



Contributing to research: the basic elements of a scientific manuscript

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The changing focus within medical and allied health disciplines towards evidence-based practice has resulted in an increasing acceptance of research and professional researchers. Despite the shift towards tertiary degree-based training for medical imaging and allied specialty streams, with many teaching institutions now incorporating compulsory research components into their final year curriculum, the level of active involvement in research among graduates remains low. In addition to this, many of those who completed their training before the introduction of university degree courses have had little or no exposure to hands-on research.

While not overtly difficult, the process of 'writing up' the findings of a research endeavour for presentation to peers can often seem a somewhat daunting task, especially for novice researchers. The structure of a scientific manuscript however follows a relatively basic and universally accepted pattern, adherence to which can greatly simplify the writing process.

To contribute to a wider understanding of research, the purpose of this paper is to provide an overview of the basic elements of a scientific research paper for journal publication. The outline provided, while not intended to be a recipe for manuscript construction, will provide a fundamental framework to assist student, junior or inexperienced researchers in their writings.

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PREFACE

With the change to university-based degree training models for educating medical radiation and allied professionals the fundamental skill base of individuals in our field is evolving [1]. Courses now focus on much more than simply the process of generating radiographic images. Graduates are assumed to have a solid understanding of anatomy and physiology, know how to care for and effectively communicate with patients, how to operate complex computing and imaging equipment, as well as knowing the legal and medico-ethical conditions by which we are bound [2].

In addition, many courses now incorporate a research component that exposes students to basic research concepts and may even involve an active research endeavour [3]. Post-graduate studies are becoming increasingly more popular as individual institutions establish their own higher degree programs.

Despite this, research within our profession is not currently being carried out or actively participated in by the majority [1, 3]. Few professional members have a solid understanding of the sequential steps involved in effectively carrying out a research project [1]. One essential component in the research cascade (arguably the most important) is the process of writing up the results so that we may share with others what our work has shown us (what benefit is information that is not shared?) [1, 4, 5].

While the completion of a research endeavour can be (and often is) a difficult and demanding task,

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writing up the findings of the work in a form that can be published for others to read (and understand) presents an entirely new challenge by itself [6, 7]. This initially may seem like a simple and easy step. However, having worked hard to complete the project work, any honours year or higher degree graduate will tell you that, if not approached correctly, manuscript writing can, unnecessarily, be one of the most challenging stages of research.

While this paper is not a 'cut and paste' template for manuscript writing and the method presented should not be considered the 'only' way to construct a paper (there are in fact many other valid and accepted formats for presenting research in scientific journals other than the one detailed here), it does provide a solid outline, overview and discussion of the key elements of one of the most widely used styles for research presentation within medical and allied health periodical publications. It is hoped that this paper will prove to be of some benefit in guiding inexperienced or student researchers, or those with no formal training in research methods, to appropriately structure scientific manuscripts.

The following sections initially introduce some helpful 'rules of thumb' in putting together and editing a research paper and then describe the basic elements which form one. For those wishing to gain an even more detailed understanding of this skill, there are several easy to read text books available [8–10].

GENERAL RULES

Within a basic accepted framework, a research paper represents an opportunity for authors to express the results, findings and outcomes of their work in an individual manner [11]. The style of writing and presentation varies enormously from paper to paper [11] and beyond the individuality of the author(s) and the discipline itself, is heavily influenced by the type of work reported, the journal of publication and the intended target audience. Despite this diversity, there are many fundamental rules that all good scientific writers follow including adherence to brevity, concision, and logical structure and flow [4, 5, 7]. Understanding and applying these rules can be useful in helping inexperienced writers improve the quality of their work. Listing every criterion of 'good writing' is well beyond the scope of this paper but the following paragraphs presents some key ideas to keep in mind when writing.

Basic writing tips

All work should be presented with a progressive, logical flow so others can follow your ideas, methods and understand how your conclusions were rationally drawn [7]. It is important to cater not just for experts in the field about which you write but also for general readers with basic or little knowledge of your topic area [4, 5, 12]. Technical terms should be defined, and jargon [4] and 'flowery' non-scientific writing avoided.

Avoid excessive repetition of words or terms (are there appropriate synonyms for substitution?). Be careful also of overuse of complicated or scientific words and terms [4], they can make reading difficult for members of the non-expert audience. Introduced abbreviations may be appropriate in describing highly technical work, allowing readers to follow the writing with little interruption to flow.

Ensure consistency of tense throughout the paper [4]. Usually the past tense is most appropriate (i.e. These experiments were performed...) after all, you have finished the research, so the majority of the research paper should be a past tense reflection of work already done.

And finally the golden rule of all writing (no matter what the topic area)—ensure the correct use of grammar and spelling [1, 4, 7]. Nothing frustrates editors and reviewers more than glaring basic textual errors. On this topic, be aware that electronic spelling and grammar checkers are not infallible [4]. The same word may take several forms, all correct, but spelt differently (there, their, they're etc.). Your spell checker does not have the ability to distinguish between different forms of the same word. Always proofread your own work prior to submission (having someone else review your work can also be very helpful) [1].

BASIC MANUSCRIPT STRUCTURE

Most scientific journals follow the basic manuscript format of 'introduction', 'methods', 'results', 'discussion' and 'conclusions' (which may arise from the discussion or be presented as a separate section) [4, 11]. Several other supplementary sections including 'acknowledgments', a 'reference list' and a series of 'figures and tables' also contribute to the formation of the complete paper. It is important to note that while this list of sections are common to a 'standard' paper, they may not necessarily be appropriate in all

forms of scientific writing. Individual manuscripts are usually preceded by an 'abstract' or overview statement. The size (word length) of each section varies from paper to paper, although some journals may set specific limits for individual sections. The length of the paper itself (excluding references) is generally between 3000 and 5000 words [11], although some may be justifiably more (i.e. review articles) or less (i.e. short technical notes).

Table 1 provides a summary of the sections contributing to a 'standard' scientific manuscript. The role and purpose of these sections are now explored and described in more detail.

Introduction

Being the first component of the paper, this section should explain the justification for the study. It should discuss relevant previous work in the area [4] (if any), which will require the author(s) to have completed a thorough literature search [12]. The majority of references to earlier work are generally made in this section. The introduction places the current work in perspective [4], states the purpose for the study and what is already known about the topic, and explains the motivation for the study. The latter will often be an identified deficiency in the existing body of knowledge [11]. Having explained the background and rationale for the current study the author(s) should justify the use of any spe-

cific tools, techniques and approaches to be employed which may be considered experimental, non-routine or those not widely understood. Everyday or 'accepted' techniques do not require lengthy discussion or justification. Do not waste space explaining what will be done (this follows in the methods section); explain why it will be done.

Having summated and presented the current level of scientific knowledge on the topic under investigation, the introduction concludes by discussing the specific problem to be addressed by the author(s), perhaps suggesting specific hypotheses that lead to an explicit statement of the aim(s) of the research.

Methods (or materials and methods)

The methods section explains exactly what was done in carrying out the research that is being reported. While traditionally this section should provide enough detail to ensure the work is independently reproducible [4], a fine balance of the level of detail provided must be found to ensure that the work does not become unnecessarily long so as to 'scare off' or 'lose the interest' of readers [11]. The author(s) should ensure that non-expert readers unfamiliar with the work can still follow the basic logic.

This section should be sequential, clear and concise. Do not waste time explaining accepted approaches or equipment use [4] (i.e. none of us will

Table 1 The structure of a scientific paper

1	Abstract	Provides a concise overview of all major sections of the paper including key results and conclusions.
2	Introduction	Should provide justification for the study by identifying a niche area within the existing body of knowledge and also identifying specific aims or hypotheses that become the focus of the described research.
3	Methods	Should describe the way the study was carried out with sufficient detail to allow repeatability and to allow others to judge the scientific reliability of the work.
4	Results	Should describe the findings of the study without interpreting them.
5	Discussion	Allows the author(s) to interpret their findings and place them in the context of the previous knowledge in the field. Recognise limitations to work, sources of bias, areas for improvement and areas for future work.
6	Conclusions	Allows the author(s) to express the conclusions that can be drawn from the study in light of the presented findings.
7	Acknowledgements	Opportunity to thank and recognise those who have assisted or contributed to the study but are not named as co-authors.
8	Reference list	Source list of materials cited directly in the text.
9	Figures and tables	As appropriate to support the information contained in or message conveyed by the study.

benefit from a step by step guide to taking a chest X-ray if such a procedure was performed as part of your work). Where methods have been described previously, cite the former work to save repetition and unnecessary text [4] e.g. *Using a method previously described by Smith et al. ...* Finally, the methods section should describe the statistical techniques used in data analysis [4, 11].

Results

This section reports the findings of the current study relevant to the focus of the paper. Collateral data collected during the same project, but not directly applicable to current paper and its purpose, only confuses the reader, is unnecessary and should be omitted. Any new information collected, not directly related to the current study but of sufficient scientific merit or interest, should be considered for presentation in a separate paper. As a general rule, one paper should reflect the investigation of one principal hypothesis although several linked sub-hypotheses may be reported in the same work.

It is often easier to list the key results in order of importance [11] or in the order that they will be explored in the discussion section. Tables may be an appropriate way of summarising data and saving written text if concise and clearly presented [12]. However, be careful not to overuse them [4]. In many cases it may not be necessary to list the full data for individual subjects or tests; summary statistics may be a more appropriate means of conveying such information [4].

In reporting statistical outcomes in the results section, always explicitly state P values, rather than just $P < 0.05$ (too many authors fail to do this). Stating the full P value allows the reader to draw his or her own educated conclusions as to the likely significance of the result [11].

It is not appropriate to discuss the findings in this section [4], but rather to concentrate on stating the results. Remember that all findings to be discussed in subsequent sections must have been presented in this section. Conversely, any results which are not discussed further should be considered for omission as they may be irrelevant.

Discussion

This is the opportunity for the author(s) to discuss their findings in light of previous work, to discuss

limitations [4], major assumptions and the generalisability of results and to highlight opportunities for future work. No new results should be discussed that have not previously been introduced [11]. It is common practice to begin the discussion section with a reiteration of the original purpose for the study or the original research aim or hypothesis [11].

Discussion of key results usually takes place in order of importance (matching the order in which they were presented in the results section). This section is often loosely linked to the key ideas raised in the introduction section. Compare and contrast findings with parallel or comparable work in the topic area. Discuss how the findings of your study may be considered e.g. to add support for a change to existing techniques or management pathways.

Where possible suggest rational explanations for unexpected or unusual results or outlying discrete data points. A sign of an experienced author and researcher is the ability to critically discuss his or her own work. Do not be afraid to state that a particular finding cannot be easily explained [11], the phenomenon may be more widespread than just your work and may be itself worthy of further investigation.

All identified limitations must be discussed or the author unjustly biases the information presented to the reader. Remember that in radiology and medical radiations we are often limited by things such as expense, ethical considerations, small patient population and equipment or specialist access. Although not an excuse to be lazy in recruitment, be aware that such factors may realistically limit available sample sizes. By discussing the limitations the author may identify opportunities for other work or improvements to the current work which may be the focus of future studies.

Conclusions

The main body of the manuscript usually finishes with a conclusion statement that may be included as an integrated part of the formal discussion section or listed as a separate heading. This section provides a concise summary of the key conclusions that can be drawn from the current work in light of the reported findings, placed in the context of any relevant earlier work. This is the opportunity for the author(s) to present to the reader the relevance of the work undertaken and to concisely define how this new information contributes to the existing body of knowledge. Recommendations for interpretation or

application of the findings are usually reinforced succinctly at this point. No new material should be introduced to the paper in this section (i.e. all points discussed here should have been raised and addressed previously).

SUPPLEMENTARY MANUSCRIPT SECTIONS

There are several other sections that supplement the main body, that combine to complete the manuscript. The presentation and ordering of these sections vary between journals but they are all usually present in most scientific papers.

Acknowledgements

The acknowledgement section is usually only a couple of lines and is an opportunity for the author(s) to recognise the assistance and support of those associated with the study but who were not listed as authors [13]. Appropriate acknowledgements may be made to supervisors, statisticians and other support staff and those associated with the design and implementation of the study (e.g. non-author research assistants or data collectors). It is appropriate at this point to thank and recognise organisations that have contributed towards the funding of the study. Departments and institutions may sometimes also be appropriately thanked for their assistance and support. Study subjects should not be named for data protection reasons but may be made reference to generally at the discretion of the authors (i.e. *the authors wish to sincerely thank those persons who volunteered their time to participate in this study*).

Reference list

The reference list is usually the last text section presented sequentially in the manuscript, it lists all of the earlier work referred to in your article [4]. The journal Radiography employs the Vancouver referencing style. This system involves numbering the citations in the reference list in the sequential order that they appear in the text. For details of the specific presentation of the in-text citations and the reference list, refer to the 'Instructions to Authors' section found at the end of each edition of the journal.

Figures and tables

The use of figures and tables in a manuscript can be an excellent way of clearly and succinctly presenting large amounts of information or for ameliorating the need to include lengthy textual descriptions. Figures can often allow the reader a visual appreciation or spatial understanding of equipment and concepts relevant to the study being reported, while tables can be useful in providing large volumes of raw or analysed data and can be a simple means of demonstrating a direct comparison between two or more data sets.

Only figures or tables which are directly related to the current study and add some benefit to the work should be included [12]. Figures and tables that do not add direct benefit to the interpretation or understanding of the specific study being reported, even if they are of substantive or significant scientific merit, should be omitted. All figures and tables presented must be referred to at some point in the text. Any figures or tables included in the article for consideration for publication should be submitted at the end of the manuscript. If your article is accepted for publication, the editorial team will appropriately insert the figures and tables into the text to accommodate the final presentation format. Each figure or table should be provided on a separate page with its own caption (title). The caption should provide a brief description of the figure or table and provide a clear explanation of any labels. Where the manuscript includes more than one figure or table, a summary 'Captions List' should also be provided, listing the figures and tables in the order they would appear in the text.

Abstract

Having written the polished version of the manuscript, the final task is to prepare a concise abstract [4, 11]. The purpose of this section, which will precede your manuscript in the journal, is to provide an overview of all the major elements of your work, the rationale and justification, the method employed, the key result(s) and conclusions drawn. The 'Instructions to Authors' section of the journal Radiography asks that authors submitting their work for publication keep their abstracts to less than 250 words. Many junior authors will find it more difficult to write a quality piece for this brief section than any of the other much larger sections. One useful practical tip for starting the formation of the abstract comes

from taking the key sentence or two from each of the major manuscript sections (i.e. introduction, methods, results, discussion and conclusions) and combining them sequentially. These sentences can then be modified to generate a succinct and integrated, flowing piece of writing summarising the reported work. Those seeking a more detailed understanding of the importance, structure and preparation of a scientific abstract should refer to the earlier work of Haynes *et al.* [14] titled: 'More informative abstracts revisited'.

Be aware that given the great diversity and volume of articles available for an avid reader, your abstract should draw the interest of the potential audience and provide an accurate but concise description of the study. Many readers will only read the abstracts, others will use the abstract as a guide as to whether or not to read the full article. This applies similarly to journal reviewers who are most likely to gain their first impression of your work from the abstract. The quality of the abstract has the potential to place a strong bias on the light in which the reviewer assesses the rest of the paper. Remember—first impressions last!

IN CONCLUSION

Although it may initially seem daunting, writing a manuscript for submission for publication need not be [15]. By following a widely accepted basic scientific design, authors can structure their work to present it in a format suitable for submission [15]. In logically addressing a handful of key headings, the process of manuscript writing can be made infinitely simpler than trying to write a single continuous research report.

Brevity and concision are important factors to consider when writing for publication [11], as are fundamental elements such as correct spelling and use of grammar. Always consider the likely target audience when constructing a research paper [4, 5, 12], as well as the discipline itself, as individual fields hold their own conventions as to the appropriate form that a manuscript should take.

It is hoped that this paper will prove useful in assisting student, junior and inexperienced researchers, within the medical radiations fields, in conveying their findings to others through publication in the College's official journal, *Radiography*. Those with no previous exposure to research may also benefit from learning how simple this process can become

and may be inspired (or more inclined) to aid in the development of their own profession by initiating or participating in active research.

FOR FURTHER INFORMATION

For further journal specific information, pertaining to the preparation and submission of a scientific manuscript for consideration for peer-reviewed publication in the journal *Radiography*, refer to the 'Instructions to Authors' section found at the end of each edition or contact the Editor-in-Chief.

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