more rapidly than were the airways in our dogs. ^E However, our data suggest that this is unlikely, ...etc.

^F Increased bronchial blood flow resulting from rapid airway rewarming after cooling has been proposed as the cause of the exaggerated fall in FEV₁ in asthmatic adults after exercise. ^G However, evidence from two other studies, as well as from our present study, does not support this proposal, ...etc.

In other Discussions, the progression of topics will be different. For example, discrepancies with previous findings are not always the topic most closely related to the answer.

The Discussion can end either by restating the answer to the question, or by indicating the importance of the work, for example, by stating an implication or a speculation. The ending for the Discussion in Examples 4 and 5 does both. The restated answer should be the same as the original answer, as in Example 6. In addition, both the ending and the answer should be identified, as in Example 6 ("In summary" and "this study in dogs shows that"). Similarly, the implication or speculation should be identified ("We speculate that").

Example 6: Ending of a Discussion [4]

^H In summary, this study in dogs shows that rapid rewarming of peripheral airways, in itself, does not exacerbate airway obstruction induced by cool dry air challenge. ^I We speculate that rapid rewarming of peripheral airways, in itself, also does not exacerbate airway obstruction induced by cool dry air challenge in asthmatic human subjects.

By starting with the answer to the question, organizing the remaining paragraphs in a logical progression beginning with topics most closely related to the answer,

and indicating the logic of the organization at the beginning of each paragraph, the Discussion emphasizes the new and important aspects of the study. Repeating the answer at the end of the Discussion, when this is done, also emphasizes the new and important aspects of the study.

These, then, are some suggestions for telling a clear story in a scientific paper. If papers submitted to the Journal follow these suggestions, the quality of writing should be noticeably improved, and even those readers who are not specialists in the field should be able to understand the paper on first reading.

References

1. Dolmage TE, Avendano MA, Goldstein RS. - Respiratory function during wakefulness and sleep among survivors of respiratory and non-respiratory poliomyelitis. *Eur Respir J* 1992; 5: 864-870.
2. Hawksworth RJ, O'Hickey SP, Lee TH. - The effects of indomethacin on the refractory period to hypertonic saline-induced bronchoconstriction. *Eur Respir J* 1992; 5: 963-966.
3. Schaberg T, Haller H, Rau M, *et al.* - Superoxide anion release induced by platelet-activating factor is increased in human alveolar macrophages from smokers. *Eur Respir J* 1992; 5: 387-393.
4. Fuller SD, Freed AN. - No influence of airway heat flux on airflow-induced bronchospasm. *Eur Respir J* 1992; 5: 707-711.

EDITORIAL NOTE

Attentive readers of our Journal will have noted that our 1993 Instructions to Authors have been changed to conform better to the excellent teachings of Mimi Zeiger on writing biomedical research papers (see also Book Review, this issue). In recent months, several authors of manuscripts in a final state towards acceptance for publication have already been advised to reshape various parts of their paper, in order to make the "story" of their study more evident.

We are now pleased to publish an editorial in which

Mimi Zeiger further indicates means for achieving the goal of "clearer writing", and offers valuable suggestions for changes in the various parts of original articles. To illustrate her points, she felt free to use examples derived from manuscripts recently published in our Journal. The authors have kindly agreed to let her remodel some parts of their paper, and we are grateful for their co-operation.

We have no doubt that our readers will - as we do - appreciate the clarity and usefulness of Mimi Zeiger's teachings. (PV).