

## How to Build a Complicated Patient Profile Graph by Using Graph Template Language: Turn Mystery to a LEGO Game

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### ABSTRACT

As a visual report, graphical patient profile can improve the readability of correlated data. It is desirable to use for submissions and publications as a way to comprehensively present safety and efficacy data. A common time frame is usually used to combine multiple forms of data, such as lab results, vital signs, and clinical events with demographic information. This type of graph can be highly complex and customized to achieve reviewers' needs. SAS's Graph Template Language (GTL) is a powerful and flexible tool used to draw these graphs. This paper provides instructions to start building with GTL, and how to combine various pieces together like playing a LEGO game. Real world examples are given to allow the readers follow step-by-step with notes. The examples are generated by SAS® 9.4 and in publication quality.

### INTRODUCTION

Patient profile are normally generated in a listing format. One output document file is created for each ID and presented in a certain order such as Demographic, Medical History, Adverse Event and Safety Results. This meets operational objectives when making patient safety decisions. However, for the efficacy results, visualization allows researchers and reviewers to better discover data trends in different ways, like using time series to track changes, or putting different results within same time frame together for correlation, or comparison before and after baseline.

The Statistical Graphics (SG) Procedures includes three easy-to-use syntax (SGPLOT, SGPANEL, and SGSCATTER) to create most commonly used analytical graphs. They have pre-defined graph templates which may lack of flexibility when several features in the graph templates need to be modified. SAS GTL is the core of ODS Graphics. One can design and build their own single template used for multiple scenarios. To get started on learning GTL, this paper explores the steps needed to create a complex graph in a way that's similar to assembling a LEGO project, with GTL components treated as structured building-blocks. Rather than a comprehensive introduction, this paper serves as a tutorial for beginners of GTL. Three easy-to-hard examples are presented. One simply needs to follow the workflow and see how each individual block and statement works and the results produced.

### BRICKS & PIECES

The parts to build a graph project can be categorized to these types:

**Statements:** define the contents of the graph; constructed by a keyword with arguments and options, mainly including plot, legend, text, draw statement.

**Blocks:** a pair of statements that constructs a block. Typically, multiple statements are nested within the block. A block can be nested within another block.

**Options:** add features to the statements

Parts No.	Category	Description
<b>Brick (Statement)</b>		
S1001	SERIESPLOT	Series plot (Line plot)
S1002	SCATTERPLOT	Scatter plot

S1003	BARCHART	Bar chart
S1004	BOXPLOT	Box plot
S1020	REFERENCELINE	Creates a horizontal or vertical reference line; Only use within a 2-D layout, e.g. OVERLAY
S2001	ENTRYTITLE	To specify graph title
S2002	ENTRYFOOTNOTE	To specify graph footnote
S2003	DRAWTEXT	Draws and anchors in a graph a text box that contains one or more lines of formatted text; location can be specified
S2004	DISCRETEATTRVAR	Creates an attribute-map variable to be referred in plot statement. Uses with DISCRETEATTRMAP block
S2005	LEGENDITEM	Creates the definition for a legend item that can be included in a discrete legend
S2006	DISCRETELEGEND	To specify legend features such as location, size, title etc.
<b>Knob &amp; Tube (Blocks)</b>		
B1001	PROC TEMPLATE; RUN;	To define, compile and save the template.
B1002	DEFINE STATGRAPH MyPlot; END;	Defines the structure of the graph and name it as e.g. 'MyPlot'
B1003	BEGINGRAPH; ENDGRAPH;	Builds content of the template within BEGINGRAPH block. Options which control graph size and appearance can be appended to BEGINGRAPH
B1099	PROC SGRENDER DATA= TEMPLATE= MyPlot; RUN;	To render pre-defined template to draw graph
B2001	LAYOUT OVERLAY; ENDLAYOUT;	Single-cell; When nested within another layout type, the OVERLAY layout defines the graph display for one cell of the parent layout
B2002	LAYOUT LATTICE; ENDLAYOUT;	Multi-cell; each cell can have different amount of space; Axes can be shared across columns or rows
B2003	LAYOUT GRIDDED; ENDLAYOUT;	Multi-cell; each cell has the same amount of space; each cell is independent
B2021	LAYOUT GLOBALLEGEND	Combines all discrete and merged legends into one; One template allows only one of this type of block; Any DISCRETELEGEND or MERGEDLEGEND outside the block will be ignored
B2031	DISCRETEATTRMAP; ENDDISCRETEATTRMAP;	Define the attribute map; Associate the attribute map with a classification variable in the plot data, and can be referred in plot statement. This block is a direct child of BEGINGRAPH statement. It is outside of any other GTL blocks
<b>TILE (Options)</b>		
<b>Managing Axes</b>		
O1001	XAXIS=X   X2	Specifies the plot's X= column is displayed on the X or X2 axis
O1002	YAXIS=Y   Y2	Specifies the plot's Y= column is displayed on the Y or Y2 axis
O1003	XAXISOPTS=	To define X-axis;

		each axis has its own separate set of options; uses parentheses to bundle options
O1004	X2AXISOPTS=	To define 2nd X-axis
O1005	YAXISOPTS=	To define Y-axis
O1006	Y2AXISOPTS=	To define 2nd Y-axis
<b>Controlling Grouped Data</b>		
O1101	GROUP=	Sets classification variable in addition to X and Y variables; By default, the plot automatically cycles through appearance features (colors, line styles, and marker symbols) to distinguish group values in the plot
O1102	GROUPDISPLAY=	To specify how group values are displayed, e.g. STACK: Stacks each group value on a single bar CLUSTER: side-by-side
<b>Plot Appearance</b>		
O2001	LINEATTRS=	To specify the appearance of the line, e.g. color, pattern, thickness
O2002	MARKERATTRS=	To specify the appearance of markers, e.g. color, size, symbol
O2003	TEXTATTRS=	Changes attributes of the text, e.g. font, font size, or color for title, footnote and even label
O2004	LABELATTRS=	To specify axis label features, used in XAXISOPS or YAIXSOPS statement.
O2005	TICKVALUEATTRS=	To specify axis tick features, used in XAXISOPS or YAIXSOPS statement.
O2006	CYCLEATTRS=	Assigns different visual attributes to each plot.
O2007	FILLATTRS=	To Specify the fill color and transparency
O2008	BARLABELATTRS=	To Specify the text properties of the bar label text
O2009	VALUEATTRS=	Controls the text properties of the legend. By default, the legend entries use VALUEATTRS = GraphValueText.
O2101	DISCRETEOPTS=	Settings for discrete axes. This option is ignored if the axis type is not DISCRETE
O2102	LINEAROPTS =	Settings for continuous data
O2103	TIMEOPTS=	Settings for Time series data, such as Date, Time, or Datetime values
O2104	LOGOPTS =	Settings for a logarithmic scale
O2901	COLOR=	GTL User Guide Appendix 4
O2902	PATTERN=	GTL User Guide Appendix 3 P.624
O2903	SYMBOL=	GTL User Guide Appendix 3 P.622
<b>Plot Identification</b>		
O3001	NAME=	To specify a name by which this statement can be referenced in a LEGEND statement.
O3002	LEGENDLABEL=	To specify legend label and can override the default legend text for each plot
<b>Labels for Plot Features</b>		
O4001	DATALABEL=	To specify the name of a variable that is used to label observations, as a column to label data points in a scatter plot, series plot, etc
O4002	DATALABELPOSITION=	To specify the position of the data labels relative to the data points and arrow heads

## PROJECTS

### Project I: Single-cell graph with line plot and bar chart overlaid (Figure 1)

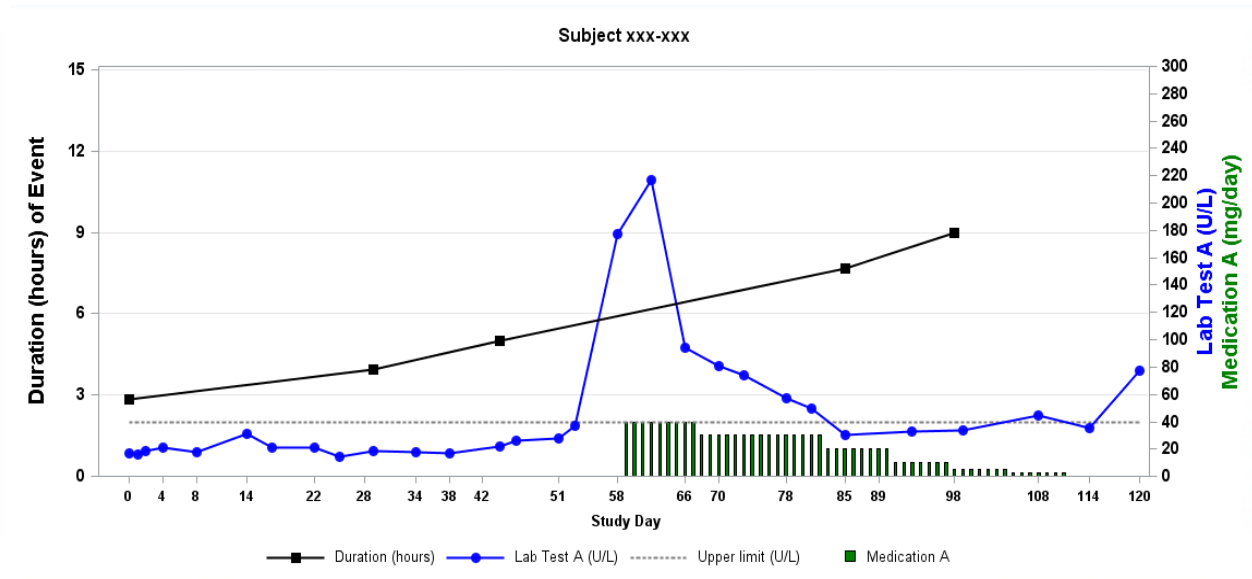


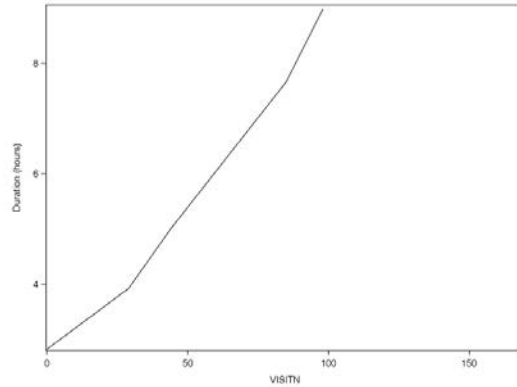
Figure 1 - Individual Patient Profile of Lab Test and Medication Dose over Time

Parts	Building Instruction & Result
B1001 B1002 B1003	<p>This graph is single-cell to use draw three different tests into one graph with sharing one x-axis.</p> <pre>* To create template Myplot;</pre> <pre>proc template;</pre> <pre>  define statgraph myplot;</pre> <pre>    begingraph /designwidth=800px designheight=400px;</pre> <pre>      endgraph;</pre> <pre>    end;</pre> <pre>run;</pre> <p>NOTE: STATGRAPH 'Myplot' has been saved to: WORK.TEMPLAT</p>
B1099 B2001	<p>* A blank graph is produced;</p> <pre>proc template;</pre> <pre>  define statgraph myplot;</pre> <pre>    begingraph/designwidth=800px designheight=400px;</pre> <pre>      layout overlay;</pre> <pre>    endlayout;</pre> <pre>  endgraph;</pre> <pre>end;</pre> <pre>run;</pre> <pre>proc sgrender data=final template=myplot;</pre> <pre>run;</pre>

S1001

\* Series plot added in LAYOUT OEVERLAY;

3

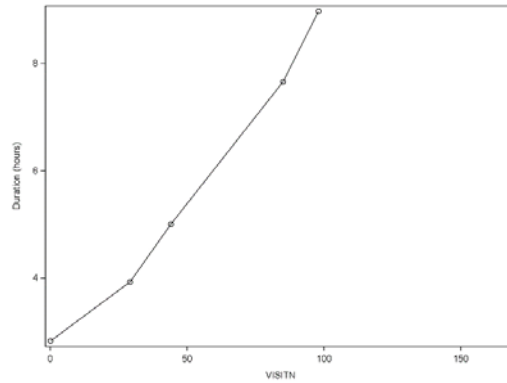


```
proc template;  
  define statgraph myplot;  
    begingraph;  
    layout overlay;  
    seriesplot x=visitn y=cfcdur;  
  endlayout;  
  endgraph;  
end;  
run;
```

S1002

\* Overlaying Scatter plot on Series plot;

4

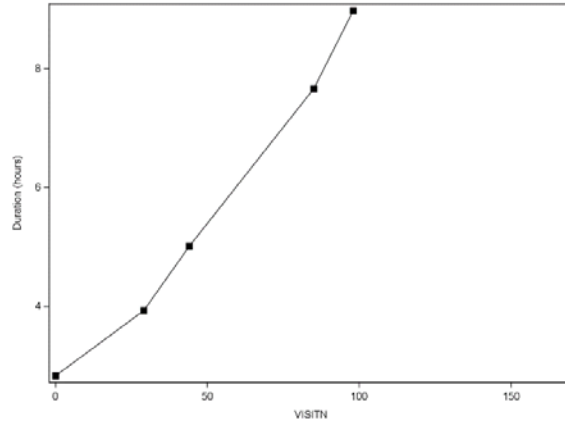


```
proc template;  
  define statgraph myplot;  
    begingraph;  
    layout overlay;  
    seriesplot x=visitn y=cfcdur;  
    scatterplot x=visitn y=cfcdur;  
  endlayout;  
  endgraph;  
end;  
run;
```

O2001  
O2002

\* Add options to control appearance of plots;

5

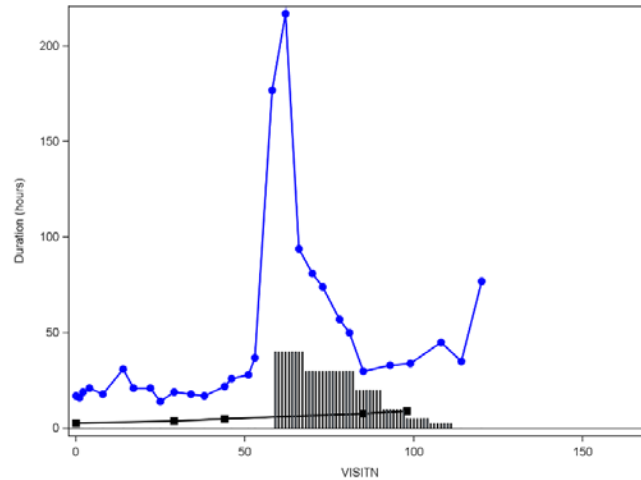


```
proc template;
  define statgraph myplot;
    begingraph;
      layout overlay ;
      seriesplot x=visitn y=cfcdur / lineattrs=(thickness=1 color=black
pattern=1);
      scatterplot x=visitn y=cfcdur / markerattrs=(size=8 color=black
symbol=squarefilled);
    endlayout;
  endgraph;
end;
run;
```

S1001  
S1002  
S1003  
O2001  
O2002

\* Overlaying more plots or bar charts;

6



Multiple Y-axis scales are laying over each other, which needs to be differentiated by defining different Y-axis.

```
proc template;
  define statgraph myplot;
    begingraph;
      layout overlay ;
      seriesplot x=visitn y=cfcdur / lineattrs=(thickness=2.5 color=black
pattern=1);
      scatterplot x=visitn y=cfcdur / markerattrs=(size=8 color=black
symbol=squarefilled);
      barchart x=visitn y=pns / barwidth=0.3;
      seriesplot x=visitn y=alt / lineattrs=(thickness=2.5 color=blue
pattern=1 );
      scatterplot x=visitn y=alt / markerattrs=(size=8 color=blue
symbol=circlefilled transparency = .05);
    endgraph;
end;
```

```
endlayout;
endgraph;
end;
```

O1001  
O1002 x 3  
O1003  
O1005  
O1006  
O2001  
O2004 x 3  
O2005 x 3  
O2102 x 3

\* Pre-defined a set of axis options by using LAYOUT OVERLAY statement: X-axis, Y-axis and Y2-axis; Macro variables can define the maximum or minimum value of each scale.

7

```
%let xvalue=%str(0 4 8 14 22 28 34 38 42 51 58 66 70 78 85 89 98 108 114 120);
```

```
xaxisopts =
(type=linear
offsetmin=0.03 offsetmax=0.01
tickvalueattrs=(size=8pt weight=bold)
linearopts=(viewmin=0 viewmax=120 tickvaluelist=(&xvalue)
tickvaluefitpolicy=rotate)
labelattrs=(size=11 weight=bold)
label='Study Day')
```

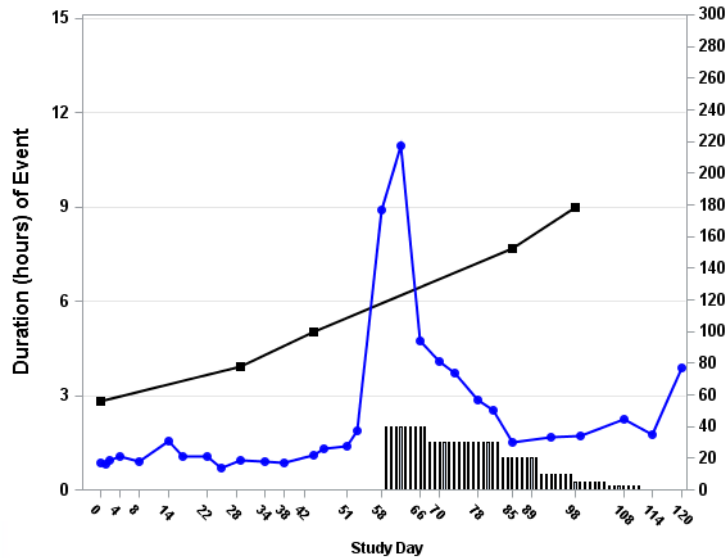
No ";" after each option, as they are for the same statement

```
yaxisopts =
(griddisplay=on offsetmin=0 offsetmax=0.01
tickvalueattrs=(size=10pt weight=bold)
linearopts=(tickvaluesequence=(start=0 end=12 increment=3) viewmin=0 viewmax=12)
labelattrs=(size=12 weight=bold color=black)
label="Duration (hours) of Event" )
```

```
y2axisopts =
(offsetmin=0 offsetmax=0.00
tickvalueattrs=(size=10pt weight=bold)
linearopts=(tickvaluesequence=(start=0 end=&maxy increment=10) viewmin=0
viewmax=&maxy)
labelattrs=(size=0) label=' ');
```

\* Use pre-defined axis options to draw multiple plots with one shared axis;

8



```
proc template;
define statgraph myplot;
begingraph;
layout overlay /
Step 7 {
xaxisopts =..
yaxisopts =..
y2axisopts =..
;

```

```

seriesplot x=visitn y=cfcdur /lineattrs=(thickness=2.5 color=black
pattern=1);
scatterplot x=visitn y=cfcdur /markerattrs=(size=8 color=black
symbol=squarefilled);
barchart x=visitn y=pns / barwidth=0.3 yaxis=y2;
seriesplot x=visitn y=alt / lineattrs=(thickness=2.5 color=blue
pattern=1) yaxis=y2;
scatterplot x=visitn y=alt / markerattrs=(size=8 color=blue
symbol=circlefilled transparency = .05) yaxis=y2;
endlayout;
endgraph;
end;

```

Tip: The order of S1xxx Statement determines which plot presents in front. The first plot that specified in the layout block is drawn first. The second plot is then added on top of the first plot, and so on. It is possible for one plot's data to obscure the data beneath it.

O1002  
O2001

- \* Adjust layers of plots;
- \* Add reference line using series plot;
- \* Adjust height and width;

9

```

proc template;
  define statgraph myplot;
    beginingraph/designwidth=800px designheight=350px;
      layout overlay /
        xaxisopts =..
        yaxisopts =..
        y2axisopts =..
      layer 1 -> barchart x=visitn y=pns/ barwidth=0.3 yaxis=y2 fillattrs=(color=grey);
      layer 2 -> seriesplot x=visitn y=altuln / lineattrs=(color=brown pattern=3
        thickness=2.5) yaxis=y2;
      layer 3 -> seriesplot x=visitn y=alt / lineattrs=(thickness=2.5 color=blue
        pattern=1) yaxis=y2;
        scatterplot x=visitn y=alt / markerattrs=(size=8 color=blue
        symbol=circlefilled transparency = .05) yaxis=y2;
      layer 4 -> seriesplot x=visitn y=cfcdur / lineattrs=(thickness=2.5 color=black
        pattern=1);
        scatterplot x=visitn y=cfcdur / markerattrs=(size=8 color=black
        symbol=squarefilled);

      endlayout;
    endgraph;
  end;

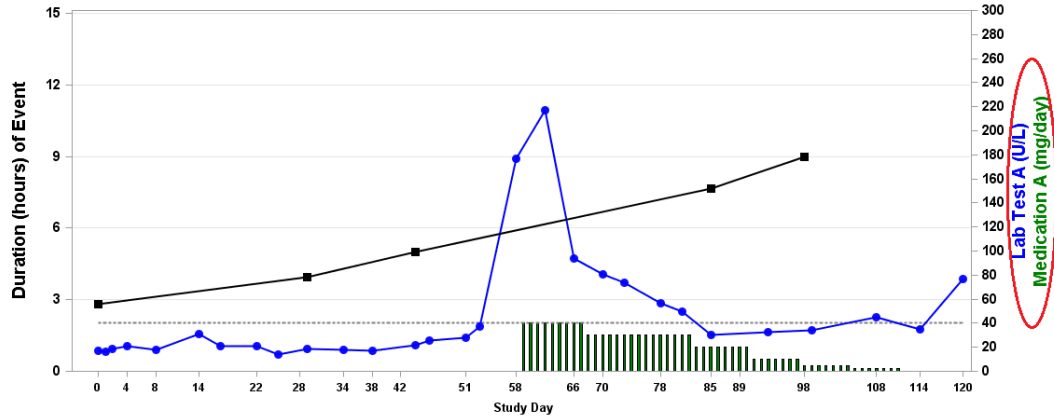
```

S2003 x 2  
O2003 x 2

- \* Add customized Y2-Axis Label using DRAWTEXT in LAYOUT OVERLAY block;

10



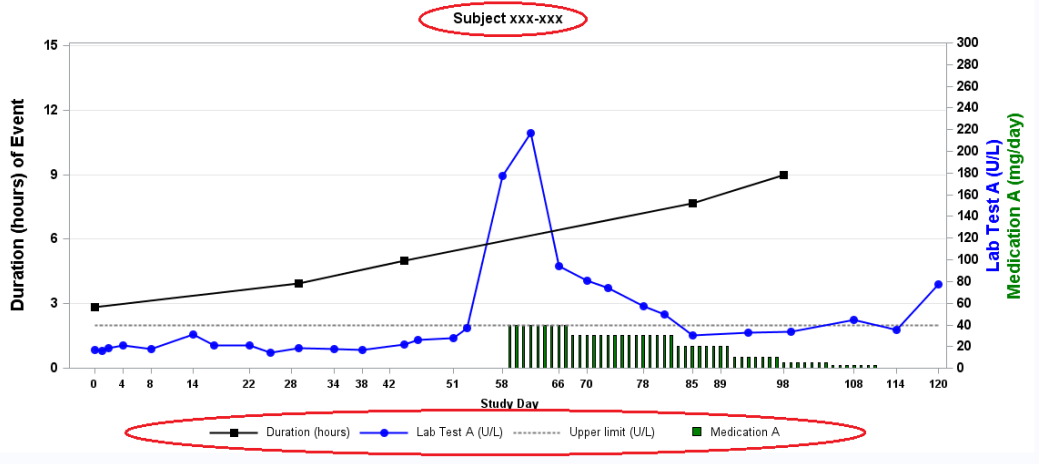


```
proc template;
  define statgraph myplot;
    begingraph/designwidth=800px designheight=350px pad=(right=7%);
      layout overlay /
        xaxisopts =...
        yaxisopts =...
        y2axisopts =...
      ;
      barchart...;
      seriesplot...;
      seriesplot...;
      scatterplot...;
      seriesplot...;
      scatterplot...;
      drawtext textattrs=(size=12 weight=bold color=blue) "Lab Test A (U/L)" /
xspace=graphpercent yspace=wallpercent x=96 y=50 rotate=90 anchor=center
width=50;
      drawtext textattrs=(size=12 weight=bold color=grey) "Medication A (mg/day)"
/ xspace=graphpercent yspace=wallpercent x=98 y=50 rotate=90 anchor=center
width=50;
    endlayout;
  endgraph;
end;
```

Specify space and location of axis label

S2001  
B2021  
O2003  
O3001 x 6

\* Add Title and Global Legend;



```
proc template;
  define statgraph myplot;
    begingraph/designwidth=800px designheight=350px border=false pad=(right=7%);
```

```

entrytitle textattrs=(size=11pt weight=bold) "Subject xxx-xxx";

layout overlay /
  xaxisopts =..
  yaxisopts =..
  y2axisopts =..
  barchart x=visitn y=pns/ barwidth=0.3 yaxis=y2 fillattrs=(color=grey)
name='bar';
  seriesplot x=visitn y=altuln / lineattrs=(color=brown pattern=3
thickness=2.5) yaxis=y2 name='ref';
  seriesplot x=visitn y=alt / lineattrs=(thickness=2.5 color=blue
pattern=1) name='ser2' yaxis=y2;
  scatterplot x=visitn y=alt / markerattrs=(size=8 color=blue
symbol=circlefilled transparency = .05) yaxis=y2 name='scat2';
  seriesplot x=visitn y=cfcdur / lineattrs=(thickness=2.5 color=black
pattern=1) name='ser';
  scatterplot x=visitn y=cfcdur / markerattrs=(size=8 color=black
symbol=squarefilled) name='scat';

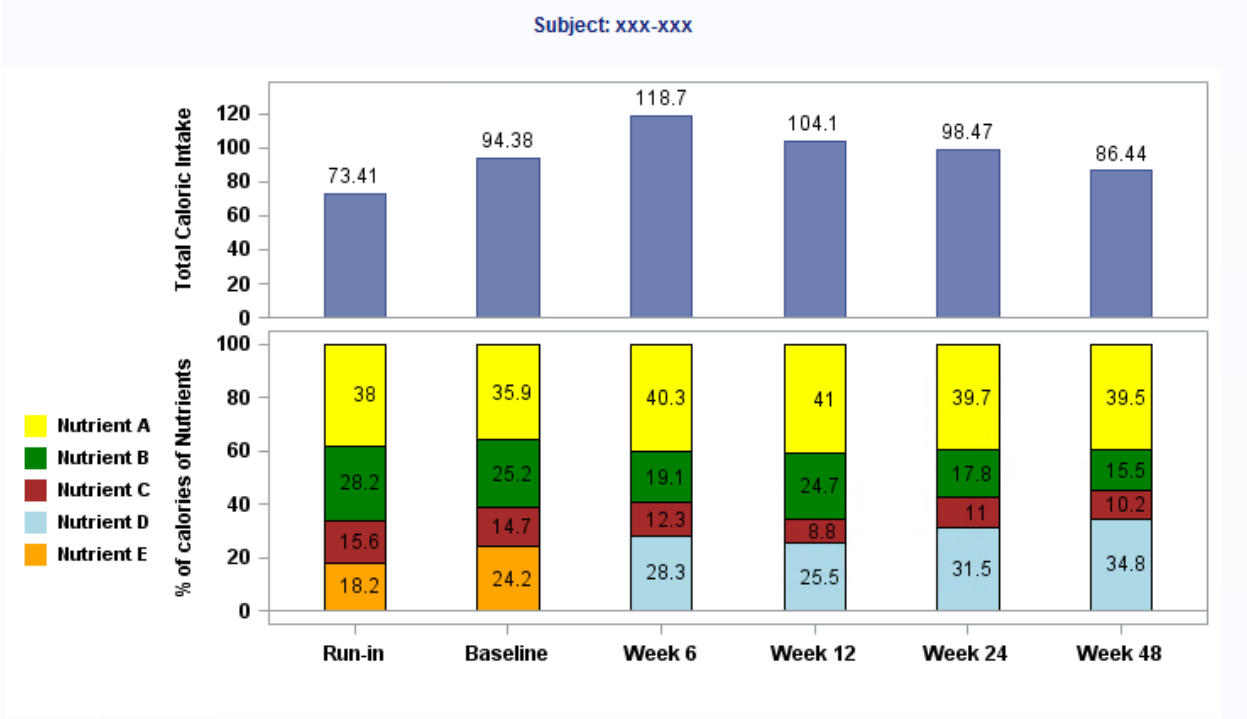
  drawtext textattrs=(size=12 weight=bold color=blue) "Lab Test A (U/L)" /
xspace=graphpercent yspace=wallpercent x=96 y=50 rotate=90 anchor=center
width=50;
  drawtext textattrs=(size=12 weight=bold color=grey) "Medication A
(mg/day)" / xspace=graphpercent yspace=wallpercent x=96 y=50 rotate=90
anchor=center width=50;
  endlayout;

layout globallegend /
  type=row border=false;
  mergedlegend 'ser' 'scat' / border=false;
  mergedlegend 'ser2' 'scat2' / border=false;
  discretelegend 'ref' / border=false;
  discretelegend 'bar' / border=false ;
  endlayout;
endgraph;
end;

```

Parallel to LAYOUT OVERLAY

**Project II: Multi-cell graph with data grouping, customized by Attribute Maps (Figure 2)**



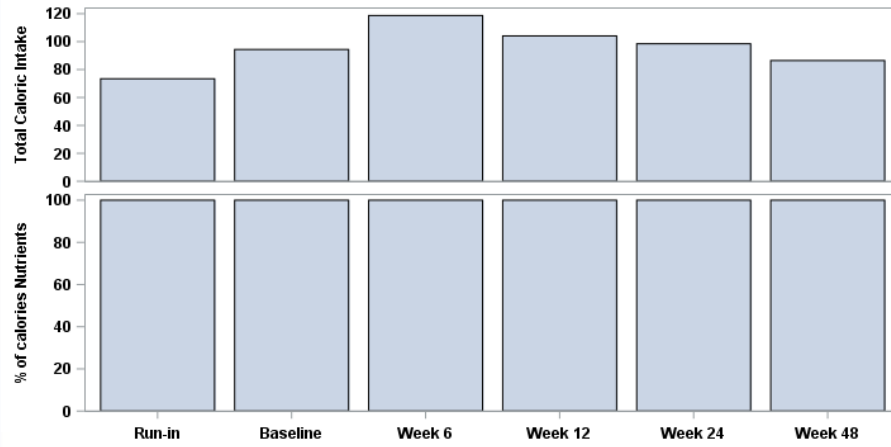
**Figure 2 - Diet Diary Average Values Over Time: Pre- and Post-Baseline Period**

Parts	Building Instruction & Result
<p>B1001 B1002 B1003</p>	<p>This graph is multi-cell. The top one presents the overall result value while the bottom one is the percentage for each component for the corresponding Total Caloric Intake as above. Two graphs share one x-axis with different y-axis.</p> <p><b>* To create template Mybarchart;</b></p> <pre>proc template;   define statgraph mybarchart;   begingraph;     endgraph;   end; run;</pre> <p>NOTE: STATGRAPH 'Mybarchart' has been saved to: WORK.TEMPLAT</p> <div style="text-align: right; background-color: #92d050; color: white; padding: 5px; width: 30px; margin-left: auto;">1</div>
<p>B2001 X 2 B2002 S1003 X 2 B1099</p>	<p><b>* To create two-cell graph using LAYOUT LATTICE without additional options;</b></p> <div style="text-align: right; background-color: #92d050; color: white; padding: 5px; width: 30px; margin-left: auto;">2</div> <div style="text-align: center; margin: 10px 0;"> </div> <pre>proc template;   define statgraph mybarchart;   begingraph;     layout lattice / columns=1 rows=2 rowweights=(0.4 0.6);   row1 {     layout overlay ;       barchart x=avisitn y=totci;     endlayout;   row2 {     layout overlay ;       barchart x=avisitn y=aval;     endlayout;     endlayout;   endgraph;   end; run; proc sgrender data=final template=mybarchart; run; quit;</pre> <div style="border: 1px solid blue; background-color: #d9e1f2; padding: 5px; width: fit-content; margin-left: auto; margin-top: 10px;">     Define proportion size of each cell   </div>

O1003 x 2  
 O1005 x 2  
 O2004 x 2  
 O2005 x 3  
 O2101

\* Combine two x-axis and only show at bottom;

3



```
proc template;
  define statgraph mybarchart;
    begingraph;
      layout lattice / columns=1 rows=2 rowweights=(0.4 0.6);

      layout overlay /
        xaxisopts=(label=" " display=none)
        yaxisopts=(label="Total Caloric Intake" labelattrs=(size=9pt
weight=bold) tickvalueattrs=(size=9pt weight=bold))
        ;
      barchart x=avisitn y=totci;
      endlayout;

      layout overlay /
        xaxisopts=(label=" " tickvalueattrs=(size=9pt weight=bold)
discreteopts=(tickvaluelist=&xticklst))
        yaxisopts=(label="% of calories Nutrients" labelattrs=(size=9pt
weight=bold) tickvalueattrs=(size=9pt weight=bold))
        ;
      barchart x=avisitn y=aval;
      endlayout;
    endlayout;
  endgraph;
end;
run;
```

Remove X-axis label & tick for Row1 graph

Tip: Step 4 pre-defined a set of variable attributes. DISCRETEATTRMAP block is a direct child of BEGINGRAPH statement. This method can dynamically assign colors to plots.

B2031 x 2  
 S2004 x 2  
 S2005 x 5  
 O2001 x 6  
 O2002 x 5  
 O2007 x 6

```
%macro attmap;
  discreteattrmap name="symbols" / ignorecase=true ;
  value '5' /fillattrs=(color=yellow) lineattrs=(color=black) ;
  value '4' /fillattrs=(color=green) lineattrs=(color=black) ;
  value '3' /fillattrs=(color=brown) lineattrs=(color=black) ;
  value '2' /fillattrs=(color=lightblue) lineattrs=(color=black) ;
  value '1' /fillattrs=(color=orange) lineattrs=(color=black) ;
  enddiscreteattrmap ;
  discreteattrvar attrvar=groupmarkers var=paramn attrmap="symbols" ;

  discreteattrmap name="symbols2" / ignorecase=true ;
  value '0' /fillattrs=(color=purple) lineattrs=(color=black) ;
  enddiscreteattrmap ;
  discreteattrvar attrvar=groupmarkers2 var=paramn attrmap="symbols2" ;
%endmacro;
```

4

```

legenditem type=marker name="N_A" /markerattrs=(color=yellow
symbol=squarefilled size=11pt) label="Nutrient A" ;
legenditem type=marker name="N_B" /markerattrs=(color=green
symbol=squarefilled size=11pt) label="Nutrient B" ;
legenditem type=marker name="N_C" /markerattrs=(color=brown
symbol=squarefilled size=11pt) label="Nutrient C" ;
legenditem type=marker name="N_D" /markerattrs=(color=lightblue
symbol=squarefilled size=11pt) label="Nutrient D" ;
legenditem type=marker name="N_D" /markerattrs=(color=orange
symbol=squarefilled size=11pt) label="Nutrient E" ;

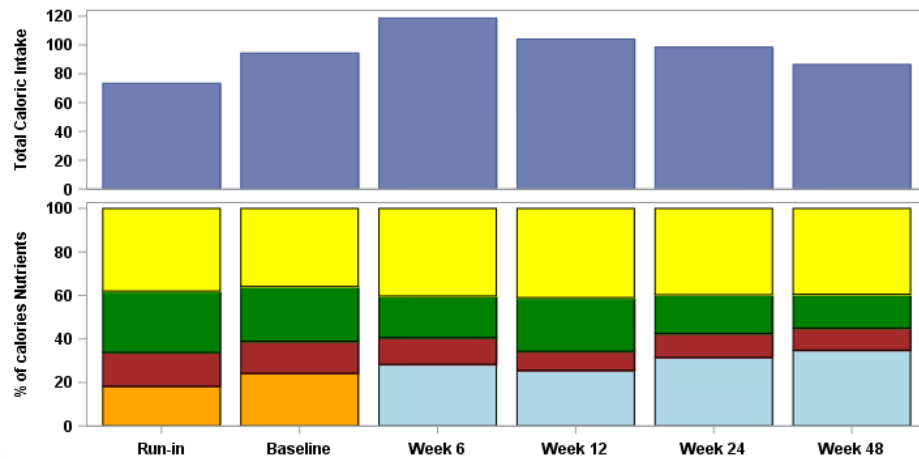
%mend;

```

O1101 X 2  
O1102 X 2

\* Color block bar chart by using defined attribute map  
(Macro %attmp);

5



```

proc template;
  define statgraph mybarchart;
begingraph;
  %attmap;
  layout lattice / columns=1 rows=2 rowweights=(0.4 0.6);
  layout overlay /
  xaxisopts=(label=" " display=none)
  yaxisopts=(label="Total Caloric Intake" labelattrs=(size=9pt weight=bold)
tickvalueattrs=(size=9pt weight=bold))
  ;
  barchart x=avisitn y=totci / group=groupmarkers2 groupdisplay=stack;
  endlayout;

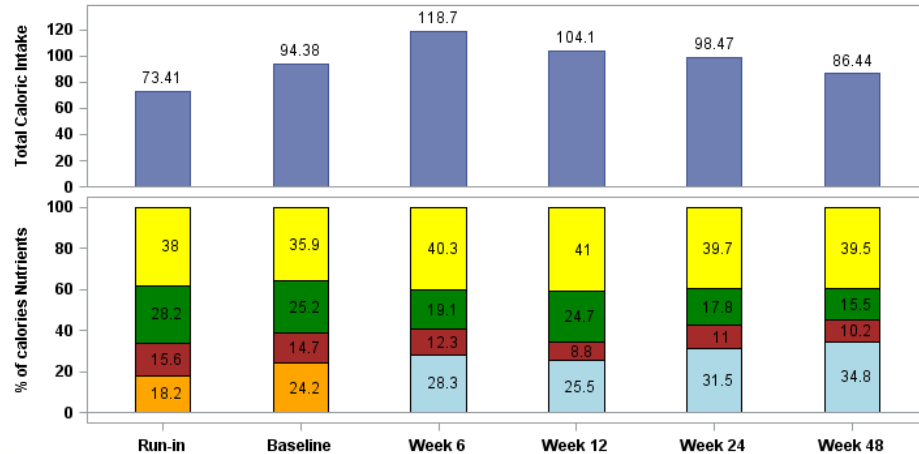
  layout overlay /
  xaxisopts=(label=" " tickvalueattrs=(size=9pt weight=bold)
discreteopts=(tickvaluelist=(&xticklst)))
  yaxisopts=(label="% of calories of Nutrients" labelattrs=(size=9pt
weight=bold) tickvalueattrs=(size=9pt weight=bold))
  ;
  barchart x=avisitn y=aval / group=groupmarkers groupdisplay=stack;
  endlayout;
  endlayout;
endgraph;
end;
run;

```

S1002  
O2008  
O1101  
O1102

\* Adjust appearance of the charts, e.g. width of bar;  
\* Add statistical results using MARKERCHARACTER;

6



```

proc template;
  define statgraph mybarchart;
    begingraph;
      %attmap;

      layout lattice / columns=1 rows=2 rowweights=(0.4 0.6);
      layout overlay /
        xaxisopts=(label=" " display=none)
        yaxisopts=(label="Total Caloric Intake" labelattrs=(size=9pt weight=bold)
        tickvalueattrs=(size=9pt weight=bold))
      ;
      barchart x=avisitn y=totci / group=groupmarkers2 groupdisplay=stack
      barlabelattrs=(size=9pt) barwidth=0.4 barlabel=true;
      endlayout;

      layout overlay /
        xaxisopts=(label=" " tickvalueattrs=(size=9pt weight=bold)
        discreteopts=(tickvaluelist=&xticklst))
        yaxisopts=(label="% of calories of Nutrients" labelattrs=(size=9pt
        weight=bold) tickvalueattrs=(size=9pt weight=bold))
      ;
      barchart x=avisitn y=aval / group=groupmarkers groupdisplay=stack
      barwidth=0.4;
      scatterplot x=avisitn y=accupct /group=groupmarkers index=paramn
      groupdisplay=overlay markercharacter=aval markercharacterposition=center
      markercharacterattrs=(color=black size=9pt);
      endlayout;
    endlayout;
  endgraph;
end;
run;

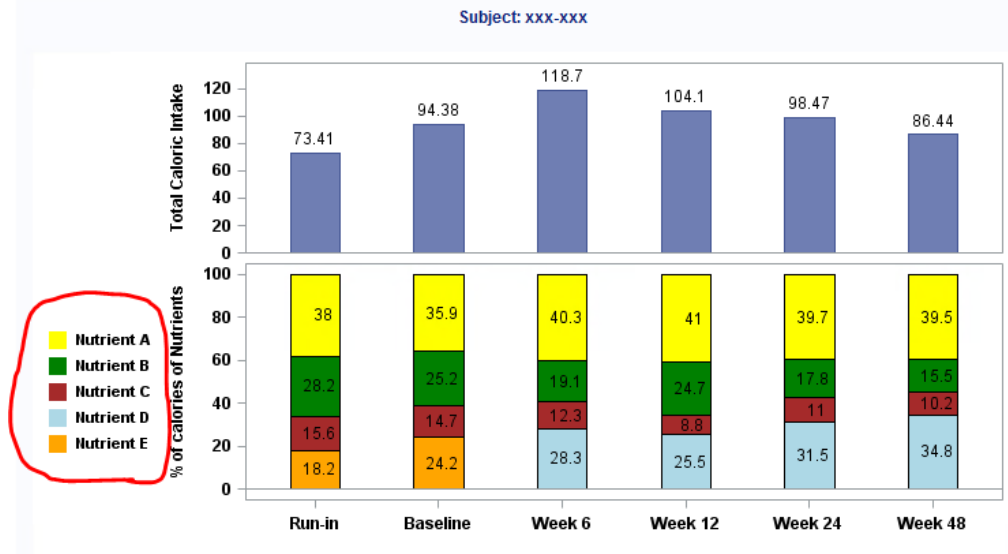
```

Use bar label to add statistical numbers above the bar

Use scatter plot to add statistical numbers within the bar

S2006  
O2009

\* Add legend and title; The display order for the color is defined in DISCRETELEGEND inside LAYOUT OVERLAY block.



```

proc template;
  define statgraph mybarchart;
begingraph;
  %attmap;
  layout lattice / columns=1 rows=2 rowweights=(0.4 0.6);
  layout overlay /
  xaxisopts=(label=" " display=none)
  yaxisopts=(label="Total Caloric Intake" labelattrs=(size=9pt weight=bold)
  tickvalueattrs=(size=9pt weight=bold))
  ;
  barchart x=avisitn y=totci / group=groupmarkers2 groupdisplay=stack
  barlabel=true barlabelattrs=(size=9pt) barwidth=0.4;
  endlayout;

  layout overlay /
  xaxisopts=(label=" " tickvalueattrs=(size=9pt weight=bold)
  discreteopts=(tickvaluelist=(&xticklst)))
  yaxisopts=(label="% of calories of Nutrients" labelattrs=(size=9pt
  weight=bold) tickvalueattrs=(size=9pt weight=bold))
  ;
  barchart x=avisitn y=aval / group=groupmarkers groupdisplay=stack
  barwidth=0.4;
  scatterplot x=avisitn y=accupct /group=groupmarkers index=paramn
  groupdisplay=overlay markercharacter=aval markercharacterposition=center
  markercharacterattrs=(color=black size=9pt);

  discretelegend "N_A" "N_B" "N_C" "N_D" "N_E" / border=false
  location=outside halign=left across=1 valueattrs=(size=10pt weight=bold)
  title="";

  endlayout;
endlayout;
endgraph;
end;
run;

```

### Project III: Structure a Complex dataset to facilitate multiple features on one data point (Figure 3)

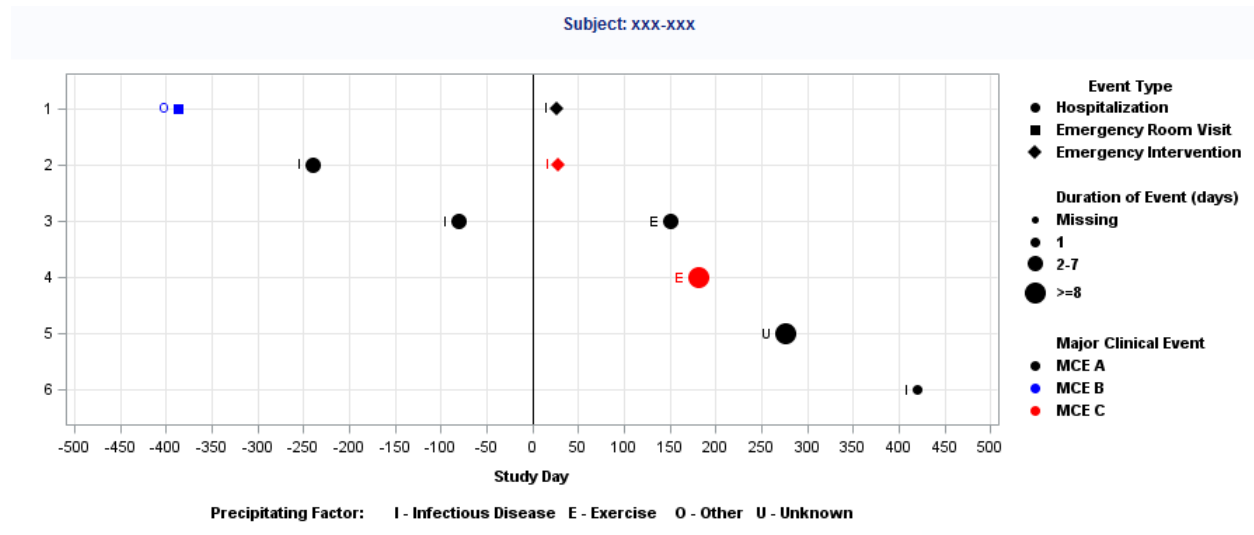


Figure 3 - Distribution of Major Clinical Events

Analysis Data:

patid	Major Clinical Event	Event Type	Precipitating Event	Study Day	Duration	Duration Category	id	Data Collection Period
xxx-xxx	MCE A	Emergency Intervention	I	26	1	2	-1	POST-TREATMENT
xxx-xxx	MCE C	Emergency Intervention	I	28	10	4	-2	POST-TREATMENT
xxx-xxx	MCE A	Hospitalization	E	151	3	3	-3	POST-TREATMENT
xxx-xxx	MCE C	Hospitalization	E	181	10	4	-4	POST-TREATMENT
xxx-xxx	MCE A	Hospitalization	U	276	10	4	-5	POST-TREATMENT
xxx-xxx	MCE A	Hospitalization	I	420	1	2	-6	POST-TREATMENT
xxx-xxx	MCE B	Emergency Room Visit	O	-387	6	3	-1	PRE-TREATMENT
xxx-xxx	MCE A	Hospitalization	I	-239	3	3	-2	PRE-TREATMENT
xxx-xxx	MCE A	Hospitalization	I	-80	2	3	-3	PRE-TREATMENT

\* Use different x-variables to present event type to be defined with different feature in graph;

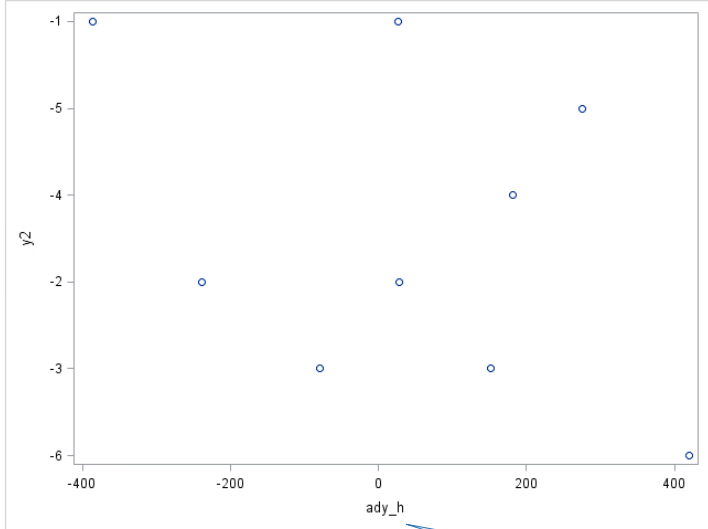
\* Use different y-variables to present duration group to be defined with different feature in graph;

```
data final;
  set dsin;
  if evtype='Hospitalization' then ady_h=ady;
  else if evtype='Emergency Room Visit' then ady_r=ady;
  else if evtype='Emergency Intervention' then ady_i=ady;
  if evtype='Hospitalization' then do;
    if durgrp=1 then y1=id;
    else if durgrp=2 then y2=id;
    else if durgrp=3 then y3=id;
    else if durgrp=4 then y4=id;
  end;
  else y=id;
run;
```



Data ready-for-graph:

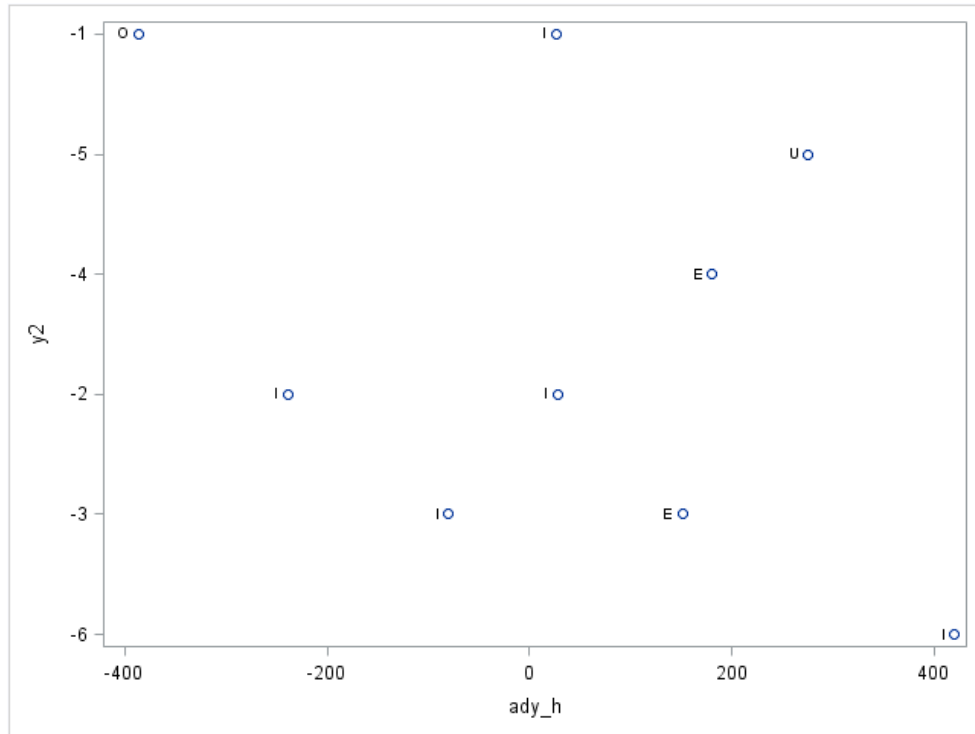
patid	Major Clinical Event	Event Type	Precipitatin Event	Study Day	Duration Category	id	Data Collection Period	ady_h	ady_r	ady_i	y1	y2	y3	y4	y
xxx-xxx	MCE A	Emergency Intervention	I	26	2	-1	POST-TREATMENT	.	.	26					-1
xxx-xxx	MCE C	Emergency Intervention	I	28	4	-2	POST-TREATMENT	.	.	28					-2
xxx-xxx	MCE A	Hospitalization	E	151	3	-3	POST-TREATMENT	151	.	.				-3	
xxx-xxx	MCE C	Hospitalization	E	181	4	-4	POST-TREATMENT	181	.	.				-4	
xxx-xxx	MCE A	Hospitalization	U	276	4	-5	POST-TREATMENT	276	.	.				-5	
xxx-xxx	MCE A	Hospitalization	I	420	2	-6	POST-TREATMENT	420	.	.		-6			
xxx-xxx	MCE B	Emergency Room Visit	O	-387	3	-1	PRE-TREATMENT	.	-387	.					-1
xxx-xxx	MCE A	Hospitalization	I	-239	3	-2	PRE-TREATMENT	-239	.	.				-2	
xxx-xxx	MCE A	Hospitalization	I	-80	3	-3	PRE-TREATMENT	-80	.	.				-3	

Parts	Building Instruction & Result
	<p>This graph is to structure a dataset first in order to draw different shapes, different sizes and different colors per different categories (Event Type, Duration of Event and MCE) on different time slots (Pre/Post-Treatment).</p>
<p>B1001 B1002 B1003 B1099 B2001 S1002 X 6</p>	<p><b>* Use scatter plot to display event;</b></p>  <pre> proc template;   define statgraph mybubble;     begingraph;       layout overlay;         scatterplot x=ady_h y=y1 ;         scatterplot x=ady_h y=y2 ;         scatterplot x=ady_h y=y3 ;         scatterplot x=ady_h y=y4 ;         scatterplot x=ady_i y=y ;         scatterplot x=ady_r y=y ;       endlayout;     endgraph;   end; run;  ods graphics on; proc sgrender data=final template=mybubble; run; ods graphics off; </pre>

O4001 X 6  
O4002 X 6

\* Add Event factor (I, E, U, O) using DATALABEL;

2

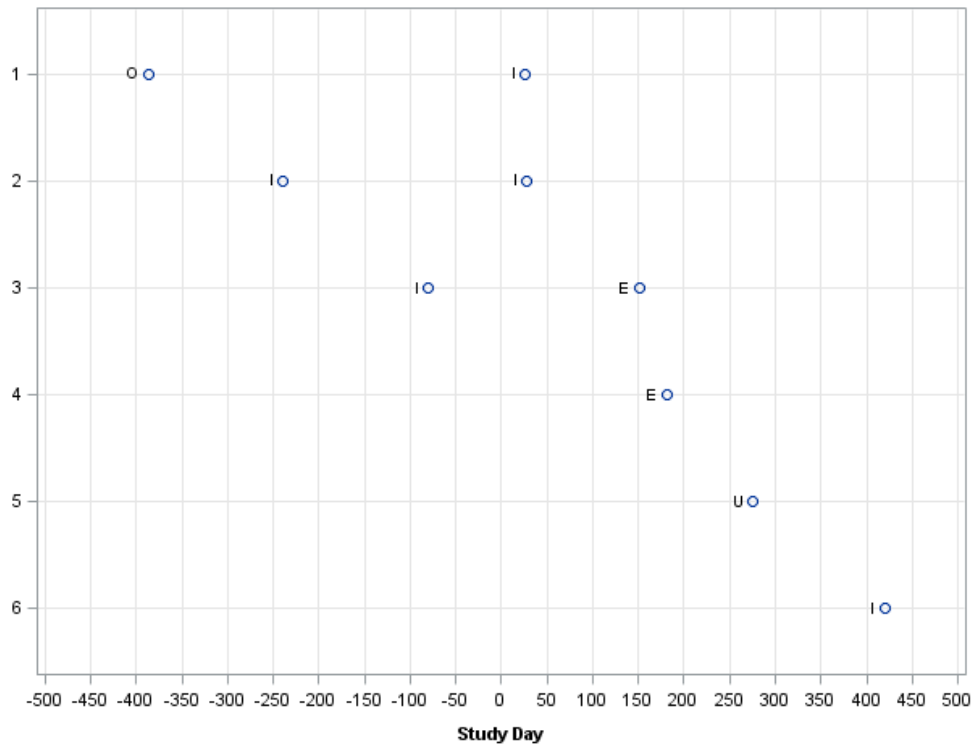


```
proc template;  
  define statgraph mybubble;  
    begingraph;  
      layout overlay;  
        scatterplot x=ady_h y=y1 / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_h y=y2 / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_h y=y3 / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_h y=y4 / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_i y=y / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_r y=y / datalabel=prevt datalabelposition=left ;  
      endlayout;  
    endgraph;  
  end;  
run;
```

O1003  
O1005  
O2004 X 2  
O2005 X 2  
O2101  
O2102

\* To define X- and Y-axis;

3



```
proc template;  
  define statgraph mybubble;  
    begingraph;  
      layout overlay /  
        xaxisopts=(griddisplay=on labelattrs=(size=8 weight=bold) label="Study  
Day" linearopts=(tickvaluelist=(&xlabel) viewmin=-500 viewmax=500)  
offsetmin=0.01 offsetmax=0.01 tickvalueattrs=(size=8pt))  
  
        yaxisopts=(griddisplay=on labelattrs=(size=1) label="  
discreteopts=(tickvaluefitpolicy=splitalways tickvaluelist=(&ylabel)  
tickvalueformat=$id.) tickvalueattrs=(size=8) offsetmin=0.1 offsetmax=0.1)  
        ;  
        scatterplot x=ady_h y=y1 / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_h y=y2 / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_h y=y3 / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_h y=y4 / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_i y=y / datalabel=prevt datalabelposition=left ;  
        scatterplot x=ady_r y=y / datalabel=prevt datalabelposition=left ;  
      endlayout ;  
    endgraph ;  
  end ;  
run ;
```

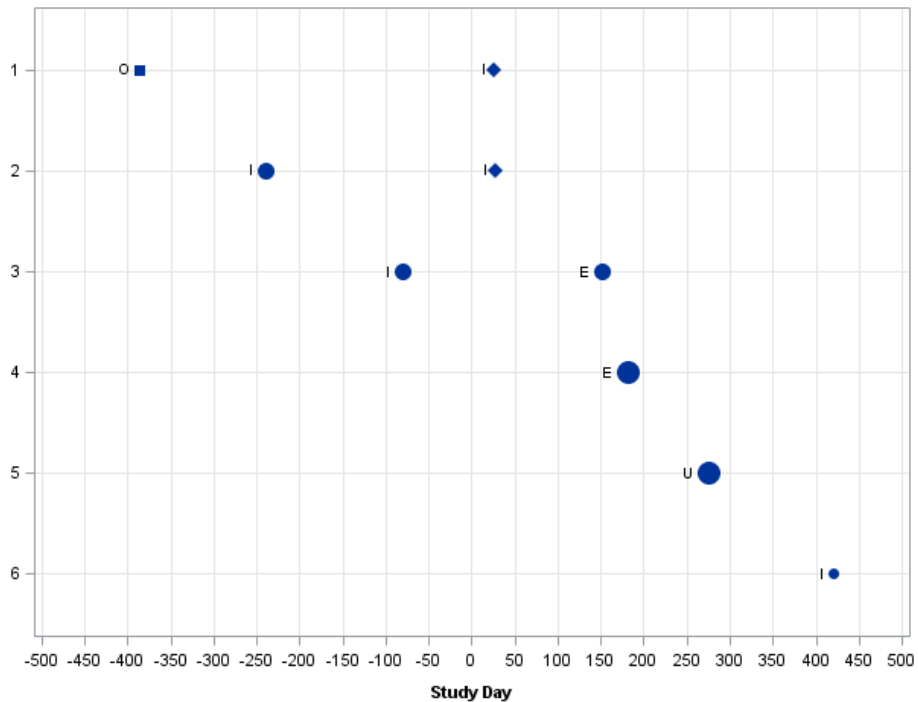
LINEAROPTS: for continuous variable, here for X role

DISCRETEOPTS: for discrete (categorical, ordinal) variable, here for Y role. If a numeric variable is assigned to the Y role, it will be treated as discrete values, never as a continuous range of values

O2002 x 6

\* Add Marker attributes;

4



```
proc template;
  define statgraph mybubble;
    begingraph;
      layout overlay /
        xaxisopts..
        yaxisopts..
      ;
      scatterplot x=ady_h y=y1 / datalabel=prevt datalabelposition=left
        markerattrs=(symbol=circleFilled size=4pt);
      scatterplot x=ady_h y=y2 / datalabel=prevt datalabelposition=left
        markerattrs=(symbol=circleFilled size=6pt);
      scatterplot x=ady_h y=y3 / datalabel=prevt datalabelposition=left
        markerattrs=(symbol=circleFilled size=9pt);
      scatterplot x=ady_h y=y4 / datalabel=prevt datalabelposition=left
        markerattrs=(symbol=circleFilled size=12pt);
      scatterplot x=ady_i y=y / datalabel=prevt datalabelposition=left
        markerattrs=(symbol=diamondFilled size=5.5pt);
      scatterplot x=ady_r y=y / datalabel=prevt datalabelposition=left
        markerattrs=(symbol=squareFilled size=6pt);
    endlayout;
  endgraph;
end;
run;
```

B2031  
S2004  
O1101 x 6  
O2002 x 3

\* Data are displayed by defined attribute map;

5

```
proc template;
  define statgraph mybubble;
    begingraph;
      discreteattrmap name="symbols" / ignorecase=true ;
      value "MCE A" /markerattrs=(color=black) ;
      value "MCE B" /markerattrs=(color=blue) ;
      value "MCE C" /markerattrs=(color=red) ;
    end;
  endgraph;
end;
```

```

enddiscreteattrmap ;

discreteattrvar attrvar=groupmarkers var=facat attrmap="symbols" ;
layout overlay /
  xaxisopts..
  yaxisopts..
;
scatterplot x=ady_h y=y1 / datalabel=prevt datalabelposition=left
markerattrs=(symbol=circleFilled size=4pt) group=groupmarkers;
scatterplot x=ady_h y=y2 / datalabel=prevt datalabelposition=left
markerattrs=(symbol=circlefilled size=6pt) group=groupmarkers;
scatterplot x=ady_h y=y3 / datalabel=prevt datalabelposition=left
markerattrs=(symbol=circleFilled size=9pt) group=groupmarkers;
scatterplot x=ady_h y=y4 / datalabel=prevt datalabelposition=left
markerattrs=(symbol=circleFilled size=12pt) group=groupmarkers;
scatterplot x=ady_i y=y / datalabel=prevt datalabelposition=left
markerattrs=(symbol=diamondfilled size=5.5pt) group=groupmarkers;
scatterplot x=ady_r y=y / datalabel=prevt datalabelposition=left
markerattrs=(symbol=squarefilled size=6pt) group=groupmarkers;
endlayout;
endgraph;
end;
run;

```

Tip: Step 5 the DISCRETEATTRVAR statement associates the attribute map with input data column 'Major Clinical Event' and assigns the name GROUPMARKERS to the named association.

S2005  
O2002 x 14  
O2003 x 4

**\* Create legend entries for the markers;**

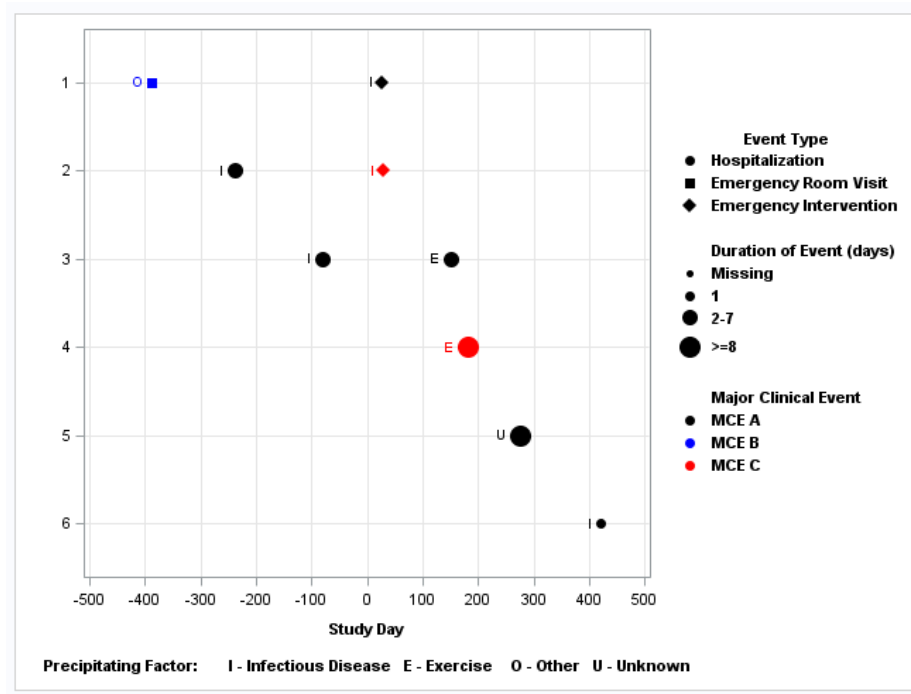
6

```

legenditem type=marker name='hosp' /markerattrs=(symbol=circlefilled
color=black size=6pt) label='Hospitalization';
legenditem type=marker name='erv' /markerattrs=(symbol=squarefilled
color=black size=6pt) label='Emergency Room Visit';
legenditem type=marker name='ei' /markerattrs=(symbol=diamondfilled
color=black size=5.5pt) label='Emergency Intervention';
legenditem type=marker name='blank1' /markerattrs=(color=white size=8pt)
label=" ";
legenditem type=marker name='t1' /markerattrs=(color=white size=8pt)
label=" Duration of Event (days)";
legenditem type=marker name='d1' /markerattrs=(symbol=circlefilled
color=black size=4pt) label='Missing';
legenditem type=marker name='d2' /markerattrs=(symbol=circlefilled
color=black size=6pt) label='1';
legenditem type=marker name='d3' /markerattrs=(symbol=circlefilled
color=black size=9pt) label='2-7';
legenditem type=marker name='d4' /markerattrs=(symbol=circlefilled
color=black size=12pt) label='>=8';
legenditem type=marker name='blank2' /markerattrs=(color=white size=8pt)
label=" ";
legenditem type=marker name='t2' /markerattrs=(color=white size=8pt)
label=" Major Clinical Event";
legenditem type=marker name='mcea' /markerattrs=(symbol=circlefilled
color=black size=6pt) label='MCE A';
legenditem type=marker name='mceb' /markerattrs=(symbol=circlefilled
color=blue size=6pt) label='MCE B';
legenditem type=marker name='mcec' /markerattrs=(symbol=circlefilled
color=red size=6pt) label='MCE C';
legenditem type=text name='I' /textattrs=(family="Arial" color=black
size=8pt weight=bold) text='I - Infectious Disease ';
legenditem type=text name='E' /textattrs=(family="Arial" color=black
size=8pt weight=bold) text='E - Exercise ';
legenditem type=text name='O' /textattrs=(family="Arial" color=black
size=8pt weight=bold) text='O - Other ';
legenditem type=text name='U' /textattrs=(family="Arial" color=black
size=8pt weight=bold) text='U - Unknown';

```

\* Add legend on the right and the bottom;



```
proc template;
  define statgraph mybubble;
    begingraph;
      discreteattrmap..
      enddiscreteattrmap ;
      discreteattrvar..;

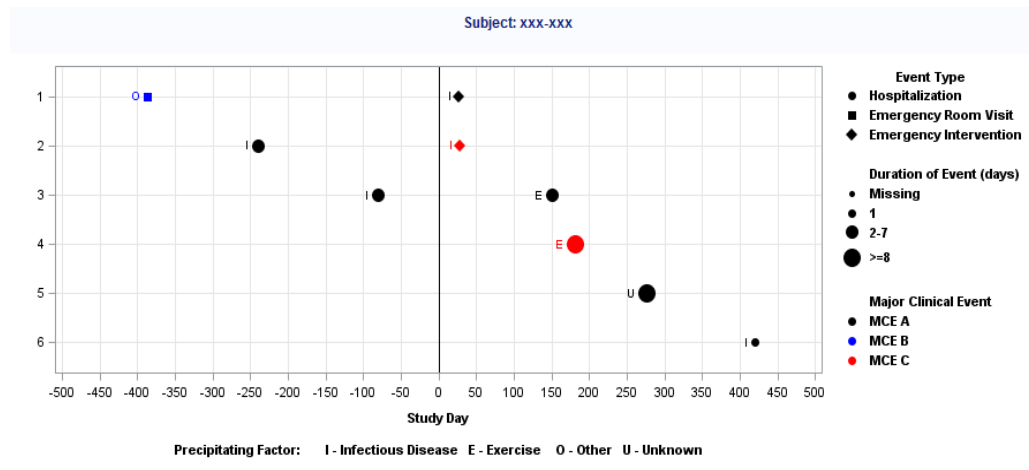
      legenditem..;
      layout overlay /
        xaxisopts..
        yaxisopts..
      ;
      scatterplot..;
      discretelegend 'hosp' 'erv' 'ei' 'blank1' 't1' 'd1' 'd2' 'd3' 'd4'
        'blank2' 't2' 'mcea' 'mceb' 'mcec' / title="Event Type" titleattrs=(size=8
        weight=bold) across=1 border=false location=outside halign=right
        displayclipped=true valueattrs=(size=8 weight=bold);
      discretelegend 'I' 'E' 'O' 'U' / title="Precipitating Factor: "
        titleattrs=(size=8 weight=bold) down=2 border=false location=outside
        valign=bottom displayclipped=true;
      endlayout;
    endgraph;
  end;
run;
ods graphics on / maxlegendarea=30;
```

Specifies the maximum percentage of the overall graph area that a legend can occupy. The default is 20. Larger legends are dropped from the display.

```
proc sgrender data=final template=mybubble;
run;
ods graphics off;
```

S1020  
O2001

- \* Add reference line;
- \* Add title;
- \* Adjust height/width ratio



```
proc template;
  define statgraph mybubble;
    begingraph/designwidth=900px designheight=340px borderattrs=(thickness=0px);
      discreteattrmap..
      enddiscreteattrmap ;
      discreteattrvar..;
      legenditem..;

      layout overlay /
        xaxisopts..
        yaxisopts..
        ;
      scatterplot..;
      discretelegend...;
      discretelegend...;
      referenceline x=0 /lineattrs=(color=black pattern=1 thickness=0.5);
      endlayout;

    endgraph;
  end;
run;

ods graphics on / maxlegendarea=30;
proc sgrender data=final template=mybubble;
run;
ods graphics off;
```

## CONCLUSION

This paper demonstrates how to generate Patient Profile graphs by using SAS GTL. The key is to identify which procedures are the blocks, knob & tube or tiles and what the relationships between them such as, which information present first, which line is on the top and which features need to be customized-defined. Once we get familiar with the parts and structures and also develop a blueprint, using tool of GTL can be as fun as playing LEGO games. We only illustrated the steps we think to be easy-following. But there are different ways to plug-in or broken-down. The final outputs can be more creative.

## REFERENCES

SAS Institute Inc. 2016. SAS® 9.4 Graph Template Language: User's Guide, Fifth Edition. Cary, NC: SAS Institute Inc.

Matange, Sanjay. 2013. "Patient Profile Graphs Using SAS®". Cary, NC: SAS Institute Inc.

Available at <http://support.sas.com/resources/papers/proceedings13/160-2013.pdf>

O'Connor, Daniel, Matange, Sanjay. 2010. "Create Comprehensive Patient Profiles with SAS®". Cary, NC: SAS Institute Inc.

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Peterson, Terek, Ramalingam, Sanjiv. 2010. "Operational Uses of Patient Profiles ... Even in an eCTD and SDTM World". Octagon Research Solutions.

Available at <https://www.lexjansen.com/pharmasug/2010/AD/AD21.pdf>

## RECOMMENDED READING

- *Graph Template Language Tip Sheet*.
- Matange, Sanjay. 2013. *Getting Started with the Graph Template Language in SAS*. Cary, NC: SAS Institute Inc. (SAS Press, 2013).

## DISCLAIMER

The scope of this paper is to present the opinions and suggestions from the authors. It does not reflect recommendations or practices of Ultragenyx Pharmaceutical, Inc. The data used in this paper is simulation data.

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