How to Read a Scientific Research Paper

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Reading is the most common way that adults learn. With the exponential growth in information, no one has time to read all they need. Reading original research, although difficult, is rewarding and important for growth. Building on past knowledge, the reader should select papers about which he already holds an opinion. Rather than starting at the beginning, this author suggests approaching a paper by reading the conclusions in the abstract first. The methods should be next reviewed, then the results—first in the abstract, and then the full paper. For efficiency, at each step, reasons should be sought *not* to read any further in the paper. By using this approach, new knowledge will be obtained and many papers will be evaluated, read, and considered. *Key words: reading, research.*
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Introduction

This is the Information Age. New knowledge is accumulating at an exponential rate. Acquiring new knowledge is essential to providing acceptable medical care throughout one's career. For most individuals, reading, whether from print or electronic media, remains the most common way for acquiring new information. Information is not enough to create knowledge. Experts have defined information literacy as consisting of several identified skills and abilities. Broad categories of these competencies are listed in Table 1.[1]

Reading can take many forms. Casual perusal of news reports or digested summaries of published papers are daily activities in an active reader's life. In this paper an approach to efficiently and critically reading and appraising a scientific research paper will be developed. In accordance with the broad competencies and skills described in Table 1, this paper will deal with recognizing the need for information, evaluation of new information, and, to a limited degree, synthesis of this information. It will not deal with how to find and access papers, as these are topics of other papers in this series and in this Journal[2,3,4] nor how to communicate scientific information, which is a topic of another series of papers previously published in RESPIRATORY CARE.[5-11]

It is through research that new therapies and ideas that have the potential to improve care are developed and evaluated. Research papers are the written reports of experiments created by the clinician scientists who performed these experiments. A research paper provides the details of the experiment and help the reader decide if the findings

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Table 1. Necessary Competencies of Lifelong Learning

Critical and creative thinking
Problem analysis
Gathering and organizing information
Abstract reasoning
Interpretive and assessment skills
Insight and intuition in generating knowledge
Effective communication
Information literacy competency, which consists of the following abilities
To recognize the need for information
To know how to access information
To understand how to evaluate information
To know how to synthesize information
To be able to communicate information

Table 2. Why Read a Particular Article?

It's an area of science or practice with which you are already quite familiar and have an active interest
The title suggests the paper supports your bias
The title suggests it may disprove your belief
It appears to be an area in which you know little, and want to know more
It could it provide a solution for a clinical issue you are currently facing
You know nothing about the subject but have a desire to improve your knowledge
It was assigned to you to be read

are likely to be useful to patients in their care. Unfortunately, reading a research paper is hard work and it takes time to do well. Not all research work is of high quality, and it is helpful to decide if the quality of the study merits reading the paper. Judging the quality of a research paper is important to the potential reader for several other reasons. Since time for reading is limited and attention span is short, the first task of an efficient reader is to select quality reports. The second important reader task is to read the selected papers efficiently. Most casual readers prefer brief summaries of new thoughts and ideas rather than tackling a detailed description of the scientific study that led to the advance. However, to achieve understanding at a deeper level demands accessing and reading the primary data sources. This level of involvement also leads to more pleasure as command of a field of knowledge develops in the reader. Further reading and understanding builds on past mastery, and continued study becomes second nature rather that a duty or task to be accomplished. However, there is never enough time, and proper selection and systematic reading are important skills to develop.

Selecting a Research Paper to Read

The first question a reader must answer is, "Why read this research paper at all?" As part of lifelong learning, most clinicians use several methods to keep up with current published information. Subjects of particular and continuing interest are often approached with broad electronic searches of medical information databases, such as the National Institute of Medicine's MEDLINE. A successful search strategy can be automated and deliver updated results via e-mail, identifying potentially useful papers on a routine basis. Another way to keep up is to review the table of contents of current medical journals for titles that may be of interest. Table 2 lists several reasons why people may decide to read a particular paper. While all of these reasons have some validity, only readers with previous understanding and interest in the subject are likely to devote the energy necessary to complete the reading task. In fact, if the paper appears to disprove a strongly held belief, it will generate the most attention in the reader.

Another reason that may attract a reader is if the paper appears to support the reader's bias. This provides only mild interest, as no personal challenge is apparent. If the paper is "assigned," it will be read but without a personal commitment to the content. The exercise will increase critical reading skills but will probably not change understanding of the subject. It can, of course, provide the background for paper selection in the future and should be encouraged when time and effort is available (as in structured classroom learning or at a journal club).

Organization of Research Papers

Research papers are rigidly constructed. Science editors require that submitted papers conform to universal guidelines and style. This is fortunate for the reader, as this predictable organization allows a consistent approach to reading and evaluating a research paper. All research papers will include a title and abstract, as well as the following separate sections: Introduction (or Background), Methods, Results, Discussion, and Conclusions. Additional information will include a list of references or endnotes, institutional affiliation of the authors, if the material has previously been presented in another form elsewhere, and grant support (if any). This organization scheme is summarized in Table 3. The names of the separate parts may be different in different journals, but there is an expectation of similar content. Details of this standard organization and other useful information about scientific publications can be found in the International Committee of Medical Journal Editors' "Uniform Requirements for Manuscripts Submitted to Biomedical Journals: Writing and Editing for Biomedical Publication."[12] Specific journals may have slightly different requirements for content organization, and these details can be found in the "In-

Table 3. Research Papers Have Identifiable Components and Are Rigidly Organized

Title
Authors
Affiliation and author contact Information
Grant support (conflict of interest)
Previous presentation of data (if appropriate)
Abstract
Introduction (background or hypothesis)
(Setting or subjects)
Methods
Results
Major conclusions
Introduction
Background information
Statement of study purpose or hypothesis
Methods
Details of study
Statistical tests chosen and decided level for significance
Results
Summary of all results
Figures
Tables
Discussion
Background
Limitations
Differences from previous similar studies
Supporting evidence from other studies
Meaning of results
Speculation of importance (or lack thereof)
Future work recommendations
References
Additional contributors not qualifying as primary authors
Audience discussion (if a report of a conference presentation)

structions for Authors," often published in the January issue or at the journal's Web home page. In addition, other important requirements, such as listing of authors' institutional affiliations, reporting of conflict of interests, formatting requirements, and qualifications to be included as an author are detailed. For the journal RESPIRATORY CARE these instructions can be found at the Web site http://www.rcjournal.com.[13]

What's in a Title?

Often the most helpful part of a paper is the title. This is what attracts the reader in the first place, and it is also where search engines look for key words and for topics. A poorly descriptive title may hide an important experiment from the reader or may not even accurately identify the subject matter. The best titles will tell the prospective reader a great deal about the study and allow quick dismissal or inclusion for further attention. Some titles will offer little useful information but only whet the reader's appetite.[7] The efficient reader prefers the most descriptive titles. For instance a paper entitled "Mechanical ventilation guided by esophageal pressure in acute lung injury"[14] tells the reader in general what this paper is about. Importantly, it does not tell the reader the study was in human subjects. Also missing is the fact that the study is a randomized, prospective, controlled study that demonstrated better oxygenation and pulmonary compliance when positive end-expiratory pressure (PEEP) was applied guided by esophageal pressure rather that proximal airway pressure. Also not included in this title is fact that no important clinical outcome benefit (survival or length of stay) was seen. While it is unlikely that all of these facts would appear in a title, some additional information could have saved the reader time in ferreting out these details. This same title could be used for a paper studying laboratory animals, not humans, it could have been a review article, or an editorial. Whether to read this article or not requires more attention and further investigation to decide. If the title had been, "Outcome of mechanical ventilation guided by esophageal pressure in patients with acute respiratory distress syndrome (ARDS): a randomized controlled study," even the casual reader would immediately have a better understanding of the content of this paper.

The Usefulness of the Abstract and an Approach to Reading It

After the title, the abstract is the next most important part of the paper to examine. Many journals now require a structured abstract with separate subheadings, allowing the reader quickly to identify the important parts of the study. Most structured abstracts contain the following sections: Background (or Hypothesis), Methods, Results, and Conclusions. While some will read the abstract from the beginning, an efficient reader will begin with the abstract's Conclusions first. This section should provide the most important facts found in the study, which can then help decide whether to read the entire abstract and, ultimately, the paper. Abstracts of most science papers are available online for free and can be identified and viewed with most search engines. Many bibliographic databases limit the number of words reported in an abstract, so some of the details of the paper will be omitted from the electronic abstract. Extraordinarily long abstracts may be truncated at a specific word limit (usually 250–300 words) and will be missing important parts of the abstract. This is unfortunate and limits the reader's ability to screen papers via electronic abstract alone. The utility of a well constructed abstract is illustrated in Figure 1, which was obtained through the public portal of the National Library of Medicine and the National Institutes of Health (http://www.ncbi.nlm.nih.gov/pubmed) for the article on esophageal-pressure-directed PEEP mentioned above.[14] If this abstract

BACKGROUND: Survival of patients with acute lung injury or the acute respiratory distress syndrome (ARDS) has been improved by ventilation with small tidal volumes and the use of positive end-expiratory pressure (PEEP); however, the optimal level of PEEP has been difficult to determine. In this pilot study, we estimated transpulmonary pressure with the use of esophageal balloon catheters. We reasoned that the use of pleural-pressure measurements, despite the technical limitations to the accuracy of such measurements, would enable us to find a PEEP value that could maintain oxygenation while preventing lung injury due to repeated alveolar collapse or overdistention.

METHODS: We randomly assigned patients with acute lung injury or ARDS to undergo mechanical ventilation with PEEP adjusted according to measurements of esophageal pressure (the esophageal-pressure-guided group) or according to the Acute Respiratory Distress Syndrome Network standard-of-care recommendations (the control group). The primary end point was improvement in oxygenation. The secondary end points included respiratory-system compliance and patient outcomes.

RESULTS: The study reached its stopping criterion and was terminated after 61 patients had been enrolled. The ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen at 72 hours was 88 mm Hg higher in the esophageal-pressure-guided group than in the control group (95% confidence interval, 78.1 to 98.3; P=0.002). This effect was persistent over the entire follow-up time (at 24, 48, and 72 hours; P=0.001 by repeated-measures analysis of variance). Respiratory-system compliance was also significantly better at 24, 48, and 72 hours in the esophageal-pressure-guided group (P=0.01 by repeated-measures analysis of variance).

CONCLUSIONS: As compared with the current standard of care, a ventilator strategy using esophageal pressures to estimate the transpulmonary pressure significantly improves oxygenation and compliance. Multicenter clinical trials are needed to determine whether this approach should be widely adopted.

Fig. 1. Abstract of an article downloaded from the public portal of the National Library of Medicine and the National Institutes of Health.

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CONCLUSIONS: As compared with the current standard of care, a ventilator strategy using esophageal pressures to estimate the transpulmonary pressure significantly improves oxygenation and compliance. Multicenter clinical trials are needed to determine whether this approach should be widely adopted.

Fig. 2. Truncation of the abstract may lead to loss of important information. Italicized words, including the entire conclusion, would be omitted with truncation at 250 words.

had been truncated at 250 words the entire abstract Conclusions section would have been deleted (Fig. 2).

The important results from the experiment are highlighted in the abstract's Conclusions section. In the example presented above, the statement "a ventilator strategy using esophageal pressures to estimate the transpulmonary pressure significantly improves oxygenation and compliance" should attract the acute-care respiratory therapist's attention and identify the need for more information. The abstract is not read in order, and the next section of interest will be the abstract's Methods section (Table 4). From this

Table 4. Suggested Order of Reading of a Research Paper

Title
Abstract conclusion
Abstract methods
Abstract results
Methods
Results
Introduction (optional)
Discussion (optional)

RESULTS: The study *reached its stopping criterion and was terminated after 61 patients* had been enrolled. The ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen at 72 hours was 88 mm Hg higher in the esophageal-pressure-guided group than in the control group (95% confidence interval, 78.1 to 98.3; P=0.002). This effect was persistent over the entire follow-up time (at 24, 48, and 72 hours; P=0.001 by repeated-measures analysis of variance). Respiratory-system compliance was also significantly better at 24, 48, and 72 hours in the esophageal-pressure-guided group (P=0.01 by repeated-measures analysis of variance).

Fig. 3. Abstract "Results" raise questions (italicized).

section of the abstract it is now clear that this is a study of humans with ARDS and it was prospective and randomized—qualities that significantly enhance the strength of the experimental data obtained. With a prior background understanding of how difficult it is to accurately measure esophageal pressure, the therapist reader is most likely to want to read more about the study than is presented in the abstract. After quickly reviewing the abstract's Results section (Fig. 3), the question "Why was the study terminated prematurely?" can be answered only by a more detailed analysis of the entire paper.

To recap, a structured abstract often helps the reader decide if the entire paper should be considered at all. Reading the abstract's Conclusions section first may allow the reader to reject the paper or it may lead to an increased interest in the details of the experiment. The abstract's Methods section may answer the question why *not* to read the paper, or it may strengthen the interest in learning more details of the study. For a novice reader the abstract's Introduction or Background section may provide a useful overview of the problem but will not help the critical reader who will want to proceed to the actual article for further details, and may be skipped. When reading the body of the paper, it is often helpful to have a copy of the abstract physically (or electronically) at hand to compare to the more expanded sections to confirm that the relevant information is consistent in both places. It is also useful to note any questions that were raised and be sure answers have been found when reading the full paper.

How to Read the Actual Paper

Once a decision is made to read the paper, the first section that needs consideration is the Methods section.

Since an understanding of the results began when reading the abstract, the Methods section will require a careful examination to determine if the study could answer the research question posed. If not already apparent, the reader should determine the hypotheses being tested with the experiment. By explicitly stating the implied hypotheses, the reader can judge the potential for success of the experiment and assess if correct statistical methods were used.[15] Careful reading of the Methods section should allow this determination to be made. This section should provide the details needed to understand the experiment and describe the procedures with enough detail that someone else could exactly repeat the study. If this is not true and important details are missing, the reader should note these and continue to search other parts of the paper to determine if these details of the experimental design can be ascertained. Some details may be found hidden in the Results section, and occasionally in the Discussion. If important details are not found and they may have affected the outcome of the experiment, the reader should consider writing a letter to the editor, identifying these deficiencies and describing how they may have affected the reported results. This critical response often elicits an author's response acknowledging the issues or providing further information clarifying the experiment. The ability to publicly question an author and receive a published response is the heart of the scientific reporting that uses challenge and refinement to create new ideas and move knowledge forward.

The Results section should be read next, with careful attention to the figures and tables. Each element of data described in the Methods section should be reported in the Results section, either in the text or in figures or tables. No interpretations of the data should be reported in the Results section, but statistical analysis and probabilities of difference should be reported here. To understand the choice of a statistical test requires understanding of the hypothesis being tested.[16] Although not a required part of the paper, a simple declarative statement of the hypothesis is very helpful in understanding the experiment and evaluating its results, as was mentioned above. In the example paper referred to above, the reader could deduce that one hypothesis being tested was, "In ventilating patients with ARDS or acute lung injury, that PEEP guided by esophageal pressure rather than by the ARDS Network guidelines will result in a higher oxygenation index (at 24, 48, or 72 h)." An appropriate statistical test for this hypothesis might be a Student's *t* test, which is used to compare group average differences of continuous, numeric variables. It is beyond the scope of this paper to discuss statistical methods, but the reader should develop a familiarity with common tests and when they should (and should not) be applied. Some of these are listed in Table 5. An introduction to statistical methods can be found in an article by Chatburn.[17] Texts such as *Statistical Reasoning in Medicine: The Intuitive P-Value Primer,* by Moyé,[18] and *Primer of Biostatistics* by Glantz,[19] as well as other texts, offer support for the beginner and advanced reader in understanding and applying statistical tests to medical information.

Table 5. Basic Statistics Used in Scientific Publications

- Descriptive statistics
  - Tables
  - Graphs
  - Percentages
  - Sensitivity and specificity
  - Mean, median, range, and standard deviation
- Inferential statistics (hypothesis testing)
  - Procedures for nominal data
    - Fisher's exact test (2 groups, 2 outcomes)
    - Chi-square test (several groups and several outcomes, unmatched data)
    - McNemar test (several groups and several outcomes, matched data)
  - Procedures for ordinal data (testing for differences between 2 groups of data)
    - Mann-Whitney rank sum test (unmatched data)
    - Wilcoxon signed rank test (matched data)
  - Procedures for continuous data
    - Pearson correlation coefficient (for testing the strength of the association between 2 variables)
    - Linear regression (for predicting the value of one variable based on the value of one or more other measured variables)
    - *t* test (testing for differences between the mean values of 2 groups of data)
    - Analysis of variance (ANOVA) (testing for differences among the mean values of several groups of data)

(Based on information in Reference 10.)

As mentioned above, a critical reader should decide if the statistical test and level of significance are appropriate for the experiment as described. In complex studies with unusual statistical analyses, the editor of the journal usually employs a statistician to verify that the correct test is chosen and the analysis accurate. Sometimes one of the authors is a statistician, suggesting that a complex analysis was chosen and performed in a suitable way. This may not help the reader's understanding of the test, but may reassure the reader that appropriate statistical oversight was applied. As a rule of thumb (from a statistically challenged reader—me), if a study needs a highly complex analysis to achieve mathematical significance, then the clinical utility of the study results are probably not very important.

If after reading the Methods and Results sections it is still not clear what the hypotheses being tested were, the Introduction (or Background) section may provide clues. This section should be read at this time, or earlier if ferreting out the hypotheses. By this time the value of further investigation (or not) of the paper should be apparent to the reader. Either there are glaring problems with the study

that must be answered or it is to be accepted as valid, at least on some points. To continue the reading process, the Discussion section is read next. Here the rules are less rigid; comparative analysis of others' work, and speculation, are usually permitted.[10] The author should self-report shortcomings and limitations in the study and attempt to explain why his results might be different from those reported by others. No new data should be revealed in this section, and no information from the other sections should be repeated. Often this section ends with a brief restatement of the major conclusions (some journals require a separate Conclusions section). The conclusions here should be only those actually tested in the study and confirmed to be valid by statistical analysis, and are often identical to those in the abstract.

When the reader has completed reading part or most of the article, it should be "filed" in memory and kept available for use later. "Memory" can be the reader's cortex or an actual physical location. An organized filing system can be very useful at this point, to allow information retrieval in the future.

Summary

The process of acquiring new information and creating knowledge is complex and heavily depends on reading scientific reports. Developing a reading method aimed at efficiently deciding to stop reading a paper as rapidly as possible has been the purpose of this discussion. The rigid and predictable structure of scientific writing helps with this task.

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