Visually Exploring Odds Ratios among Risk Factors for Fetal and Infant Mortality in Kent County, MI

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ABSTRACT

Infant mortality is considered to be an important measure of the health and well-being of a nation, state, county, or municipality. The Kent County Fetal Infant Mortality Review (FIMR) program examines the case histories of all the deaths of infants one year of age or less whose mothers are residents of Kent County, Michigan. Each de-identified infant mortality case is reviewed by the FIMR Case Review Team (CRT) to see if any of more than 175 risk factors are present, and if they contributed to the infant's death. Each risk factor is grouped under a larger category such as family planning, medical issues, substance use, social support, or mental health. Understanding the associations between these categories of risk factors, including which are most likely to occur simultaneously, is an important part of developing resources to support mothers in these situations and reduce infant mortality. To explore these relationships, we calculated the odds ratios between each risk factor category pair using a custom %OR macro, then utilized a custom %CHART macro to create a modified radar chart in the GRADAR procedure. These unique visualizations let us intuitively understand the existence and strength of relationships between each category of risk factors. To understand and utilize the methods discussed, you should have at least a basic understanding of SAS® macros, and some knowledge of statistical methodology.

INTRODUCTION

Infant mortality is considered to be an important measure of the health and well-being of a population. It is important to examine infant mortality so that we may see emerging trends and act on them; if infant mortality is truly an indicator of the health of the community then if infant mortality rates are going down, we have evidence that the community's health is improving. If these rates are going up then we need to figure out why and focus on additional methods and strategies to decrease these numbers.

In Michigan, we currently give a live birth certificate to any infant that shows signs of life, regardless of gestational age or birth weight as based on the state's definition of a live birth. The Kent County Fetal Infant Mortality Review (FIMR) program reviews all the deaths of infants one year of age or less whose mothers are residents of Kent County, Michigan. Kent County is the only FIMR program in the state that reviews all of its infant deaths. This is done so that the data may be analyzed to look at possible causes of disparities in infant mortality among the various racial groups and ethnicities.

The FIMR Case Review Team (CRT) meets monthly to review de-identified case summaries of all infant deaths. One aspect of the review is to ascertain whether or not some 175 issues are either "present", "contributory", or "unknown" relative to the infant's death. Many of these issues, such as prematurity and exposure to second-hand smoke, are considered to be "risk factors" for an adverse pregnancy outcome such as an infant death. In identifying the presence of these issues and examining the relationships among them, we hope to identify both gaps in services and opportunities to demonstrate the need for improvements in care, which would lead thereby to reducing the infant mortality rate.

The issues the CRT considers may be broken down into 18 different categories:

- Culture – Includes issues surrounding cultural beliefs regarding pregnancy and health, as well as language barriers.

- Environment – Examines the place where the mother and infant live, where the infant sleeps, and how the infant is fed. This includes issues such as second-hand smoke and overcrowding.

- Family Planning – Considers the mother's use of birth control prior to the pregnancy and whether or not the pregnancy was intended.

- Family Transition – Summarizes the stability of the living situation of the mother and infant before, during, and after the pregnancy. Example issues include homelessness and divorce/separation.

- Family Violence/Neglect – Records any abuse and/or neglect of the mother, father, other children, and the infant under review. This category also includes any Child Protective Services referrals or police reports.

- Injuries – Includes all injuries to the infant such as Shaken Baby Syndrome and poisoning/toxicity.

- Medical (Fetal/Infant) – Includes issues pertaining to the health of the infant from the time of birth until death, including non-viable fetus (22 weeks of gestation or less) and congenital anomaly.

- Medical (Mother) – Includes issues pertaining to the health of the mother before and during the pregnancy, such as insufficient/excess weight gain and sexually transmitted infection (STI).

- Mental Health/Stress – Examines the mother's mental health and the presence of any issues that can cause significant stress, such as concerns about money or citizenship.

- Payment for Care – Records the type of insurance that the mother has or how she pays for her healthcare.

- Pediatric Care – Examines the care the infant received after they were discharged from the hospital following birth. Example issues include missed immunizations and missed pediatric appointments.

- Preconception/Interconception Care – Examines the care the mother received prior to the pregnancy and includes dental/oral care and weight management. Added in 2013, this is the newest category of issues and has therefore accumulated very little data so far.

- Prenatal Care/Delivery – Examines the care the mother received during her pregnancy as well as the care she received during the delivery of the infant. Example issues include late entry to prenatal care and inappropriate use of the emergency department (ED).

- Services Provided – Includes issues relating to the services that the mother received during and after her pregnancy. Example issues include poor provider communication and client dissatisfaction.

- Social Support – Considers the level of social support that the mother received during and after her pregnancy, as well as the mother's education and any disabilities she might have.

- Substance Use – Summarizes issues related to the use or abuse of tobacco, alcohol, over the counter (OTC) drugs, prescription medications, and street drugs from pre to post pregnancy.

- Transportation – Summarizes issues that may affect the mother's ability to access health care or other needed services.

- Documentation – This category serves as a record for the CRT on any issues with the documentation surrounding the infant's death, such as inconsistent information and missing data.

Visualizing relationships among these categories of issues as identified by the CRT for each infant death will be the focus of this paper. Due to the lack of meaningful data in Preconception/Interconception Care, Payment for Care, and Documentation, we will exclude them from this analysis and focus on the remaining 15 categories.

THE DATA

There have been 1,027 FIMR cases reviewed in Kent County between the years of 2001 and 2016. All the infant deaths received a live birth certificate and a subsequent death certificate. The FIMR database contains a separate record for each de-identified infant who died and includes demographic information on the mother, father, and infant, as well as information on the identified issues.

As mentioned above, one of the duties of the FIMR CRT at their monthly meeting is to determine how or if each issue factored into an infant's death. They mark an issue with a "P" if it was present in the case and with a "C" if it was present and contributory to the infant's death. In several cases, a "U" was entered if it

was unknown if the issue was present or contributory to the death of the infant from information given in the case summary, but circumstances led the review team to suspect that the factor would have been either present or contributory if the data had been complete. The occurrence of an unknown issue is rare. Present, contributory, and unknown issues are combined for the purpose of our analysis.

To create the data used in the following visualizations we invent a numeric variable to represent each category of issues. If any issue under the category was marked as present, contributory, or unknown, the category variable was set to 1, otherwise it was set to 0. Display 1 below shows a sample of the INPUT data set with these 15 numeric category variables:

Case_ID__	culture_issues	environment_issues	famplan_issues	transitions_issues	violence_issues	injuries_issues	fetalmed_issues	mother_issues	mentalhealth_issues	pediatric_issues	prenatal_issues	service_issues	social_issues	substance_issues	transport_issues
4101022-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4101054-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4102033-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4103044-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4103068-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4105055-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4106030-1	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0
4107002-1	1	0	1	0	0	0	1	1	0	0	1	0	0	1	0
4107034-1	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0
4108035-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4109026-1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0

Display 1. INPUT Data Set

ODDS RATIOS AND THE %OR MACRO

According to PubMed Central, "An odds ratio (OR) is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure." (PubMed, 2010) They go on to say that "The odds ratio can also be used to determine whether a particular exposure is a risk factor for a particular outcome, and to compare the magnitude of various risk factors for that outcome." (PubMed, 2010) In this paper we are examining the odds ratio between two issue categories to determine whether the presence of an issue in the first category increases the odds of the presence of an issue in the second category. Odds ratios are calculated from frequency tables using the formula (A*D)/(B*C) where A, B, C, and D are equal to the frequency table cells as shown in Table 1 below:

	Second Category is Not Present	Second Category is Present
First Category is Not Present	A	B
First Category is Present	C	D

Table 1. Odds Ratio Calculation Example Table

An odds ratio greater than 1 signifies that the presence of at least one issue in the first category is associated with higher odds of the presence of at least one issue in the second category. An odds ratio less than 1 signifies that the presence of the first category is associated with lower odds of the presence of the second category, and an odds ratio equal to 1 means the presence of the first category does not affect the odds of the presence of the second category. Using the FREQ procedure in SAS, we generate a table comparing the Injury and Environment issue categories and calculate the odds ratio using the formula discussed above:

	Environment Issues = 0	Environment Issues = 1
Injury Issues = 0	800	18
Injury Issues = 1	119	90

Table 2. Odds Ratio Calculation for the Injury and Environment Issue Categories

(800 x 90) / (119 x 18) = 72,000 / 2,142 = 33.6

We will interpret the odds ratio statistic of 33.6 as follows: FIMR cases where an injury to the infant occurred are more than 33 times as likely to also have had at least one documented issue with the mother and infant's living environment. As so many infant injuries occur in the home environment, including burns from stoves and cigarettes, as well as strangulation from twisted bedding, an odds ratio this high is not too surprising.

We need to repeat this analysis a great many times, and it is efficient if we build a SAS macro to perform the above steps on each issues category. The %OR macro has three inputs: &ISSUE1 is the issue category to be compared, &LABEL is the label for the row of odds ratios within the final data set, and &NAME is the name of final data set. The macro first uses a %DO loop with %IF, %THEN, and %ELSE statements to compare &ISSUE1 to each of the other issue categories. Next, tables comparing each category to the others are generated with PROC FREQ and the OUT= option, where all output is suppressed except the category variables and the count. The data from the OUT= option is then transposed and the odds ratio calculation is performed in a DATA step following the manipulation:

```
%MACRO OR(ISSUE1,LABEL,NAME);
    %DO i = 1 %TO 15;
    %IF &i = 1 %THEN %LET ISSUE2 = CULTURE_ISSUES;
    %ELSE %IF &i = 2 %THEN %LET ISSUE2 = ENVIORNMENT_ISSUES;
    …
    %ELSE %IF &i = 15 %THEN %LET ISSUE2 = TRANSPORT_ISSUES;
    PROC FREQ DATA=INPUT NOPRINT;
        TABLES &ISSUE1*&ISSUE2/NOCOL NOCUM NOPERCENT NOROW OUT=OR;
    RUN;
    PROC TRANSPOSE DATA=OR OUT=OR_TRANS;
        VAR COUNT;
    RUN;
    DATA &NAME._&i;
        RETAIN ISSUE;
        SET OR_TRANS;
        AD = COL1*COL4;
        BC = COL2*COL3;
        &ISSUE2 = AD/BC;
        …
    RUN;
    %END;
    …
%MEND;
```

The last step of the %OR macro is to merge the 15 data sets created by the %DO loop into a final data set which contains the odds ratios of &ISSUE1 with every other category. After running the %OR macro for each category, we use a simple DATA step to combine all odds ratios into a single data set, as seen in Display 2 below. The missing value on the diagonal marks where a category is compared to itself. This is the data that will be used to create the odds ratio visualizations:

issue	culture_issues	environment_issues	famplan_issues	transitions_issues	violence_issues	injuries_issues	fetalmed_issues	mother_issues	mentalhealth_issues	pediatric_issues	prenatal_issues	service_issues	social_issues	substance_issues	transport_issues
Culture		2.903383214	2.540010023	2.242160279	1.14931173	0.600430416	28.71758437	54.33737024	2.40283353	1.293637575	4.746928747	3.255154639	7.98028114	5.355263158	3.143369176
Environment	2.903383214		4.794985161	9.417291354	9.859641728	33.61344538	1.722334004	26.07070707	7.913301255	9.958079784	4.313043478	3.449186257	9.963827055	6.805835294	5.463073852
Family Planning	2.540010023	4.794985161		5.606984479	2.636383301	2.224561404	11.50147929	90.85606061	6.466450917	2.61258423	6.414835165	7.298	3.886060606	11.78217822	4.914545455
Transitions	2.242160279	9.417291354	5.606984479		9.687611091	6.031823745	6.140350877	88.10966057	16.5849914	4.794901808	7.748995984	4.591775701	11.20180529	9.727849956	9.934094085
Violence	1.14931173	9.859641728	2.636383301	9.687611091		8.662541647	4.51465721	118.5037406	10.10315534	4.547491039	5.915322581	2.970170455	16.36755319	9.806128831	7.325446009
Injuries	0.600430416	33.61344538	2.224561404	6.031823745	8.662541647		0.700339559	22.4375	5.842402402	5.292982456	3.58186398	1.840684068	12.96652004	13.81459566	2.403927069
Infant Medical	28.71758437	1.722334004	11.50147929	6.140350877	4.51465721	0.700339559		79.73727422	11.24933238	2.485370052	18.57321028	11.29345794	11.6022409	31.02040816	5.591537133
Mother Medical	54.33737024	26.07070707	90.85606061	88.10966057	118.5037406	22.4375	79.73727422		115.5330709	12.4135274	105.1218274		164.8238806	362.0512821	47.27380952
Mental Health	2.40283353	7.913301255	6.466450917	16.5849914	10.10315534	5.842402402	11.24933238	115.5330709		5.108225108	7.839849966	7.032	7.80626345	19.00596009	21.10465116
Pediatric	1.293637575	9.958079784	2.61258423	4.794901808	4.547491039	5.292982456	2.485370052	12.4135274	5.108225108		4.507317073	2.7628125	6.350877193	7.417763158	4.308423215
Prenatal	4.746928747	4.313043478	6.414835165	7.748995984	5.915322581	3.58186398	18.57321028	105.1218274	7.839849966	4.507317073		7.1508	8.881454545	21.4554704	6.545012165
Service	3.255154639	3.449186257	7.298	4.591775701	2.970170455	1.840684068	11.29345794		7.032	2.7628125	7.1508		5.197449609	10.24100156	3.373015873
Social	7.98028114	9.963827055	3.886060606	11.20180529	16.36755319	12.96652004	11.6022409	164.8238806	7.80626345	6.350877193	8.881454545	5.197449609		12.53641087	25.94683544
Substance Use	5.355263158	6.805835294	11.78217822	9.727849956	9.806128831	13.81459566	31.02040816	362.0512821	19.00596009	7.417763158	21.4554704	10.24100156	12.53641087		5.128280961
Transportation	3.143369176	5.463073852	4.914545455	9.934094085	7.325446009	2.403927069	5.591537133	47.27380952	21.10465116	4.308423215	6.545012165	3.373015873	25.94683544	5.128280961	

Display 2. Final Odds Ratio Data Set for All Issues Categories

CREATING THE CHARTS - %CHART MACRO

The radar charts are created using the GRADAR procedure and the data generated from the %OR macro. As seen in Display 2 above, ISSUES is a string variable which comprises the name of each issue category and INJURIES_ISSUES is a variable that contains the odds ratios for injury issues compared to each other category. Note that PROC GRADAR treats the odds ratios as frequencies in order to create these visualizations. The SAS code to create the radar chart for the Injury issue category can be seen below:

```
PROC GRADAR DATA=GRAPH;
    CHART ISSUES/FREQ=INJURIES_ISSUES STARTYPE=WEDGE SPIDERWEB
    HEIGHT=2.5 WSTAR=2 NOFRAME CSTAR=RED CSPOKE=GRAY;
RUN;
```

The STARTYPE= option determines the appearance of the radar chart. For these visualizations we choose WEDGE, which gives the charted odds ratios the appearance of a closed polygon with spokes emanating from the center of the chart. WEDGE was chosen over the POLYGON option because POLYGON suppresses the spokes, which make it difficult to determine the numeric value of the odds ratios. Additional choices available in the STARTYPE= option include CORONA, RADIAL, and SPOKE charts.

The SPIDERWEB option forces the chart to display lines connecting the spokes where tick marks would be placed instead of displaying the default tick marks. This option makes it easier to determine the value of the odds ratio where the polygon intersects with the spokes. Additional options in the code above control the size of the chart and the color of both the polygon and the spokes.

Like the odds ratio calculations above, we build a %CHART macro to automate the radar chart creation process for efficiency. Additionally, the %CHART macro utilizes the SQL procedure to calculate the number of FIMR cases with each factor from the INPUT data set, and then concatenates this information with the chart title and the category name to create more informative labels on the charts. The %CHART macro has two inputs: &VAR is the issues category variable to display and &LABEL is the name of that variable as we desire it to appear in the chart title:

```
%MACRO CHART(VAR,LABEL);
    PROC SQL NOPRINT;
        SELECT SUM(&VAR._ISSUES) INTO :TOT FROM INPUT;
    QUIT;
    PROC SQL;
        CREATE TABLE LABELS AS SELECT
            SUM(CULTURE_ISSUES) AS CULTURE_TOT
            ,SUM(ENVIORNMENT_ISSUES) as ENVIORNMENT_TOT
            …
            ,SUM(TRANSPORT_ISSUES) as TRANSPORT_TOT
        FROM INPUT WHERE &VAR._ISSUES = 1;
    QUIT;
    …
    DATA GRAPH;
        MERGE OR_OUTPUT LABELS_TRANS;
        ISSUES = CATX("",ISSUE," (N=",TRIM(COL1),")");
    run;
    PROC GRADAR DATA=GRAPH;
        …
        TITLE "Odds Ratios: &LABEL Issues (N=%TRIM(&TOT))";
        …
    RUN;
%mend;
```

The first use of PROC SQL in the macro calculates the total cases where at least one issue in the category being charted was present and stores the result in the &TOT macro variable. The second use of PROC SQL calculates the number of cases where both the selected issue category and each of the other categories was present and stores the result in a series of macro variables.

The results from the second use of PROC SQL are transposed and merged with the combined output from the %OR macro to create category labels that now include the sample size of each category. The &TOT macro variable is used in the chart title to show how many of the 1,027 FIMR cases had at least one issue present within the charted category.

VISUALIZATION DISCUSSION

The final radar chart in Figure 1 below shows the odds ratios between the Injury category and all of the other issue categories.
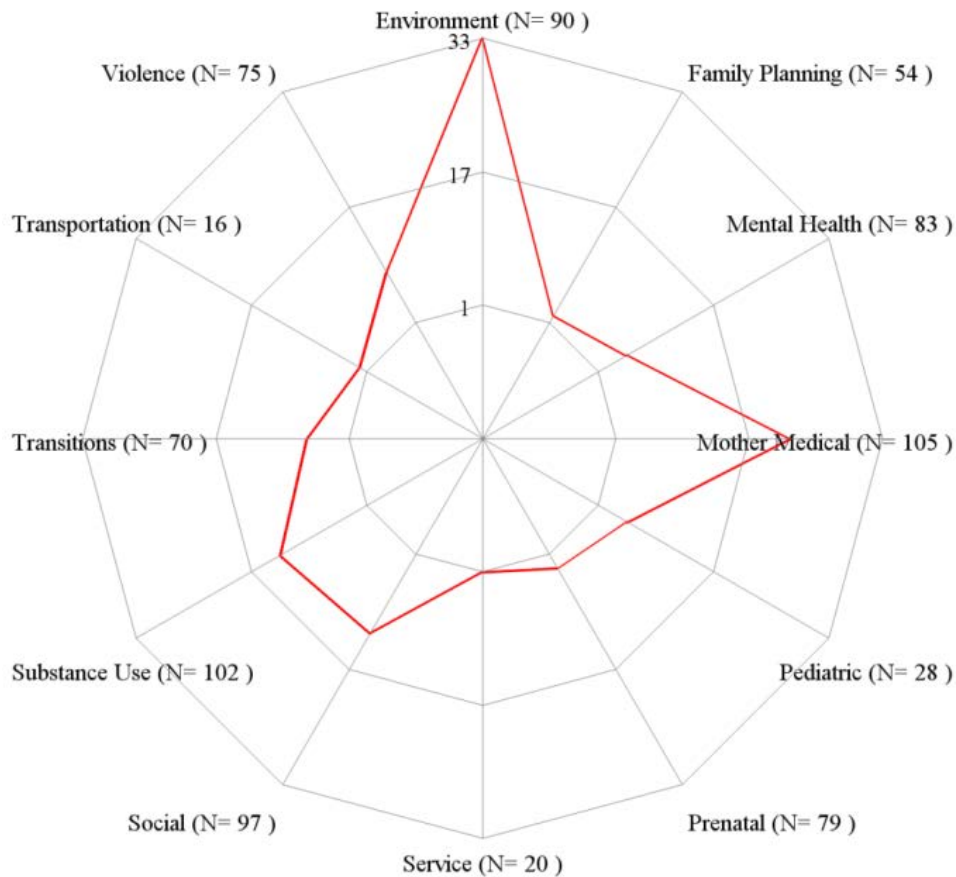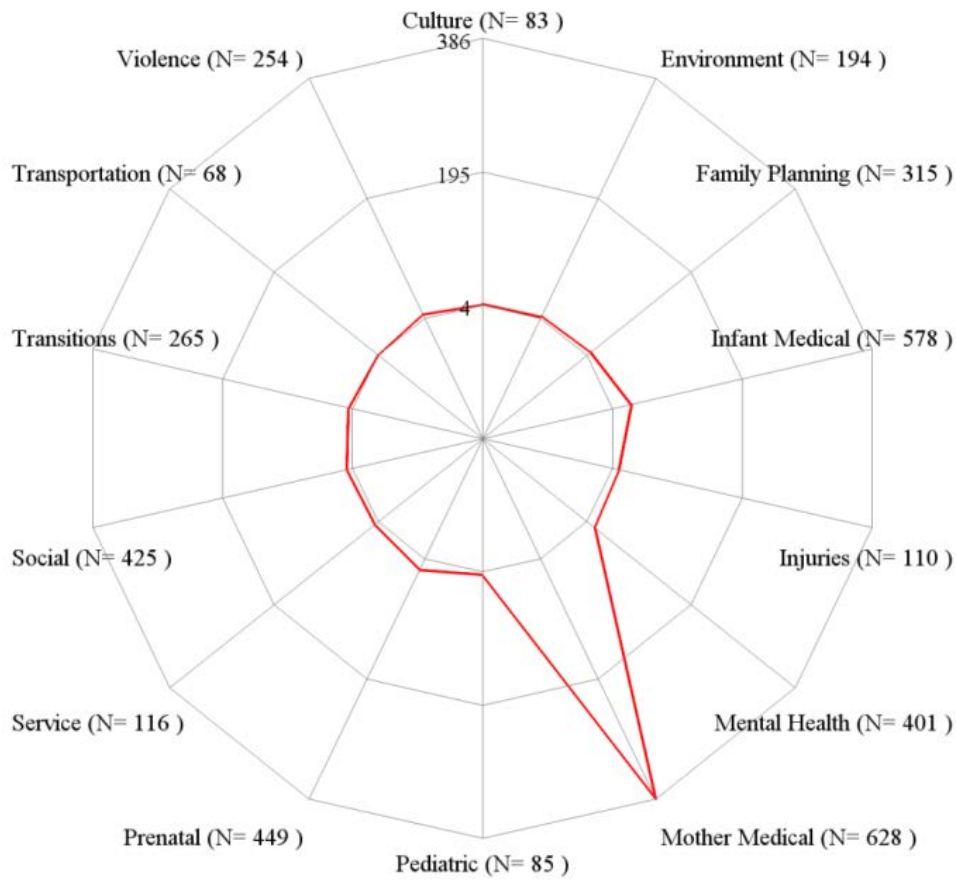

Figure 1. Odds Ratio Visualization for Injury to Infant

With this visualization, we can readily see that FIMR cases with an infant injury are 33 times as likely to also have had an issue in the mother and infant's living environment. The mother of the infant in such cases is also more than 17 times as likely to have some sort of medical issue. In addition, cases with an infant injury had increased likelihoods for the presence of substance use/abuse, social support issues, and reported violence/neglect.

Odds Ratios: Substance Use Issues (N=637)

Figure 2. Odds Ratio Visualization for Substance Use

Beyond identifying new relationships, these radar charts also demonstrate the strength of the associations we already monitor so that we may truly grasp the magnitude of their co-dependency. Figure 2 above displays the radar chart for Substance Use. We can see the overpowering link between substance use/abuse pre to post pregnancy and medical issues for the mother, and to a lesser degree, the infant.

Odds Ratios: Service Issues (N=125)
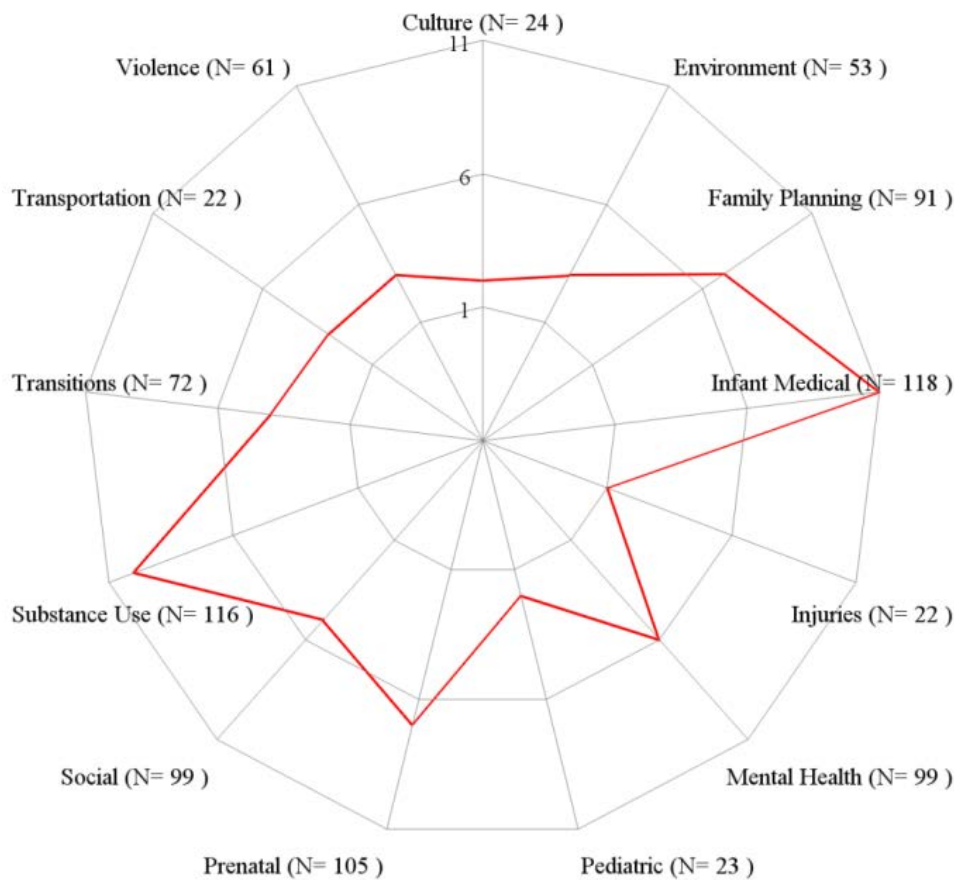
Figure 3. Odds Ratio Visualization for Service Issues

These charts also allow us to challenge our preconceived notions of what types of issues actually co-exist for these families. In Figure 3 above we examine the odds ratios of the service category. Since this category examines issues relating to poor provider communication, as well as client distrust and dissatisfaction, we may expect to see a strong relationship between cases with service issues and those with cultural issues, hypothesizing that a language barrier could be a significant source of any communication problems. However, the radar chart shows that although service issues are strongly associated with many other categories, including infant medical, mental health issues, and substance use/abuse issues, cases with a service issue are in fact only twice as likely to have a cultural issue as well.

VISUALIZING ODDS RATIOS BY RACE

One of the goals of the FIMR program is to investigate discrepancies in infant mortality among racial and ethnic populations. The race and ethnicity of the mother, infant, and father (if known) are collected in the demographic information of each case. We are able to incorporate race/ethnicity information into the visualizations by first using the %OR macro to calculate the odds ratios for each category pair by race/ethnicity, then by using a modified version of the %CHART macro to display the odds ratios for two racial/ethnicity groupings at a time. Although we established earlier that the Kent County FIMR program reviews all of its infant deaths, only White and Black mothers are examined in these visualizations because we found that displaying three or more races in a single chart looked too cluttered and decreased the effectiveness of the visualization.

Like the %CHART macro, the %CHART_RACE macro uses PROC SQL to calculate the sample size in an issue category and create more informative chart labels, but in this instance the PROC SQL

statements and DATA step calculations are separated by race. The labels are combined using a simple DATA step and SET statement prior to the invocation of PROC GRADAR. Employing the OVERLAY option in PROC GRADAR creates a comparative radar chart using the levels of the specified variable, in this case the race of the mother. Since the category labels were made longer to accommodate separate sample sizes for the Black and White mothers, STARLEGEND, STARLEGENDLABEL and SPKLABEL options were used to replace the category labels on the spokes with numbers and to build a legend which displays the category labels below the radar chart. Lastly, some PROC GRADAR options used in the %CHART macro, like WSTARS and CSTARS, now have two parameters which correspond to the two race polygons on the chart:

```
%MACRO CHART_RACE(VAR,LABEL);
    PROC SQL NOPRINT;
        SELECT SUM(&VAR._ISSUES) INTO :TOT_WHITE FROM INPUT
        WHERE MOB_RACE = "WHITE";
    QUIT;
    PROC SQL NOPRINT;
        SELECT SUM(&VAR._ISSUES) INTO :TOT_BLACK FROM INPUT
        WHERE MOB_RACE = "BLACK";
    QUIT;
    …
    DATA GRAPH;
        SET GRAPH_W GRAPS_B;
    run;
    …
    PROC GRADAR DATA=GRAPH;
        …
        CHART ISSUES/FREQ=FREQ STARTYPE=WEDGE SPIDERWEB OVERLAY=RACE
        SPKLABEL=CATEGORY STARLEGEND=NUMBER STARLEGENDLAB="Issues"
        LSTARS= 1 1 HEIGHT=2.5 WSTARS=2.5 2.5 NOFRAME
        CSTARS=(BLUE,DARKORANGE) CSPOKE=GRAY;
    RUN;
%MEND;
```

Odds Ratios: Infant Medical Issues (N White=269, N Black=250)
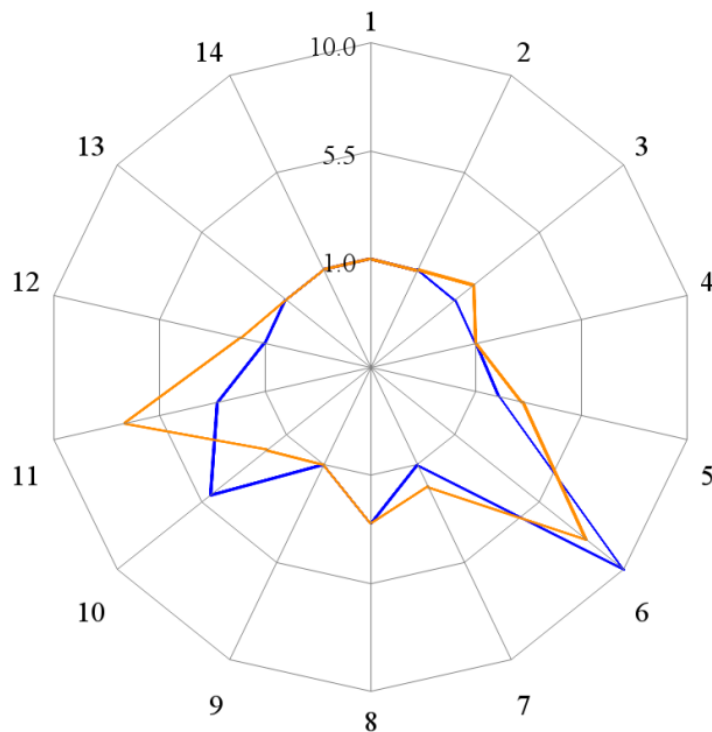
Issues
1 Culture (W= 9 , B= 24)   2 Environment (W= 39 , B= 79)
3 Family Planning (W= 120 , B= 131) 4 Injuries (W= 17 , B= 35)
5 Mental Health (W= 151 , B= 159) 6 Mother Medical (W= 248 , B= 236
7 Pediatric (W= 26 , B= 29)   8 Prenatal (W= 164 , B= 182)
9 Service (W= 37 , B= 51)   10 Social (W= 109 , B= 213)
11 Substance Use (W= 244 , B= 191) 12 Transitions (W= 80 , B= 123)
13 Transport (W= 12 , B= 47)   14 Violence (W= 56 , B= 131)
Race ── Black   ── White

Figure 4. Odds Ratio Visualization for Infant Medical Issues by Mother's Race

The radar chart in Figure 4 above shows the odds ratios for infant medical issues with the race of the mother included. For cases where at least one infant medical issue was present, White mothers were more likely to have substance use/abuse issues and family planning issues, while Black mothers were more likely to have social and medical issues. Being able to examine relationships between issues category by race allows us to discover what relationships are strongest within each race and thereby develop targeted education and outreach to address those unique concerns.

CONCLUSION

Creating odds ratio visualizations with PROC GRADAR has allowed us to quickly recognize and gauge the strength of relationships between categories of risk factors in infant mortality. Whether exploring new relationships, demonstrating the strength of those we know exist, or challenging our preconceived notions of which issues are related, these radar charts give us an intuitive way to understand the situations these families are facing and develop more effective strategies to assist them.

The next steps with these visualizations will be to delve further into the larger issue categories to see if we can get a better handle on what is driving the strength of relationships like those seen between the

categories of substance use and mother's medical issues in Figure 2. Both are large categories which contain information that could be further broken down, such as issues relating to the mother's age, type of substance used, and issues relating to mother's weight during pregnancy. We also plan to create visualizations for other race pairs, including Hispanic, Asian, and Native American mothers so that we can discover what relationship issues are strongest within each of these racial/ethnicity groups and come up with targeted education and outreach to effectively address them.

These visualizations have been, and will continue to be, a powerful tool in increasing our understanding of the issues facing at risk families and in reducing infant mortality in Kent County.

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