Reviewer Recommendations

How to visually represent data

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Visual representation of data is an evolving field driven by advances in statistical programming [1] and graphical design and the expansion of academic social media, creating an audience requiring concise yet impactful information. The tools to produce visual representations, whether it be graphs, infographics or even multimedia figures, are now widely available and can be used to communicate the results of research studies [2]. As part of *Anaesthesia*'s Reviewer Recommendations series, we will outline why visual representation of data is important, describe the different ways to visualise information and how best to do it, and list the common pitfalls to avoid.

Why visually represent your data?

Data visualisations should demonstrate findings concisely in a scientifically precise manner that adds value for the reader. Processing visual data is known as 'pre-attentive processing' as there is no initial higher cognitive function. Visualisations are therefore easier for humans to process, use less cognitive resource and lead to enhanced recall of information when compared with written information [3]. Visualisations can be exploratory or communicative. Exploratory visualisation is where data are presented in chart form to help the investigator recognise patterns or relationships which may not otherwise be clear. A common example may be an initial histogram after data collection to determine data distribution and identify possible outliers. In the dissemination of scientific information, communicative visualisations can be used to display data, comparisons and patterns in the form of charts, or convey the overall message or timeline of information such as in infographics or multimedia presentations. Data visualisation should be intuitive and reveal data to the reader rather than requiring them to interrogate the message themselves. When done well, it effectively communicates the overall message of a complicated clinical paper simply (Fig. 1). It can also increase the accessibility of research to patients and the public. Visualisations, in whatever form, should always add value to the overall work.

Different methods to visualise data

A recent study found that graphs perceived as 'beautiful' were inherently more trusted, with participants of higher educational level more likely to trust a graph if it was aesthetically pleasing [Lin and Thornton, preprint, https://psyarxiv.com/dnr9s]. This included graphs which the authors purposefully created to be misleading. Clearly, images should show robust and precise information, but if they can also be visually pleasing then engagement is likely to be higher. Data can be visualised in a variety of ways, each pertaining to specific data types and aims of presentation.

Charts encompass graphs, tables and diagrams (Fig. 2) [5]. They enable complex data to be distilled into easy-to-understand representations, usually of patterns or comparisons between groups. A graph is a chart that plots data against two or three dimensions. A table summarises information in a plot containing rows and columns. A diagram is a simplified drawing or schematic visual that aims to explain data rather than represent it. Charts can be simple or complex and aim to visualise static data. Clearly, subsequent statistical analysis to interrogate meaning from data can be displayed in an array of different charts. The overarching theme is that chart representation must be precise, accurate and meaningful.

Infographics tell a story. They can combine images (including charts) and combine different aspects to give an overall message. Infographics tend to include minimal text and use image combinations in a visually striking manner. It is becoming more common to see infographics describing research methods and findings. Infographics should summarise and deliver a message, which may direct the viewer to the figures themselves and indeed the full paper. Summary infographics are often employed because social media does not allow for lengthy text descriptions of complex phenomena. The use of social media platforms to display data increases the accessibility and reach of the research but does not come without pitfalls. Graphics designed for social media can be reductive, therefore care is needed to ensure the whole message is conveyed [2].

The move away from printed medical journals towards online publication allows for the presentation of moving visual images in the form of animations or recorded videos. Animations have the added advantage of being interactive, with the user clicking on topics for more information or choosing the direction in which the animation proceeds. Animations can be a combination of charts and infographics which progress to address key aspects of the paper [6]. Sound can be added to animations to provide further clarity and increase reader engagement. Multimedia articles can include all the above formats with brief text to demonstrate a topic, including case reports. The overall aim is to make a topic more engaging by allowing the viewers to interact with the different media on display. Some journals, such as *Anaesthesia Reports*, publish multimedia articles which include still images or videos with minimal text to portray interesting and novel messages [7].

How to visually represent your data

The practicalities of visual representation can be split into sections: the message; visual tips; software; accessibility; and common pitfalls. The most important aspect of data visualisation is function and that the data and overall messages are correctly represented and not lost within the style or design. Think carefully about the message you want to convey, whether it is the overarching conclusion of your project, or a specific but important detail. Determining the purpose of displaying the message as a visualisation is the first step. This may be to add clarity, simplify a complex mechanism or make the information more user-friendly to a non-medical audience. Ideally, data visualisation would have been thought about at the study design stage. Consider who the intended audience is and their needs.

In the context of academic publication, authors typically target medical professionals but increasingly the mainstream media are also interested in high-impact publications [8]. This also raises the issue of image copyright. Copyright is an intellectual property right which prevents unauthorised copying and publishing of original work. Data itself cannot be copyrighted; but research outputs such as publications, and the images contained within, are protected by copyright [9]. Equally, care needs to be taken if you decide to integrate non-original images into visualisations. If you are using images which you do not have a copyright for, ensure you get permission from the copyright owner. If generic images from search engines or websites are used, ensure that the licence details are adhered to; some images may not require credit, may require credit but no payment and others may require permission and payment to use.

If you are designing images to be placed on social media, then consider the reach and the audience who may access the images. People may be drawn to your visual images rather than all the information you present, therefore make sure your images represent your data and message effectively and cannot be construed to mislead in the absence of reading the whole text. As with all communication methods, it is worth getting a variety of opinions on your images. What may make sense to you may not be clear to others. If the images are designed to be interpreted by non-medical professionals, then review by a lay person will be invaluable in ensuring clarity of communication (Fig. 2), especially with respect to the language used.

Visual tips

There are some helpful rules in graphic design to ensure that images are engaging and as aesthetically pleasing as possible. When considering data visualisation for manuscript submission, consistency is key. Ensure that you read the author guidelines of the relevant journal thoroughly and that all the images meet these requirements. Where multiple visualisations are produced, ensure there is consistency in both design and display. The font, resolution and colour palette for example should be maintained throughout the images. Author guidelines often recommend resolution and file type plus other display features such as font, use of symbols and graph layout. Avoid patterns within images; block colours are better. Icons can be used to exhibit a clear theme and ensure consistency throughout infographics and can showcase your images as belonging to your 'brand'. Icons are simple symbols or designs which pictorially represent an object or idea. They can be found within software packages, downloaded from third parties or created originally. They can also act as visual cues to direct the eye to different places on a page. The typeface you use also needs to be considered. Widely, fonts are split into serif (with decorative lines or tapers e.g. Times New Roman) and sans serif (clean lines such as Calibri). Sans serif fonts are recommended to ensure function and clarity.

Think about what kind of medium your image is going to be displayed on. You may need to adjust the size and shape of your images to fulfil a mobile phone layout if that is how most users are going to be accessing your information. For example, optimal Twitter image sizing is 900 x 450 pixels, whereas this is 1200 x 628 pixels for Facebook. Ensuring the size is correct will optimise the clarity of the image. How your image is displayed is also important in determining the colour mode. Cyan, magenta, yellow and key (CMYK) are the colours traditionally used in the printing process, and so printed images are best displayed using this colour palette. However, on-screen images are better presented using red, green, blue (RGB) mode. Palettes that are colourblind friendly should be chosen to ensure accessibility for readers with conditions such as protanopia, deuteranopia and tritanopia. Free programmes and websites allow for colour 'picking' where colour codes can be copied from other sources and colour combinations can be simulated for readers who are colourblind. Dr Paul Tol (https://personal.sron.nl/~pault/) has created a number of palettes designed specifically for displaying scientific data.

Programmes

Most statistical software allows graphical representation of data. Statistical packages such as GraphPad Prism (GraphPad Software, San Diego, CA, USA) and R (R Foundation for Statistical Computing, Vienna, Austria) using the ggplot2 package [10] are recommended as packages which allow clear graphs to be easily created and manipulated to fulfil most journal author guidelines.

There is also a plethora of free and paid for programmes for graphic design. Free programmes such as Visme.co (DBA Visme, Rockville, MD, USA) or Canva.com (Canva, Sydney, Australia) offer templates for visualisations and are straightforward to use, with the option of upgrading membership and paying for additional functionality. The trade-off when using free programmes is that the company logos are often included in the images you produce and functionality may be limited. If you feel it is worth investing in data visualisation software, then Adobe Creative Cloud (Adobe Inc., San Jose, CA, USA) offers a suite of programmes which can be used for different aspects of data visualisation. For example, Illustrator can be used to create icons, and InDesign used for figure creation (Fig. 2). These programmes may offer staff or student discounts via academic institutions.

Accessibility

When creating a visual representation of your data, it is important that everyone can access it. A useful, more comprehensive resource is the United Kingdom government website [11]. Factors to consider include: ensuring you use a large enough clear font so that it is clearer for visually impaired people; using colourblind friendly palettes; choosing fonts that help people with dyslexia (e.g. Trebuchet MS); using appropriate spacing and not being afraid to use white space; and produce audio descriptions or transcripts for people who are visually impaired. Your images should be targeted towards your specific user group if applicable.

Common pitfalls

The most important pitfall to avoid is unintentionally misleading or providing false information. It is imperative that visualisations are honest and accurately reflect data. Common errors include cherry-picking data or graphs that look attractive over data that are more pertinent or accurate, or altering images (e.g. graph axis points) to improve the appearance of an image. Not everything needs to be or should be represented visually. Sometimes, a concept may be better described with text and a visualisation may confuse or detract from the message. Equally, sometimes less is more. Creating a chart for every single outcome you measured can overload the reader and detracts from the key information you want to convey. Ensure you have chosen the correct type of graph for your data. Conversely, you also need to ensure that the images are not reductive, and that important data aren't lost if creating a visualisation requires simplification of a complex concept. Finally, beware of 'administrative debris'. If an image is embedded in text, minimise the distance from the key to the image. Referring to an image which is far from the relevant text uses up precious cognitive load and can lessen the reader's concentration and interest.

Conclusion

The use of well-designed, appropriate and accessible visualisations of data can add value to scientific publications by helping the reader appreciate key messages and enhance engagement with the article. This is becoming increasingly important as journals move away from print and use electronic output (including social media) as a dissemination method. You should consider carefully how data visualisation can be best used to achieve optimal dissemination of the results of the research to their target audience.

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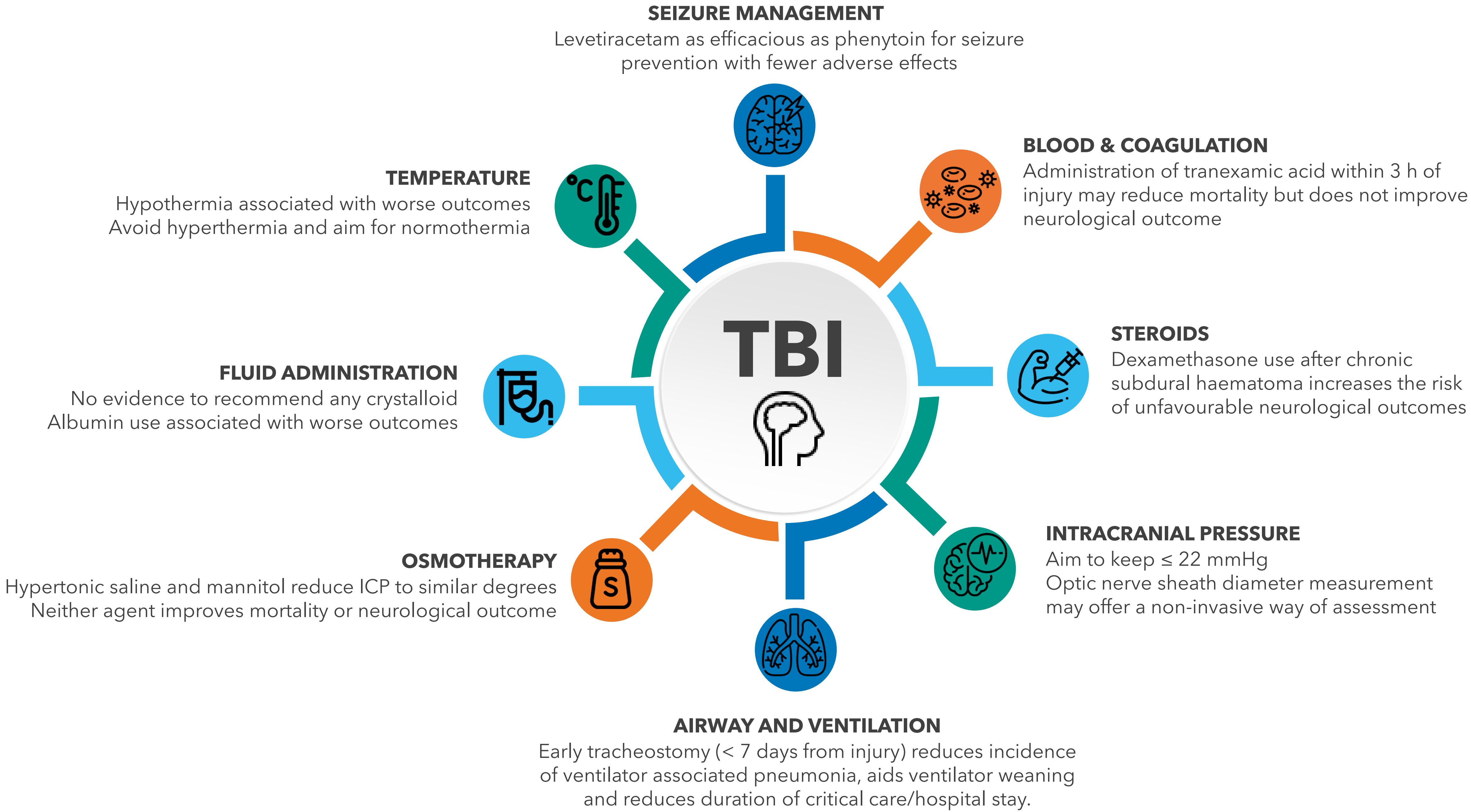
Legends for figures

Figure 1. Example of a figure highlighting the key points from a narrative review in a concise and engaging display [4]. The use of colour and icons draws the viewer to the figure, with concise text focusing on the key messages. The palette is colour-blind friendly using orange (red 238, green 119, blue 51; hexadecimal EE7723), blue (red 0, green 119, blue 187; hexadecimal 0077BB, cyan (red 51, green 187, blue 238; hexadecimal 33BBEE) and teal (red 0, green 153, blue 136; hexadecimal 009988).

Figure 2. A checklist to consider when designing a visual illustration of data as well as common methods to display raw data. It remains common for submitted manuscripts to include the wrong type of graph for a given dataset.


SEIZURE MANAGEMENT
Levetiracetam as efficacious as phenytoin for seizure prevention with fewer adverse effects
BLOOD & COAGULATION
Administration of tranexamic acid within 3 h of injury may reduce mortality but does not improve neurological outcome
STEROIDS
Dexamethasone use after chronic subdural haematoma increases the risk of unfavourable neurological outcomes
INTRACRANIAL PRESSURE
Aim to keep ≤ 22 mmHg
Optic nerve sheath diameter measurement may offer a non-invasive way of assessment
AIRWAY AND VENTILATION
Early tracheostomy (< 7 days from injury) reduces incidence of ventilator associated pneumonia, aids ventilator weaning and reduces duration of critical care/hospital stay.
OSMOTHERAPY
Hypertonic saline and mannitol reduce ICP to similar degrees
Neither agent improves mortality or neurological outcome
FLUID ADMINISTRATION
No evidence to recommend any crystalloid
Albumin use associated with worse outcomes
TEMPERATURE
Hypothermia associated with worse outcomes
Avoid hyperthermia and aim for normothermia
TBI
°C
S

Checklist for Data Visualisation

- Is the message clear and consistent?
- Is the image interpretable on its own?
- Does it add value?
- Has accessibility been optimised?
- Is it engaging and attractive?
- Could it be misinterpreted?
- Are the underlying data referenced or available if requested?

HISTOGRAM

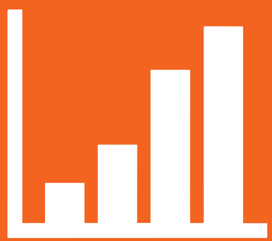
Used to summarise discrete or continuous data that are measured on an interval scale

PIE CHART

A circular statistical graphic, which is divided into slices to illustrate numerical proportion

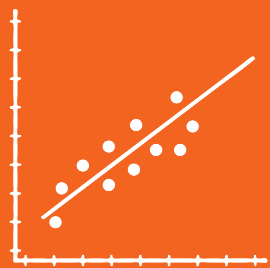
BAR CHART

Displays categorical data with rectangular bars with heights or lengths proportional to the values that they represent



SCATTER GRAPH

Graphs pairs of continuous numerical data, with one variable on each axis, to look for a relationship between them



LINE GRAPH

Utilises points and lines to represent change over time