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Radar plots: a useful way for presenting multivariate health care data

M. Joan Saary[a,b,*]

[a]Gage Occupational and Environmental Health Unit, Department of Occupational and Environmental Health, St. Michael's Hospital, Toronto, ON, Canada

[b]Department of Medicine, University of Toronto, Toronto, ON, Canada

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Abstract

Objective: Health care researchers have not taken full advantage of the potential to effectively convey meaning in their multivariate data through graphical presentation. The aim of this paper is to translate knowledge from the fields of analytical chemistry, toxicology, and marketing research to the field of medicine by introducing the radar plot, a useful graphical display method for multivariate data.

Study Design and Setting: Descriptive study based on literature review.

Results: The radar plotting technique is described, and examples are used to illustrate not only its programming language, but also the differences in tabular and bar chart approaches compared to radar-graphed data displays.

Conclusion: Radar graphing, a form of radial graphing, could have great utility in the presentation of health-related research, especially in situations in which there are large numbers of independent variables, possibly with different measurement scales. This technique has particular relevance for researchers who wish to illustrate the degree of multiple-group similarity/consensus, or group differences on multiple variables in a single graphical display.

Keywords: Statistical data interpretation; Multivariate analysis; Computer graphics; Information dissemination methods; Outcome assessment; Consensus

1. Graphing multivariate data

There are some data for which meaning is not necessarily clear when presented in tabular or text formats. As the number of variables measured increases, so does the difficulty in describing their meaning. Survey data is a case in point. Survey data are increasingly used to gather information about a range of topics including, but not limited to, symptoms, quality of life, perceptions of care, and satisfaction. When such data are gathered on multiple groups and then compared, the usual method of comparison is to perform statistical tests, be they χ^2, ANOVA, multivariate analysis of variance, or *t*-tests and then describe the numerical data in text or table format. However, although data tables are sometimes excellent methods for storing data, they are often difficult media for communicating and analyzing it [1].

In addition to text or tables, research results can also be presented in graphical formats. Graphical displays are particularly suitable for illustrating relationships and trends concisely. However, graphs can become visually "difficult" when the number of variables and groups to be displayed is large, or when the measurement scales are different. For example, potential difficulties in data communication emerge when there are multiple variables for each of several groups. The challenge for the reader is to comprehend the meaning of multiple-group differences on a list of variables. We may know the average of all cases or the percentage of variance explained by an independent variable, but we do not find out if a particular case fits a pattern [1]. Furthermore, despite the existence of numerous books that detail various ways of graphing multivariate data, the field of medicine continues to rely heavily on text, tabular, and simple graphical description of data. The purpose of this paper is to introduce radar graphing as a useful technique for the presentation of multivariate health care data.

Most graphs in popular media present limited amounts of information. The bar chart and the trend graph are examples of graphical forms that usually present limited data. Other graphical forms that limit the sophistication of the graphical information displayed include pie charts that are only capable of breaking a whole into its component parts, and bivariate plots that show [only] the relationship between two variables, the "norm" for the relationship, and outliers [1]. Displaying multivariate relationships in two dimensions requires "some ingenuity" [2,3].

* Corresponding author. Occupational Health Clinic, St. Michael's Hospital, 30 Bond Street, 4th Floor, Shuter Wing, Toronto, ON, Canada M8V 3E3. Tel.: 416-709-6737; fax: 416-255-0689.

E-mail address: joan.saary@utoronto.ca

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What is New?

What this paper adds to existing literature:

1. Introduces readers of clinical medical literature to a useful form of graphing more common to the fields of engineering, chemistry, and marketing.
2. Illustrates how to produce a radar chart with standard, widely available software.

Multivariate data can be represented visually in a variety of two-dimensional ways such as glyphs, profiles, Andrews' curves, Chernoff faces, and boxes [4]. In searching for alternative ways to examine and display patterns in data, a form of graphing called the radar plot was identified. This type of graph is practical and profoundly useful for a wide variety of data present in the current medical literature. My interest in radar graphs developed when I sought to succinctly express stakeholders' views on numerous variables concurrently. I had gathered an enormous amount of rich interview data and wanted to describe the degree of consensus or discord among the groups. I sought to determine ways to present the data that would enhance the patterns found among groups and that would supplement text-based presentation. There are abundant applications for this versatile graphing method in both clinical and basic science health care research.

For clinical studies, examples of uses of radar graphs might include the following:

1. Changes over time in multiple variables
   a. In a single individual
   b. In different groups
2. Multiple–treatment group differences on multiple-outcome measures
3. Difference between disease conditions on multiple variables.

Radar graphing could also be considered an effective mechanism for graphing basic science data; some examples of which might include

1. Comparative compositions of pharmaceuticals
2. Molecular or genetic similarity between cases or groups
3. Biologic marker composition/variability between different tissues or tumors.

2. Radial plots

Radial plots have existed for years as important descriptive tools for multivariate data. In general, the common feature of radial plots is that they are a circular graphing method and have a series of spokes or rays projecting from a central point, with each ray representing a different variable label. The values of the variables are encoded into the lengths of the rays, and the values so plotted are sometimes connected to form an enclosed figure [5]. They are akin to profile plots that have been wrapped about a central point. Dominant perceptual properties often include size and shape of the resulting figure [3]. In some situations, characteristic shapes such as stars are used to represent optimal configurations [6]. In other cases, symmetrical polygons are also used as indicators of the normal or nominal conditions [5].

In the 1950s, during his investigation of variation in natural populations, Anderson [7] used the metroglyph as a semigraphical method of analysis, illustrating the data from four individuals for whom ratings on a 3-point scale for five different qualities were available. Although a botanist himself, Anderson proposed that his semigraphical glyphs could be useful in fields as diverse as physiology, morphology, psychology, and linguistics [7]. Later in the 1970s, Kiviat graphs were introduced by Kiviat and Kolence as a means for monitoring computer system hardware performance [8,9]. Kiviat plots are now commonly used in a wide range of fields, predominating in business management as a tool for comparing performance metrics [10], and in engineering, computing, and information technology for monitoring system development trends, etc. [11]. In fact, many fields use radial plots in one form or another. Star charts [12], with their side-by-side glyph arrangement for different groups, are commonly seen in the fields of analytical chemistry, toxicology, and petroleum geology [13–16]. Alternate names for similar plots include circle diagrams, polygons, and snowflakes [4].

3. Radar plots in medical research

Radial plots in any of their various forms have not been widely used in the field of medicine. Scant examples of their use include distinguishing metabolic profiles of different cancer classes with star plots [17], and using star charts to display EEG (electroencephalogram) spectral values [18].

Of particular interest for this paper is the radar plot, so named because of the way it resembles a Plan Position Indicator—the typical two-dimensional layout of radar return from a radial trace commonly used in air traffic control, weather forecasting, onboard ships, etc. As with other forms of radial plotting, the use of radar charts in the medical literature is rare, but present. Yamaguchi et al. [19] used radar charts for monitoring multiple-item self-ratings of sleep disturbance over time; Kosaka et al. [20] used radar charts to express quality-of-life factors in breast surgery patients; Minemawari and Kato [21] used the radar chart as a geriatric assessment system; and Jette and Jette [22] present comparisons of health-outcome data measured using various questionnaires with radar charts.

The radar plot, when used as a method to display data, is much simpler than when it is associated with statistical analyses, which can sometimes be complex because of the multidimensionality. This is perhaps one key reason why the clinical science of medicine has not adopted radar graphing; at the outset, it might appear to be too complex a mathematical technique to be practical. Another challenge with such plots, as with others, is that the order of arrangement of variables can impact perception of the data [3]. Clearly though, graphs can be arranged along a continuum from descriptive to analytical. Motivating the audience to access the data is an important purpose for graphs. A graph can break up extensive narrative and encourage the reader to continue to engage the material [1].

I became enthusiastic about the radar chart as a way to graphically illustrate stakeholder consensus. Typically, consensus is presented as percentage agreement. Correlations or kappas can also be used, but are not appropriate for certain types of data, or with numerous groups where multiple correlations require follow-up, and sample sizes large enough to support statistical power for such analyses may be difficult to obtain. Percentages are often plotted as bar charts, but each variable must then be either presented on a separate chart, or listed separately such that the degree of overlap or agreement is not obvious. However, when each stakeholder is represented by a particular shape on a radar graph that emerges from their results on each of several measured variables, the overlap becomes clear.

To illustrate, a fictitious scenario was created in which patients from three different towns were asked to rate their level of satisfaction with their interaction with the health care system on a scale from 1 (dissatisfied) to 5 (totally satisfied) on seven different variables: physician knowledge (MD Knowledge), physician attitude (MD Attitude), simplicity of the system (Simplicity), access to emergency care (Access), wait time for tests (Wait Time), costs incurred if any (Cost), and availability of specialists (Availability).

Group mean results are presented in Table 1 using the traditional approach of providing means for all the variables. Although informative, the table does not give an overall sense of each group's opinions.

Comparing the radar chart (see Fig. 1—generated in Excel, Microsoft Excel© 2006 Microsoft Corporation) to the tabular data in Table 1, total satisfaction is represented by the outermost ring. In other words, the ideal situation is represented by the perimeter. Clearly, from this chart it is apparent that patients in Town B are more satisfied than the other two. In addition, it is also clear that all three patient groups were satisfied with MD Attitude, compared to Access, Cost, and Availability where there is greater dispersion. Patients in Town C give poorer ratings (the inner ring) than the other two groups on all but two variables.

Table 1
Means for satisfaction variables

	Mean satisfaction ratings						
	MD Knowledge	MD Attitude	Simplicity	Access	Wait Time	Cost	Availability
Town A	1	5	4	4	5	3	3
Town B	5	5	4	5	5	5	4
Town C	2	5	3	2	3	2	1

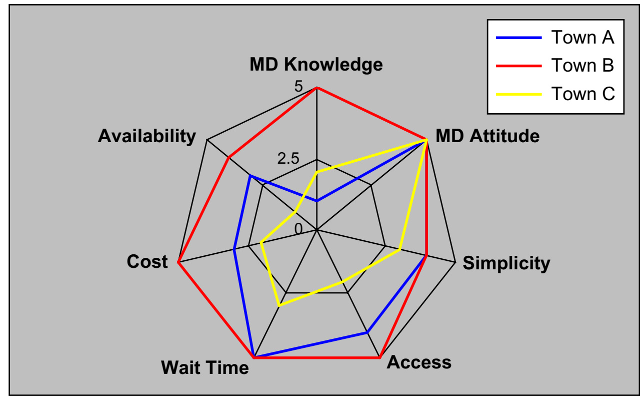

Fig. 1. Radar chart comparing three groups on seven variables.

Now, comparing the radar chart to the same data presented in a typical bar chart (see Fig. 2), the radar chart is notably less cluttered. It provides an immediate sense of the big picture, as well as the detail for each individual variable. The radar chart form of graphical presentation is a more efficient way to display a wide variety of data in a single picture. In addition, the radar chart can accommodate additional information without becoming overwhelming, simply by adding spokes to the wheel.

An example of the use of radar graphs for large volumes of information is seen in the work of El Ansari and Phillips [23]. Data from four different stakeholder groups are overlaid on a graph of 16 variables each ranging from 1 to 7. Data from multiple groups on multiple variables can be easily summarized on a single intelligible graph, the text explanations of the same taking pages to elaborate. This is not to say that the graph oversimplifies the data, but only that patterns are more easily ascertained.

4. Generating the radar plot

Radar plots can be produced by a variety of commercially available computing programs. The output from two of such

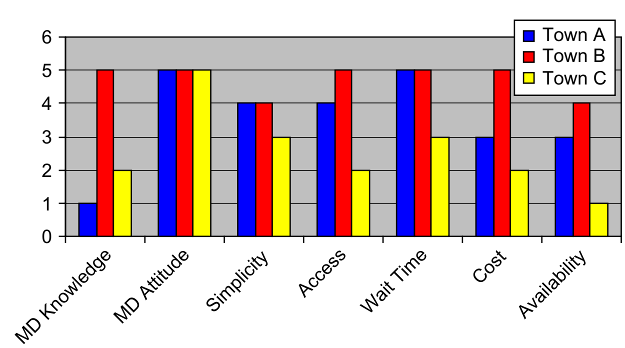

Fig. 2. Bar chart comparing three groups on seven variables.

Table 2
Data for SAS© chart production example—number of deaths by location, gender, and treatment group

Age	Gender	Treatment	Deaths
1	1	1	10
1	1	2	4
1	1	3	7
1	1	4	6
1	1	5	15
1	2	1	2
1	2	2	14
1	2	3	2
1	2	4	1
1	2	5	19
2	1	1	14
2	1	2	2
2	1	3	5
2	1	4	7
2	1	5	2
2	2	1	1
2	2	2	20
2	2	3	7
2	2	4	5
2	2	5	4

programs will be presented as the reader is guided through the process of producing the charts: the SAS© statistical software package (SAS Institute, Cary, NC, USA), and Microsoft Excel© 2006, Microsoft Corporation.

When using the GRADAR procedure in SAS©, the data typically consists of one or more group variables and one or more outcome variables for which there is a count or frequency for each level of the group variable (see Table 2). The vertices of the radar plot are determined by the levels of a single variable that is given in the CHART statement. The spokes in the chart are positioned much like a clock starting at the 12-o'clock position and moving in a clockwise direction.

In Excel, the radar plot is generated by using the Insert function that allows the option to insert one of a variety of charts. Radar plots are among a number of other less commonly used graphing styles available on this menu including surface, doughnut, bubble, and stock plots. In this example, Excel does not prepare the chart by performing calculations on the raw data; hence, the sums (or means) of the raw-data groups must be represented in a separate new table (see Table 3).

To demonstrate the production of radar charts in SAS©, a fictitious data set including several categorical variables

Table 3
Data for Excel© chart production example—sums of number of deaths for each level of treatment derived from same raw data in Table 2

Treatment group	Total deaths
Control	27
0.25 mg	40
0.50 mg	21
0.75 mg	19
1.00 mg	40

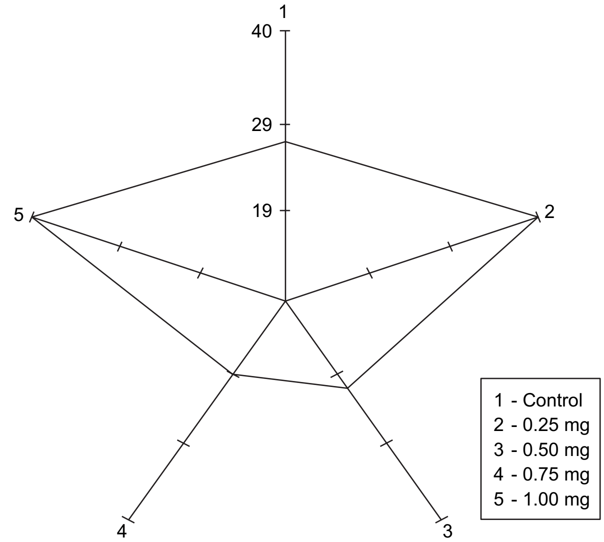

Fig. 3. Number of deaths in 1 year for each treatment: results from SAS©.

and one continuous variable was created. For this data set (see Table 2), the outcome measure was the number of deaths over a 1-year period in a control and four treatment levels of a new drug (1 = control, 2 = 0.25 mg, 3 = 0.50 mg, 4 = 0.75 mg, and 5 = 1.00 mg) stratified by gender (1 = male, 2 = female) and age (1 = <50 years, 2 = ≥50 years).

An example of code to generate the simple SAS© radar plot in Fig. 3 comparing only the five treatment levels would be:

```
proc gradar data=example;

chart treat / freq=count ;

run; quit;
```

For this example, vertices are created for each level of the treatment group variable, and a star is created with each spoke representing one of the five levels of treatment, and

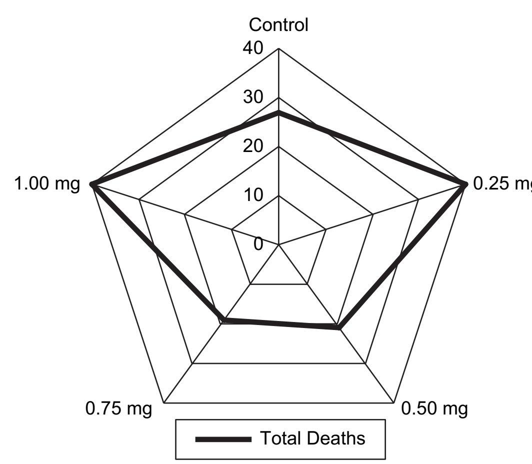

Fig. 4. Number of deaths in 1 year for each treatment: results from Excel©.

each point on the spoke reflecting the magnitude of the variable COUNT, which in this case would be the number of deaths in a year for each of the control and four treatment categories. Fig. 4 illustrates the same radar chart generated from the data in an Excel© spreadsheet.

If another group variable is also considered, say gender, then the values of COUNT are aggregated across gender within each level of treatment. In this example, to display the deaths in each treatment group on separate charts for each gender as in Fig. 5 (Fig. 6 for Excel©), use the ACROSS = <variable> option in the CHART statement:

```
proc gradar data=example;

chart treat / freq=count across=gender;

run;

quit;
```

Figs. 7 and 8, however, are more efficient radar charts because one gender is overlaid on top of another. In Excel© specifying the data ranges for each series will allow multiple groups' results to be displayed on a single chart. In SAS©, use the OVERLAY = <variable> option in the CHART statement:

```
proc gradar data=example;

chart treat / freq=count overlay=gender;

run;

quit;
```

Although it is clear from the resulting shapes in Figs. 5 and 6 that the genders appear to have differences in death rates for the various treatment options, the overlaid Figs. 7 and 8 much more distinctly indicate that the control group had a higher number of deaths among males, whereas treatment with 0.25 mg has markedly a greater number of deaths for females. The gender difference in numbers of deaths is less substantial for treatments with 0.50 mg, 0.75 mg, and 1.00 mg. Group differences could also be enhanced in this type of graphing by removing the radial grid lines altogether and focusing on the resulting shapes of the graphed data.

The simple examples in this paper demonstrate the utility of radar graphing for illustrating group differences. In this case, if the number of treatment options was to increase, or if the other grouping variable (i.e., age) was also overlaid, the radar graph would remain an appealing presentation method compared to tabular or other graphing formats because the graph would remain uncluttered.

5. Conclusion

Researchers must both convince audiences of their analysis and allow audiences to examine the data and determine the meaning for themselves. Often, however, tables and basic figures are the means relied upon to convey information. Although the examples in this paper are relatively simplistic for explanatory purposes, it is clear that additional variables that increase the number of spokes, and additional group variables that increase the number of overlays, do not hinder the ease of interpretation the way such additional information complicates bar charts or text.

This paper has described the usefulness and simplicity of a radial plotting technique called radar plotting for graphing multivariate data. Although commonly used in other fields such as business management and engineering, it has not found a stronghold in the presentation of health-related research results. Herein lies an important opportunity for knowledge translation to the medical community.

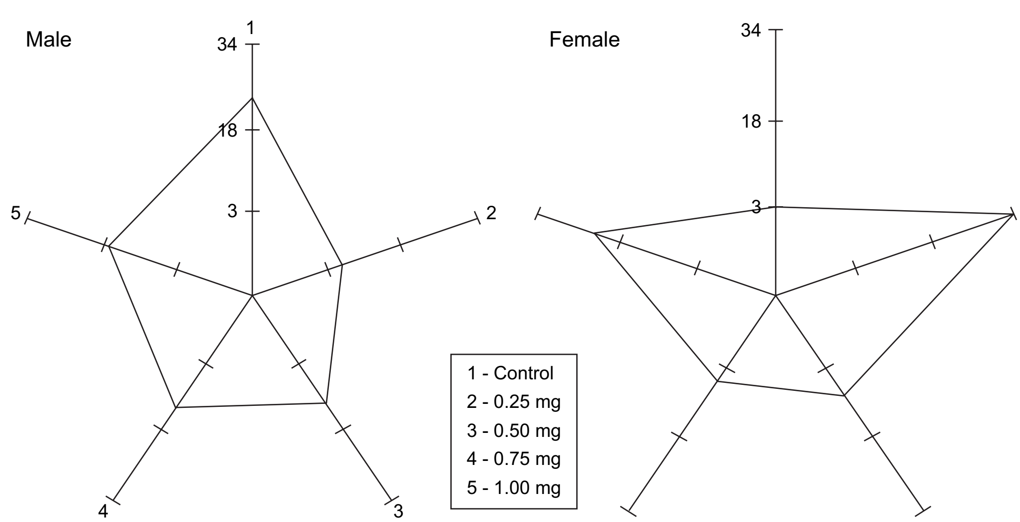

Fig. 5. Gender differences in death rate by treatment separately from SAS©.

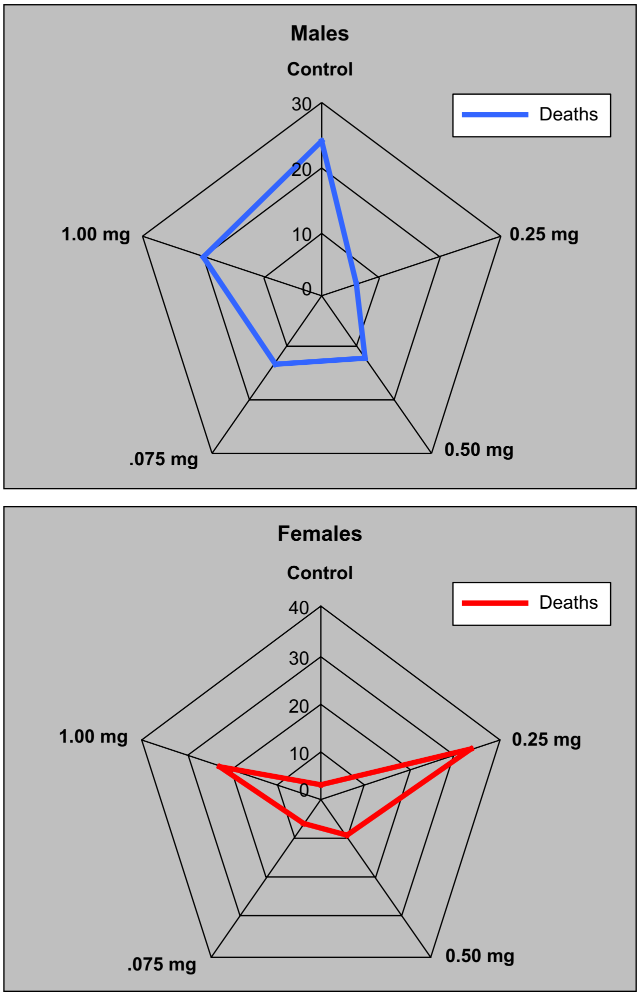

Fig. 6. Gender differences in death rate by treatment separately from Excel©.

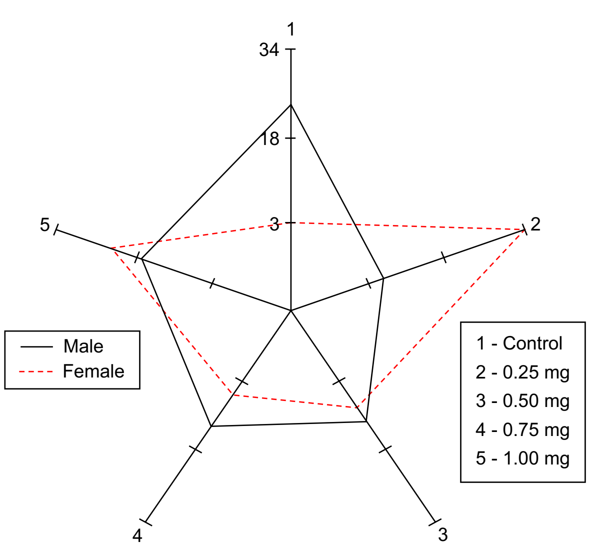

Fig. 7. Gender differences in death rate by treatment overlaid from SAS©.

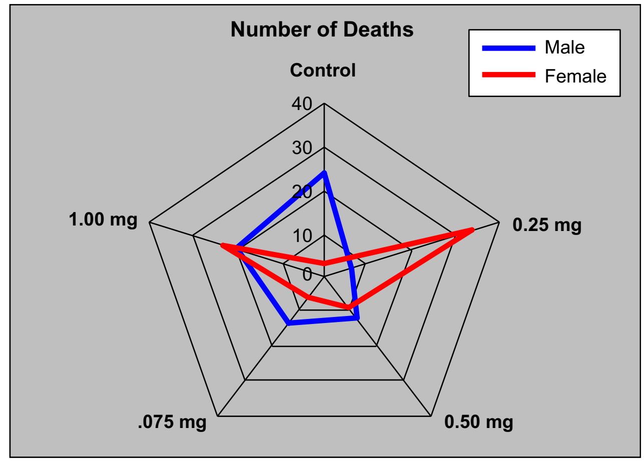

Fig. 8. Gender differences in death rate by treatment overlaid from Excel©.

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