

Enhancing Your Manuscript With Graphic Elements, Part 2: Figures

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By using graphic elements, authors can help readers understand and remember the important messages of their research. In part 1 of this topic, I discussed the best approach for using tables in scientific writing.¹ In part 2 of this topic, I will look at the best approach for using figures.

The *AMA Manual of Style* defines *figure* as “any graphical display used to present information or data.”² Figures can be used to clarify, explain, highlight, or illustrate information in a manuscript. Types of figures include (but are not limited to) charts, graphs, illustrations, text, clinical images, and photographs. In the present article, I will look at the 2 major categories of figures—statistical and nonstatistical—and discuss uses for each.

When Do You Need a Figure?

When authors consider adding a figure to a manuscript, they must first determine whether the figure has a purpose. Figures are not helpful if they are cluttered or simply repeat data from the text.³ If a manuscript has too many figures, readers may not look at all of them. Authors should carefully consider the addition of each figure in a manuscript and ensure that each is helpful and necessary.

Unlike tables, which are best for communicating specific information or exact numbers,³ figures are best for communicating a basic point at a glance or demonstrating trends or relationships.⁴ In other words, tables typically function as reference tools for readers, whereas figures typically function as analytic tools.

When determining what type of figure to use, authors should first ask themselves what they would like to communicate to readers. If authors would like to communicate relationships, statistical figures—or graphs—are likely most appropriate. If authors would like to communicate proof of findings or display explanatory information, nonstatistical figures (eg, photographs, images, diagrams) are likely most appropriate.

Statistical Figures (Graphs)

For statistical figures, authors must choose a graphing format appropriate for the type of relationship they would like to communicate. For example, line graphs are appropriate for showing trends, and bar graphs are appropriate for showing magnitudes.⁴ Below, I describe common graphing formats and indicate which relationships they best depict. See *Figure 1* for examples of each.

Bar Graph

Bar graphs display counts or percentages on a single axis.² The bars represent data belonging to various categories (identified on a baseline) and may be displayed vertically or horizontally. The bars should have uniform widths, and the widths of the bars should be wider than the spaces between them. Bar graphs are appropriate for displaying time-series, ranking, part-to-whole, deviation, and nominal-comparison relationships.⁵

Line Graph

Line graphs display quantitative values by using data points on 2 or 3 axes.² The data points are connected by curves to show trends or relationships. Line graphs typically depict the dependent variable on the y-axis and the independent variable on the x-axis.⁶ Line graphs are best for displaying time-series and distribution relationships.⁵

Dot Plot

Dot plots display quantitative data (other than counts or percentages) on a single axis.² Data are represented by markers (eg, dots) and may be plotted on the x or y axis. Data categories are identified on the baseline. Dot plots typically include error bars, box symbols, or whisker symbols to designate variability.² Dot plots are useful for displaying time-series, ranking, and nominal-comparison relationships.

Scatterplot

Scatterplots display individual data points according to coordinate values on 2 continuous, quantitative axes.² Like line graphs, scatterplots display the dependent variable on the y-axis and the independent variable on the x-axis. The data points in scatterplots are not connected by curves, but a statistical curve may be inserted into the figure to demonstrate trends in the data.² Scatterplots are best for displaying correlations.⁵

Considerations of Statistical Figure Construction

Once authors have determined what type of statistical figure or graph they need, they should consider the following guidelines:

Depict Findings Fairly and Accurately

Authors must take great care to ensure that their graphs display an accurate representation of their findings. For example, authors should not alter the scales of the figure axes to make their data seem more meaningful. Scales should start at zero whenever possible.³ If a graph must have a quantitative scale that does not start at zero, authors should use points instead of bars to display their data. The length of bars also portray meaning; if a scale does not start at zero, the use of bars can be misleading (*Figure 2*). If appropriate, authors should use standard deviation to show variability in their data; substituting standard error of the mean may make the data seem more consistent than it is.³

Ensure Graphs are Clear, Concise, and Uncluttered

Authors should ensure that each figure contains the data needed only to answer a specific question. If a figure is meant to answer too many questions at once, it may appear cluttered and confusing to readers. Authors should consider breaking complex figures into multiple simpler figures, if possible.

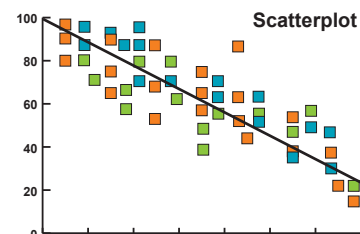
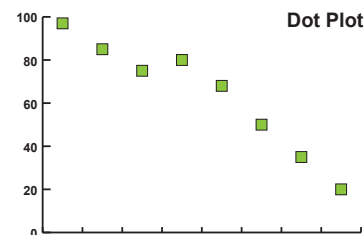
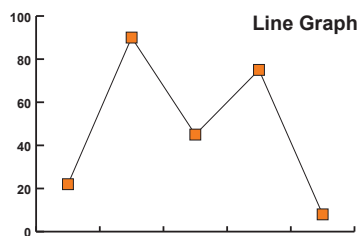
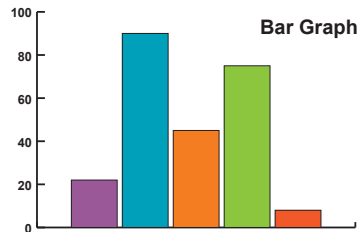


Figure 1. Examples of statistical figures.

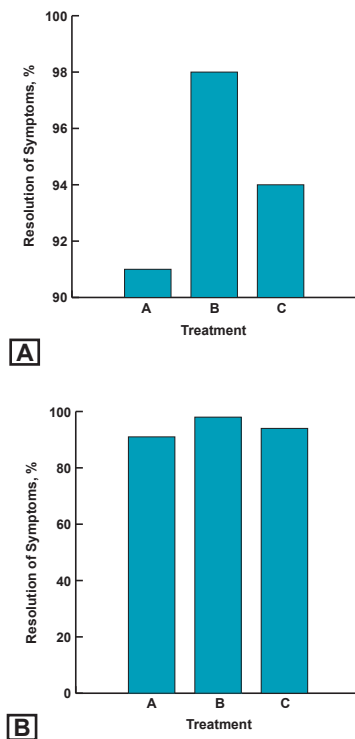


Figure 2.

Example of how altering the scale of a bar graph can be misleading. In Figure 2A, which has a scale that starts at 90, it appears as though substantial differences were found between treatment groups. In Figure 2B, which has a scale that starts at 0, it is clear that the differences between groups were actually much smaller. Bar graphs should always have scales that start at 0. Smaller scales are more appropriate for other types of figures, such as line graphs and dot plots.

In addition, figures should draw readers' attention to the information in the figure, not to the figure itself.³ In statistical graphs, authors should minimize the number of nondata elements.^{3,6} For example, authors should include only necessary symbols and labels and consider labeling every other index line (eg, 20, 40, 60 instead of 10, 20, 30, 40, 50, 60) to keep the focus on the data.⁷ Authors should also avoid a 3-dimensional format for a figure that has 2 dimensions of data. The display may make it more difficult for readers to identify important comparisons or determine exact values.²

Choose Graphing Formats That Are Easy to Interpret

Some graphic comparisons are easier to interpret than others.³ For example, readers will easily interpret comparisons along a common scale (eg, on an x-axis), but they may have difficulty comparing differences between angles.³ For this reason, authors should use pie graphs sparingly; often, another figure type will communicate the message in an easier-to-read manner.²

Nonstatistical Figures

Nonstatistical figures are visual representations of information that do not contain data. Unlike statistical figures, these types of figures are less defined and encompass a variety of images, drawings, and textual displays of information. In this section, I will look at common types of nonstatistical figures, including clinical images and photographs, diagrams, illustrations, and textual figures (Figure 3).

Clinical Images and Photographs

Figures with clinical images or photographs are used for displaying clinical findings, test results, and procedures.² These types of figures may include ultrasonograms, computed tomographic scans, magnetic resonance images, and other forms of clinical images. They may also include images of patients, tissue samples, microscopic findings, or physicians demonstrating techniques.⁸ Clinical images and photographs are appropriate for demonstrating absolute proof of findings,⁴ explaining findings that cannot be adequately described in the text, and showing "before and after" findings.

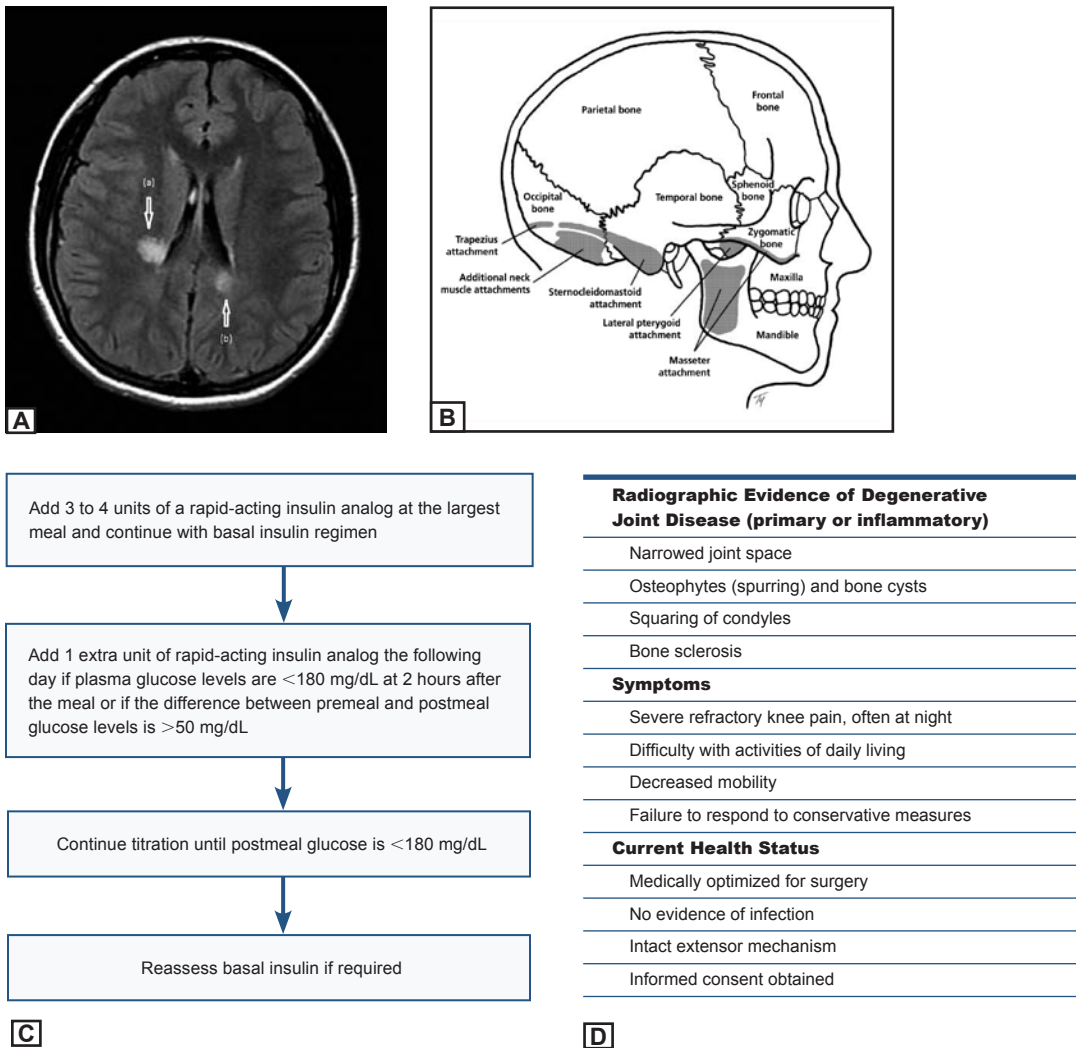


Figure 3.

Examples of nonstatistical figures: (A) clinical image, (B) illustration, (C) diagram, and (D) textual figure. Figure 3A reprinted from Noss MR, Carter M. Episode of pediatric demyelination. *J Am Osteopath Assoc.* 2013;113(3):250; Figure 3B reprinted from Meyer PM, Gustowski SM. Osteopathic manipulative treatment to resolve head and neck pain after tooth extraction. *J Am Osteopath Assoc.* 2012;112(7):457-460; Figure 3C reprinted from LaSalle JR, Berria R. Insulin therapy in type 2 diabetes mellitus: a practical approach for primary care physicians and other health care professionals. *J Am Osteopath Assoc.* 2013;113(2):152-162; and Figure 3D adapted from Van Manen MD, Nace J, Mont MA. Management of primary knee osteoarthritis and indications for total knee arthroplasty for general practitioners. *J Am Osteopath Assoc.* 2012;112(11):709-715.

Illustrations

Illustrations are often used to explain structures, mechanisms, relationships, and procedures that are difficult to convey with photographs or clinical images.² For example, parts of a cell may be easier to identify in an illustration than in a photograph of microscopic findings.

Diagrams

Types of diagrams include flowcharts (procedure or sequence of activities), algorithms (branched pathways for identifying or managing a condition), pedigrees (familial relationships), and maps.² These types of figures are useful for visually displaying complex relationships or parts of a study.

Textual Figures

Textual figures contain only text and present information that does not contain comparisons. These types of figures can be used to describe steps of a procedure or to summarize consensus statements or guidelines.

Considerations for Nonstatistical Figures

Because photographs can lose some detail and contrast when printed, authors should use only high-quality images for figures.⁴ Photographs should be taken in focus and with high resolution, and authors should use adequate lighting, solid-colored backgrounds, and multiple camera settings to ensure they capture the best possible image.⁴ If the size of the object is important to convey, authors should consider including a ruler or common object (eg, coin) in the shot as a reference point for readers.⁸

When preparing photographs or clinical images for submission, authors should make sure the image shows only what is important; they should crop out unnecessary parts (*Figure 4*).^{4,8} Particularly for clinical images, authors should ensure figures do not contain any patient information or identifiers. If a photograph cannot be cropped, then authors should consider superimposing arrows or labels to call out the most important elements of the image. Authors should also describe the view (eg, axial, coronal) for radiologic images.

For diagrams and illustrations, authors should ensure clarity by defining all abbreviations, providing appropriate labels, using standard symbols and shape boxes (eg, square=male individual and circle=female individual in pedigrees), and including detailed explanations of diagrams in figure captions.^{2,7}

Textual figures should be concise, well organized with bullets or a numbered list, and appropriately referenced. Text that is presented in a figure should act as a quick reference for readers. If lengthy explanations are needed, the information is likely best presented in the body of the manuscript.

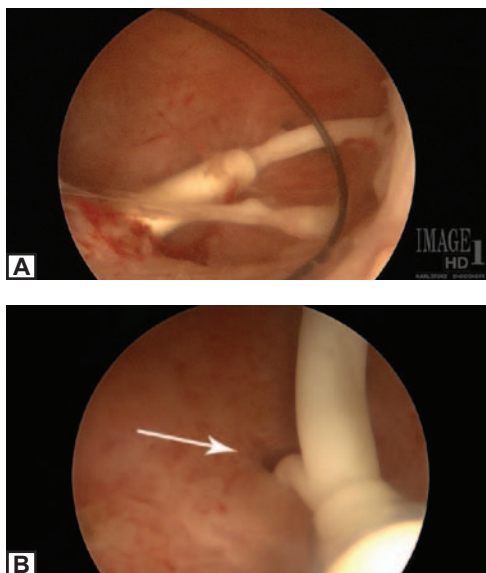


Figure 4. Two images of an intrauterine device perforating the uterus. In Figure 4A, the image is framed too widely and contains unnecessary details, making it hard for the reader to identify the perforation. In Figure 4B, the image is framed appropriately, shows only the necessary details, and has an arrow to help readers identify the perforation. Figure 4B reprinted from Murray JF, Bozek JS. Intrauterine device–related uterine perforation. *J Am Osteopath Assoc*. 2013;113(2):178.

Components of Figures

Regardless of the type of figure being used, authors must ensure that figures include key elements that allow readers to identify and interpret the information presented. In the following section, I will discuss considerations for some of the common components of figures (*Figure 5*).

Figure Number and Caption

Figures should be numbered sequentially according to the order in which they are noted in the text. Figure titles consist of the designation “Figure” followed by the appropriate consecutive number (ie, Figure 1, Figure 2).² If a manuscript contains a single figure, then the figure title is simply “Figure.”

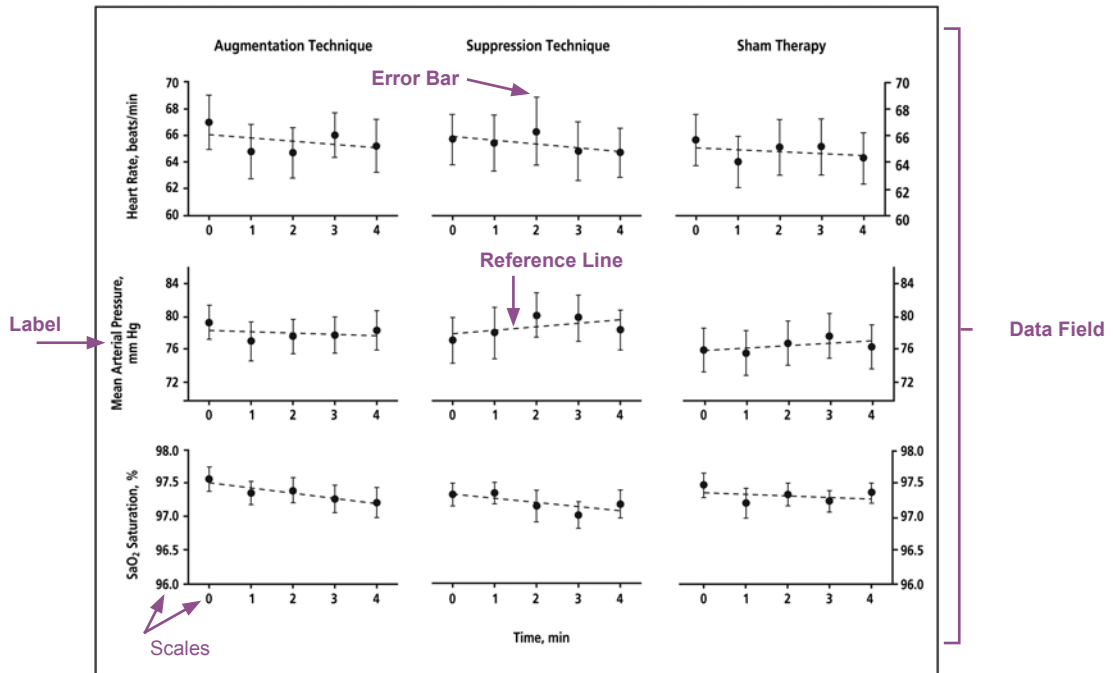


Figure 1. Group heart rate, mean blood pressure, and arterial oxygen saturation during cranial osteopathic manipulative medicine augmentation technique, suppression technique, and sham therapy. No statistically significant differences from baseline were noted for any variables during any therapy.

Figure 5. Common components of figures. Figure adapted from Shi X, Rehner S, Prajapati P, Stoll ST, Gamber RG, Downey F. Effect of cranial osteopathic manipulative medicine on cerebral tissue oxygenation. *J Am Osteopath Assoc.* 2011;111(12):660-666.

Figure captions appear after figure numbers. The caption should be a brief description of the figure in sentence format.^{2,4} If a figure has multiple parts, authors should designate those parts with letters (eg, Figure 1A, Figure 1B), and each part should be individually described in the caption. As with tables, figures should be able to stand on their own; figure captions should provide enough information so that readers can understand the message without referring to the main text.⁶ Any statistical methods used to generate the data should be noted in the figure caption.²

Data Field

The data field is the space in which the data are plotted.³ Depending on the type of figure, the data field may contain data points, bars, lines, symbols, labels, keys, or legends. It is bordered on the left by the y-axis and on the bottom by the x-axis. All elements in the data field need to be identified using the figure caption, labels, or a key.³

Scales

Scales appear on x- and y-axes and indicate values for data in a graph, often by use of tick marks.³ Values typi-

cally increase from left to right and bottom to top.² The scales used on each axis should match the range of the data.⁶ The scale should be slightly larger than the highest value plotted on the figure,² but scales should not extend beyond what the graph demands.⁷ For example, a set of data that ranges from 0 to 72 should be plotted on a scale of 75, not 100. In addition, the lengths of the 2 axes should be visually balanced.⁶

Symbols

As previously mentioned, it is important that authors use standard, widely accepted symbols in figures. Symbols should also be uniform across figures.² For example, if triangles are used to represent group A and squares are used to represent group B in figure 1, then those symbols should represent the same groups in subsequent figures.

Authors may also use color, shading, or patterns to differentiate the information in their figure. Shading is preferable to patterns when distinguishing groups or patterns, because patterns are harder to discern.²

All symbols, colors, shades, and patterns should be clearly defined in the data field with labels, in a key, or in the figure caption.²

Error Bars, Box Plots, Whisker Plots

Error bars are used to display variability in data, whereas box and whisker plots are used to show nonnormal distribution. For error bars, the range of variability must appear both above and below data points, because the range that they represent may not be symmetrical to the data point plotted.³ Box and whisker plots should follow convention when possible: top of the box, 25th percentile; bottom of the box, 75th percentile; horizontal line inside the box, median or mean; whiskers, 10th and 90th percentiles; circles, outliers.² Error bars, box plots, and whisker plots should all be defined in the figure caption or in the data field.²

Labels and Indicators

In graphs, authors should label the x- and y-axes, as well as the values being plotted, on the scales. Both the numbers and the labels for the axes should be readable and clear.⁶ If labels for symbols appear within the data field, authors should ensure that the labels do not clutter the message. Likewise, any reference lines showing trends or statistical curves should not compete with the data.³

In nonstatistical figures, authors should ensure that all visual indicators (eg, arrows, rulers) are clearly defined in the figure caption.²

Submitting Figures for Publication

When submitting figures for publication, authors should adhere to the guidelines of the journal to which they are submitting, as technical requirements and style guidelines vary from journal to journal.⁴ In general, however, authors should consider the following when they are preparing their figures for submission:

- All data, names, and descriptions that appear in the figures should match the data, names, and descriptions that appear in the text of the manuscript.
- Figures should be submitted as separate documents (ie, not embedded in the text of the manuscript).
- Authors should provide all data points for statistical figures in case a journal's designers need to recreate the figure.
- Photographs, images, diagrams, and illustrations should be submitted as separate, high-resolution JPEG or TIF files. Authors should check journal requirements to ensure their figures meet resolution requirements. The *JAOA* prefers images that are 300 DPI, or dots per inch.

- Authors should secure appropriate permissions from the original publishers of reproduced or adapted figures and include these permissions when they submit their manuscript. Permission is also needed from identifiable individuals in photographs.⁹

Conclusion

When preparing figures, authors should choose the appropriate figure type for their information, address guidelines for the specific components of their figure, and adhere to journal submission requirements. By following these steps, authors can ensure that their figures are an effective means for visually communicating the message of their manuscript.

References

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