

A CHECKLIST FOR WRITING REPORTS OF ORIGINAL RESEARCH FOR PUBLICATION

Publication justifies funding for research, makes reputations, and builds careers.¹ Several good books²⁻⁴ and scores of articles have been written about how to write scientific papers for publication, but busy researchers could benefit from a highly condensed guide. *Years before the use of checklists became a manifesto for saving lives*⁵, my colleague, the late Susan Eastwood, Emeritus Editor in the Department of Neurological Surgery at the University of California, San Francisco, was convinced that a checklist could help time-strapped scientists produce high quality research reports. Evidence had shown that the checklist was an effective way to teach critical appraisal skills⁶⁻⁹ that makes economical use of time. As editors who had worked with authors over a combined period of 30 years, we knew that many of them, particularly those in training or early in their faculty careers, often found it difficult to plan scientific publications. Our hope was that our checklist would assist scientists with developing their research reports in a timely and efficient way. Since writing and revising are distinct tasks, once the report is written, scientists may wish to consult a single publication¹⁰ to learn ways to ensure that they are using clear, precise, effective scientific prose.

The checklist draws on the collective wisdom of journal editors, scientific writing instructors, and proponents of high quality biomedical publication.^{1-4, 11-17} It is a self-teaching tool that authors can modify to meet their needs. It details the elements of a publishable report of original research according to the specifications of most biomedical journals that have a clinical or translational research focus, and can be paired with any of the published standards for clinical papers, such as the QUORUM and CONSORT guidelines.⁹⁻¹¹ Although the checklist follows the standard IMRaD (Introduction, Methods, Results, and Discussion) format used by most such journals, the elements are similarly essential in other formats, such as those of Nature Medicine or Science.

CHECKLIST*

Title

- ___ describe the report in the style used by the journal or specified by its Instructions to Contributors
- ___ incorporate as many key words as possible

Include specifically:

- ___ the independent variable [the causal, determining, or preceding variable in a hypothesized relationship], if any
- ___ the dependent variable [a variable hypothesized to be caused by or depend on the independent variable]
- ___ the thing(s) studied [eg, cell line, reagent, animal, drug, population]
- ___ the main technique or method used
- ___ the outcome

Be explicit -- do not use Effect of... when you mean Proliferation of..., Increase in..., or Reduction in.

Instead of: *Effect of Percussive Injury in Rat Brain*

use, for example: *Prolonged IgG Immunoreactivity Causing Blood-Brain Barrier Breakdown
after Percussive Brain Injury in Rats*

Authors' Names and Affiliations

- ___ your full name, preferably with a middle initial [your "publishing identity" for bibliographic indexing]
- ___ your coauthors, named by their preferred "publishing identities"

___ authors' affiliations *at the time the study was done*, with a footnote to different current addresses if relevant.

Key Words

___ the words selected are the best possible to define the paper

___ the words provided do not exceed the number specified by the journal

Use bibliographic database categories [eg, United States National Library of Medicine MeSH headings†] as key words, and also in the title and abstract, to increase likelihood of the paper's rapid retrieval in a literature search.

Abstract -- *while observing the journal's instructions, summarize:*

___ the hypothesis or specific question(s) the study was intended to answer

___ the scientific context that makes the question important

___ the thing(s) studied [eg, cell line, reagent, animal, drug, population]

___ the study design and methods of measurement and analysis, including statistical methods

___ the most important results, including effects of adjusting for confounders

___ the primary conclusions, stated specifically

___ the contribution the study makes to science in the field

Incorporate as many key words as possible. State the results in terms of the new information they provide, giving numbers in parentheses. If statistical methods were used, state actual P values and confidence limits to show precision and statistical significance of results.

Introduction -- *tell briefly but precisely:*

___ the scientific context and immediate background of your research focus

___ what is unknown, or the problems with previous research your study seeks to resolve

___ the hypothesis or specific question(s) the study was intended to answer

___ the general experimental approach you took to answering the question, if not obvious

Make it easy for readers to see:

- what you set out to do [*hypothesis or question(s)*]
- why you set out to do it

State the question(s) [in the Introduction] and the answer(s) [in the Discussion] in the same terms so the connection between them is unmistakable.

Materials and Methods

___ preliminary or pilot studies, if any [*summarize briefly, using the Abstract section of this checklist as a guide*]

-the study as designed, state:

___ the study design [*for clinical papers*, eg, descriptive study, case-control study, randomized control trial]

___ whether the study was done prospectively or retrospectively [*for clinical papers*]

___ the thing(s) studied [eg, cell line, reagent, animal, drug, population] and the source

___ materials [eg, drugs, culture media] and equipment used, and the source [eg, manufacturer's name and location]

-then describe:

___ the protocol as designed, including dependent variables, independent variables, controls, baseline

- ___ the methods in detail, described in sequence, with the reason for each step and the procedures described in relation to one another
 - ___ methods derived from others' work, with references; modifications of methods and the reasons for them
 - ___ method of assignment to study groups and means of avoiding bias [*for clinical papers*, eg, randomization method, blinding or masking procedure, inclusion and exclusion criteria]; prospectively defined rules for stopping the study, if relevant; follow-up procedures, if relevant
 - ___ methods of measurement in logical order, including how validity and reliability of measurements were assessed [eg, use of standardized procedures, tests, instruments, reference laboratory use,]
 - ___ methods for analysis of data, including statistical analysis, in sufficient detail to permit replication
 - ___ explanation of whether and how data were transformed, whether and how analyses were adjusted for confounding factors, and whether power calculations were done
- ___ procedures ensuring ethical conduct [eg, institutional review board approval for a study of humans or animals]
- ___ statement that the protocol is available on request

Make it easy for readers to see:

- what you used (*agents, animals, equipment*) and the sources
- what you did and the reason (*protocol*)
- how you did it, exactly

Make the methods sufficiently complete to permit a researcher knowledgeable about the field to evaluate and replicate the study. Even a small detail--eg, not mentioning that cells were washed at a particular juncture--can obviate replication.

Results

-for clinical papers only, the study as conducted, include, as appropriate:

- ___ number of subjects or quantities completing the protocol in each study group
- ___ number of subjects or quantities withdrawn, excluded, or dead, and the reasons; number of subjects lost to follow-up assessment
- ___ characteristics of the thing(s) studied (including controls, if relevant), with demographics if relevant
- ___ duration of the study
- ___ how the study as conducted deviated from the study as planned, and the reasons
- ___ success, compromise, or failure of efforts to avoid bias [eg, blinding or masking procedures], and the reasons

-for clinical or basic science papers, the study findings, include, as appropriate:

- ___ estimated effects of intervention, stated as comparisons among study groups [eg, differences in risks, rates, or means of outcome variables measured]
- ___ summary data and appropriate descriptive and inferential statistics
- ___ results stated in absolute numbers, not simply in percentage changes
- ___ measurements of variability for outcome variables (eg, ranges, standard deviations)
- ___ measurements of precision for estimates of effects (confidence intervals)
- ___ actual *P* values [eg, $P = 0.06$; not just $P < 0.05$ or $P > 0.05$]
- ___ complications of intervention and adverse events in controls, if relevant

___ individual subject-specific data, if practical or necessary

___ repository where original data and any additional or supplemental data can be obtained [eg, Web site URL]

Make it easy for readers to see:

- the results your methods produced, point by point
- the findings you infer from those results, without discussing what those findings may mean or imply
- the information your data provide; that is:

instead of: *An increase in pCO₂ and the associated decrease in pH shifted the oxygen dissociation curve to the right.*

restate the finding in physiologic terms: *An increase in pCO₂ and the associated decrease in pH promoted the release of oxygen into the tissue.*

Confine data given in numbers to tables and figures as much as possible--do not itemize or repeat them in the text.

The Results section parallels the Methods section directly--each method has a corresponding result, each result, a corresponding method.

Each paragraph states a result followed by the supporting data (which is preferably cited in parentheses) and, if relevant, information about the control.

Reserve interpretation of the findings--their meaning, implications, and consequences--for the Discussion section.

Discussion -- state:

___ the answer(s) your results provide to the study question(s), communicated in the same terms you used to state the study question(s) in the Introduction and Abstract

___ how your results support the answer(s) to the study question(s)

___ your interpretation of the results of the study

___ the new information that your interpreted results add to current knowledge, assessed in the context of relevant results reported previously by yourself and others

___ confounding or ancillary considerations and limitations of the study, including possible sources of bias

___ your conclusions and their specific impact on, or consequence(s) to, science in the field

___ the extent to which your results, inferences, and conclusions can be generalized, with implications for applicability and exclusions [eg, methodologic, biologic, clinical, social, economic, ethical]

___ the specific contribution(s) of the reported study findings

Make it easy for readers to see:

- the answer(s) you found to your study question(s) and your conclusions--not a repetition of your key results
- what led you to your conclusions from what you found, including the influence of relevant literature
- the role or significance of your findings in view of current knowledge
- the impact, consequences, and implications of your findings
- why, and to whom, your findings are important

State the answer(s) in the Discussion in the same terms you used to state the question(s) in the Introduction and Abstract, so the connection between them is unmistakable; for example as follows:

In the Introduction: *This study was undertaken to test the hypothesis that AQP4 is involved in cerebral edema.*

In the Discussion: *The results of this study show that AQP4 plays an important role in cerebral water balance in response to the development of brain edema.*

Avoid tediously cataloging previous studies--instead, discuss relationships among your findings and previous work.

Neither overstate nor underplay the contribution your work makes.

References – *include among them:*

- ___ earlier publications reporting data from the study you are now reporting [eg, abstracts, cumulative clinical series]
- ___ all findings and ideas underlying or leading to your conclusions
- ___ validation of outcome measurements
- ___ only references you have read in their original form; for derivative references, cite the secondary source

Placement of reference citations in the text should leave no ambiguity about the attribution of ideas.

Get complete, accurate bibliographic data from the original article--mistakes in database citations let reviewers know that you've not read the full paper in its original form.

Acknowledgments – *include among them:*

- ___ credit to funding sources and other support [eg, specify the grant/fund number, recipient, and giver's name]
- ___ disclosure of any real or potential financial or other conflict of interest
- ___ credit to substantial contributors not qualifying for authorship--acknowledge everyone who warrants it

Determine that the people whom you cite do not object to being acknowledged.

Tables & Figures

- ___ data given in numbers are confined to tables and figures as much as possible--not itemized or repeated in the text
- ___ all data referred to in tables, figures, text, and abstract correspond to one another; all totals are correct
- ___ there is minimal redundancy in data and information presented among the figures and legends, tables, and text
- ___ the tables and figures accurately represent the information they convey and are simple and parallel in design
- ___ in tables, the rows and columns line up, and each row or column has a header that is specifically informative
- ___ in figures, all elements are labeled; each legend describes the corresponding figure completely, and all labels and indicators on the figure are defined or explained

Make all tables and figures (with legends) clearly understandable without reference to the text.

Overall Review

- ___ all relevant issues, problems, and conceptual elements are present and presented in logical order
- ___ no conceptual or structural element of the paper is ambiguous, missing, contradictory, or unnecessarily redundant
- ___ no discrepancies exist between the tables, graphs, charts, other figures, abstract, and the text
- ___ human subjects are referred to by case numbers; any potentially identifying information is omitted or masked
- ___ the report is concise, precise, accurate, structurally ordered, and meets every specification of the journal or publisher

Make it easy for readers to see:

- why and how the study was done
- how the results obtained in the study relate directly to the hypothesis or study question(s) initially posed
- how the conclusions drawn relate directly to the results obtained in the study
- the consequence of the findings to science in the field and their broader implications

NOTES:

* Adapted in part from Asilomar Working Group on Recommendations for Reporting of Clinical Trials in the Biomedical Literature. *Checklist of information for inclusion in reports of clinical trials*. *Ann Intern Med* 124(8):741-743, 1996. The concept of the Introduction and Discussion as the respective vehicles for stating in the same terms the study question(s) posed and answer(s) found originated with Mimi Zeiger: *Essentials of Writing Biomedical Research Papers* (second edition). New York: McGraw-Hill, 1999. Stephen B. Ordway (Editor Emeritus, Gladstone Foundation, San Francisco, California) made critical contributions to this checklist.

† To find MeSH headings and determine key words, access the National Library of Medicine at <www.ncbi.nlm.nih.gov/PubMed/> and access the ‘MeSH Browser’, or go directly to Medical Subject Headings at <www.nlm.nih.gov/mesh/meshhome.html>. For the ‘List of Journals Indexed in Index Medicus’, including abbreviations for use in reference lists and a list of subject headings that can be referred to for key words, access <<http://www.nlm.nih.gov/tsd/serials/lji.html>>.

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