

# Data Visualization Challenges in Reducing Maternal and Child Mortality

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## Abstract

The United Nations Sustainable Development Goal 3 includes reducing maternal and child mortality by 50% by 2030. In recent years, leading healthcare providers and global public health experts have begun to realize the importance of data visualization for understanding the causes of death and proven best practices in reducing mortality.

The aim of this work is creating a dynamic and interactive data visualization and utilization lab enabling 193 countries to share proven best practices. The lab will facilitate data collection, analysis, presentation of results and provide a structured framework of what works (where, how and why) to support thousands of existing and new efforts in reducing maternal and child mortality.

This research is supporting the World Health Organization, UNICEF, the United Nations Family Planning Agency and the World Bank who are working together with the University of North Carolina – Chapel Hill World Health Organization Coordinating Center.

In this study, we have identified the most trusted and accurate databases for maternal and child mortality as well as the reasons for these deaths. We are now identifying the proven best practices used throughout the world in reducing maternal and child mortality. We are exploring many data visualization challenges including collecting reliable data, plotting real-time data, effective data analyses, and discovering the right tools to visualize the data.

The findings of this research will become a major part of structured improvement and implementation practices that support the United Nation's Sustainable Development Goals for health.

**Key Words:** data visualization, statistical challenges, maternal and child mortality, improvement science, implementation science, healthcare, benchmarking, best practices

## 1. Introduction

In 2015, there were 216 maternal deaths per 100,000 live births in the world, 4200 children out of every 100,000 died before age 5, and 3100 infants per 100,000 live births died before their first year [1]. Even though the number of deaths has been declining since 1990, clearly much remains to be done to reach the United Nation's Sustainable Development Goal 3 of reducing maternal and child mortality by 50% by 2030.

In recent years there has been an explosion of new methods in data science especially in tools and methods for dynamic interactive data visualizations. These new tools help us explore the data to discover new patterns, help us understand data relationships, and help us present these results and relationships in meaningful ways. Many different disciplines are using data visualization tools to identify causes of death and the complex range of variables leading to these deaths. These causes range from many different diseases, water quality, education, communication, access to healthcare (including transportation challenges), poor nutrition, and even the quality of the care itself.

In 2005, the National Academy of Engineering (NAE) and the Institute of Medicine (IOM) highlighted the need for a systems approach to healthcare and the application of systems engineering tools in improving healthcare. New information technologies and applications of computer science in collecting, using and understand the data are providing new high-tech medical solutions. We are faced with an incredible growth in healthcare data from hospitals, clinics, primary care providers, public health agencies, and formal clinical trials. However, this abundance of data is virtually useless until it is organized and analyzed and turned into useful information [2].

Statistical analyses are important for guiding decisions in healthcare quality. There are many new tools and methods to help us summarize and understand the effectiveness and costs of medical practices, goods and services. Healthcare organizations including hospitals, large health care provider groups and government health and human service agencies, use statistical methods to understand current health care usage, to assess the needs of consumers and to make decisions about allocating limited resources. Hospitals and other provider groups use statistical methods to develop continuous quality improvement programs to improve the efficiency and quality of healthcare. Pharmaceutical and technology companies use statistical methods when developing new products.

Hospitals and other healthcare provider groups attempt to provide high-quality services in a useful way. Statistics are useful in determining whether they are successful in meeting specific performance goals. Then the statistical evidence can be used in the development of designed quality improvement programs to improve healthcare services. Specific standards, best practices, or benchmarks of service are used to measure the success of these programs. Statistical information regarding whether the best practices are met is used to assess the effectiveness of quality improvement programs.

This article is structured as follows. The next section presents a literature review on improvement and implantation science in healthcare and the use of data visualization in healthcare. Then the research method is described. Next, analysis and results are presented. Finally, conclusions and directions for future research are discussed.

## **2. Literature Review**

### **2.1 Improvement Science and Implementation Science**

In recent years, leading healthcare providers and global public health experts have begun to realize the importance of implementation science. Many efforts in implementation science have focused on implementing best practices to reduce maternal and child mortality. Improvement Science and Implementation Science must be closely linked. There can be no true improvement without implementation and no implementation without improvement. Quality improvement and implementation are inseparably related and mutually reinforcing.

As defined during the Annual National Institute of Health Conference on Implementation and Dissemination, “Implementation is the use of strategies to adopt and integrate evidence-based health interventions and change practice patterns within specific settings” [3]. Challenges of linking research knowledge into practice have led to understanding the need of the concept of Implementation Science [4,5]. Implementation Science is defined as “the methods to promote the systematic uptake of clinical research findings and other evidence-based practices into routine practice and hence improve the quality and effectiveness of health care” [6].

There is a wide gap between science and actual practice. These gaps are the challenges in implementation. We want to understand why actual results differ so much from what we expect based on the results of scientific studies. A number of challenges come out of unique organizational and cultural norms [7,8]. Also, there is lack of understanding in current research evidence by both clinicians and hospital managers [9]. Funding, information technology, and human resources are typically limited and unsupportive in rural areas [10].

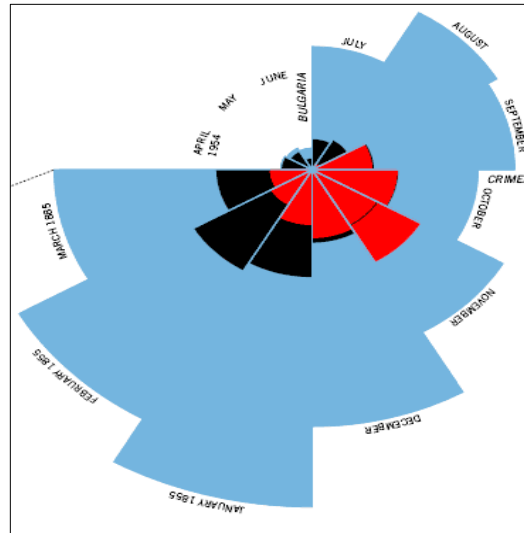
Although there are still many challenges in implementation, there are examples of successful implementation programs. Fixsen et al. identified seven implementation drivers based on the unities among successful implementation programs. These drivers are staff selection, preservice and in-service training, ongoing coaching and consultation, staff evaluation, decision support data systems, facilitative administrative support, and systems interventions [11]. In implementation research, it is important to explore the four different words of “what”, “how” “where” and “who”. What needs to be implemented, how will the task be supported, who should do the work of identifying and implementing best practices, and where the best solution must be implemented [12].

## 2.2 Data Visualization in Healthcare

Although solving the problems and statistical analyses are principal, data visualization will certainly play an increasingly important role in data analytics. Many years ago, back to the foundations of health science in 1855, Dr. John Snow mapped the cases of a London cholera epidemic during his exploration in discovering the cause of cholera (Figure 1). In 1858, Florence Nightingale plotted deaths in the Crimean War. Ms. Nightingale’s graphics helped convince people of the need for sanitary reforms (Figure 2).



Figure 1. John Snow’s 1855 cholera map [13]



**Figure 2.** Nightingale's 1858 plot of war deaths [14]

Visualization has found increasing use over the last several years, and visualizations have become useful tools for creating meaning from data to help people to see and understand the data. New software increase the speed of sophisticated analyses and plotting data in multiple dimensions has become commonplace. These new analytic tools enable incredibly fast dynamic and interactive visualizations. Visualizations are also helping us understand complex, high-dimensional simulation results and how to control and better design the simulations. We can find many visualization best practices in the visualization steering literature [15,16]. Visualization has moved beyond the lab and has taken on a much more communicative role [17-19]. In healthcare, visualizations are being studied as an intermediate for provider-patient communication [20]. We believe data visualizations can also play a very important role in communicating best practices to providers.

### 3. Method

We are using these dynamic interactive data visualization tools and methods to investigate different causes of maternal and child mortality by countries and regions, comparing results of improvement initiatives, and trying to understand these improvements, and to create best practices for specific regions. A colleague has defined this as evidenced-based precision community health. But finding the best practices is only part of the challenge, understanding how to implement these best practices is truly the hard part. We have been using data provided by the Institute for Health Metrics and Evaluation which is partnered with the University of Washington and the Gates Foundation. We feel this data is among the most reliable in the field. After the data was requested and delivered, several different data analysis tools were used to analyze it including Excel, JMP Pro 13, and Tableau. The data given to us can be analyzed either as the total number of deaths or as a rate per 100,000 live births. It is important to analyze both of these data sets to get a better idea of where the real problem lies. For example, when analyzing the total number of maternal deaths, India is by far the leading culprit. However, when analyzing as a rate per 100,000 births, India is on the lower end of the spectrum. This makes sense due to India having among the highest populations in the world. However, since our goal is to reduce the total amount of deaths across the globe, both datasets need to be analyzed in parallel. We used our data

analysis tools to do this by taking advantage of the data processing capabilities of JMP Pro along with the geographic map feature of Tableau.

Using JMP Pro and a Pareto plot, it can easily be seen which causes account for the most deaths both as a rate per capita and total number. It is then important to research which countries have the highest and lowest death rates among these causes of death. By discovering which countries and regions are susceptible to different types of disease and fatalities, we will be able to look into methodologies and determine which practices have proven to be effective. For in-depth learning, the ministers of health and other local experts for the successful and failing countries will need to be contacted in order to fully comprehend their maternal and infant healthcare procedures. After further analysis of these procedures, we will need further analyses to discover why they were effective and if (or how) these best practices can then be implemented in other countries' healthcare practices.

#### 4. Analyses and Results

Globally, the leading cause of maternal death since 1990 has been hemorrhage during and after birth. This alone has caused over 2.7 million maternal deaths since 1990. A maternal death is defined by the “GBD as any death of a woman while pregnant or within one year of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes. Ages included range from 10 to 54 years.” After discovering that hemorrhage was the leading cause of maternal deaths over the years, we decided to look at which countries have the lowest and highest maternal mortality rates specifically relating to maternal hemorrhage. We found that the countries with the highest rates of mortality were typically located in the central African region including: Somalia, Central African Republic, Chad, and Sierra Leone. A lot of this can likely be attributed to the fact that this has been a war-stricken region for a while now. Other common causes of maternal death in this region aside from hemorrhage include: hypertensive disorders and infections. 16.03% of maternal death cases are caused by pregnancy-related infections. In 2017, there were 21,204 maternal deaths in the world caused by pregnancy-related infections (Figure 3).

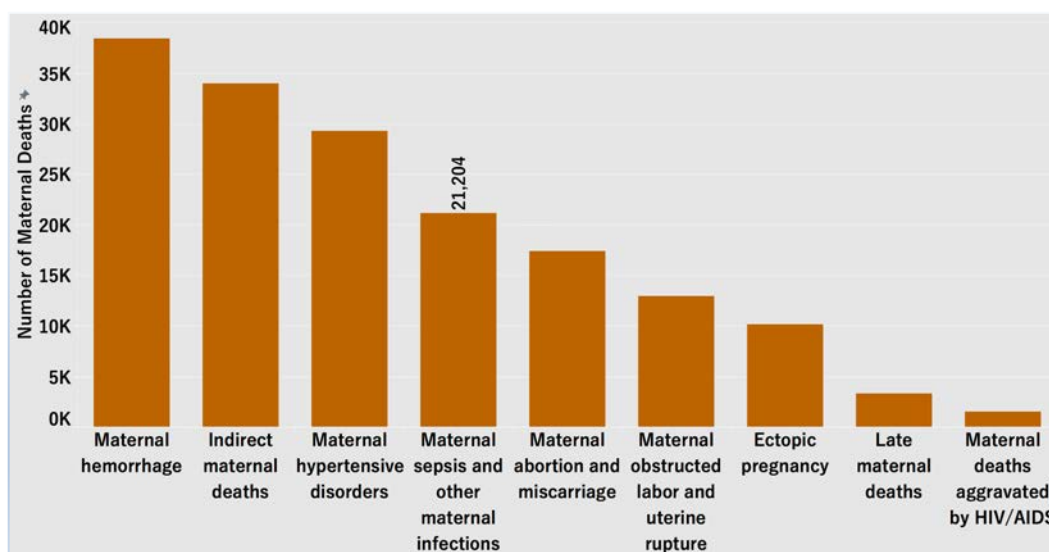
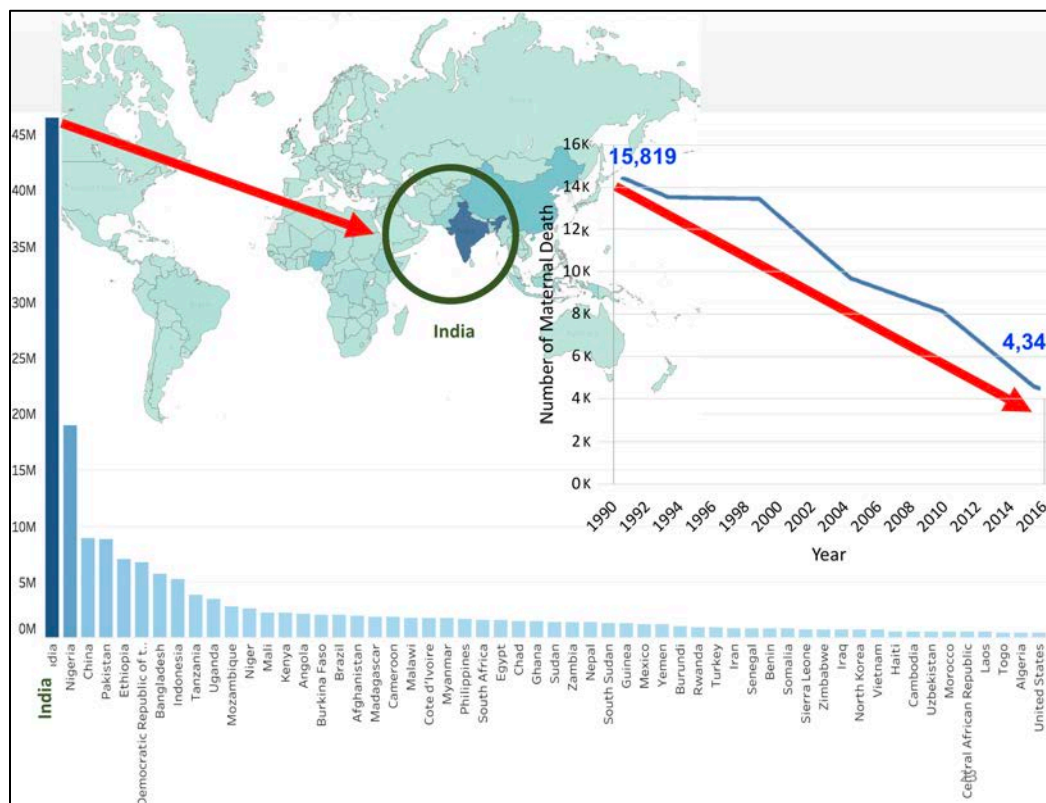


Figure 3. Different Causes of Maternal Mortality (2017)

Looking at the different causes of deaths, we further investigated infections. India has the highest number of maternal mortality caused by infection. The data show, however, that between 1990 and 2017, maternal mortality caused by infection worldwide dropped by about 45% and there is a huge decline (15,819 to 4,291) in number of maternal deaths caused by infection in India from 1990 to 2017 (Figure 4).



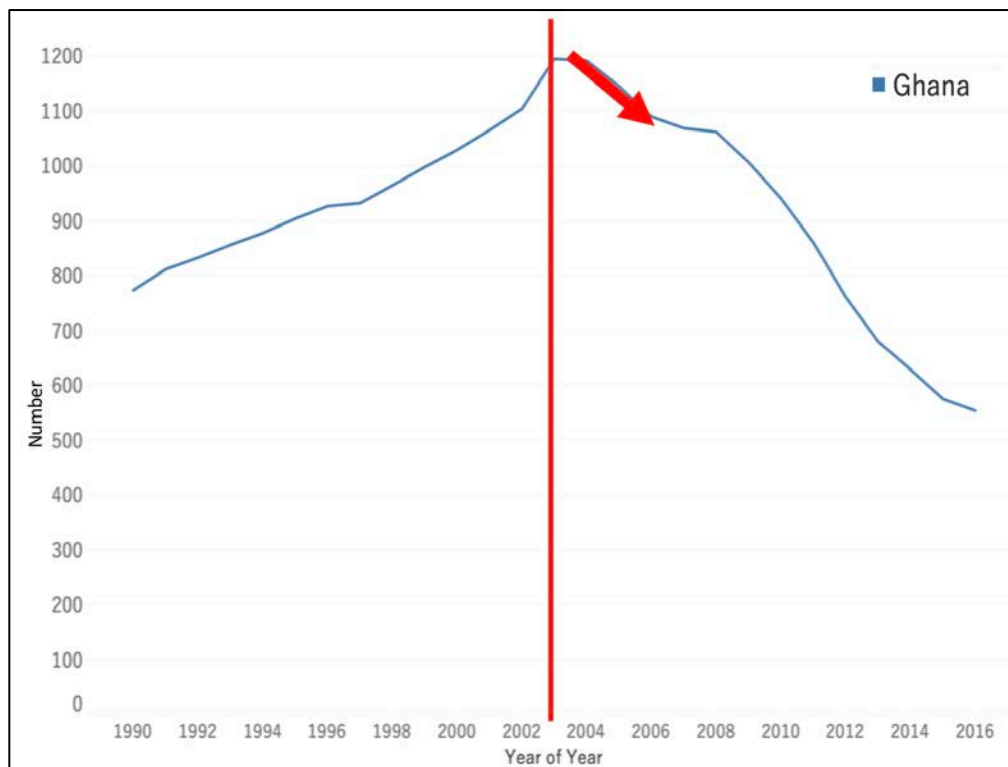
**Figure 4.** Maternal mortality caused by infection

Each year about 700 million people are infected by mosquito spread diseases worldwide resulting about one million deaths [21]. According to UNICEF, everyday over 1200 children die from malaria transmitted due to the mosquito bite [22].

Malaria is the main cause of deaths for children under age 5 in Sierra Leone, Mali, and Nigeria. Most of the child deaths caused by malaria occurred in African region, but the number of deaths caused by malaria dropped over 50 percent from 1990 to 2017 (Figure 4). We found that the countries with the highest rates of mortality were typically located in the African region including Niger, Sierra Leone, Mali, Nigeria, and Chad. Some of these deaths can likely be attributed to the fact that this has been a war-stricken region for many years. Other common causes of children's deaths in this region aside from diarrhea and malaria include infections and measles disease.

Ghana is an interesting case study with the mortality rate caused by malaria. In 2015, there were an estimated 439,000 malaria deaths worldwide, 70% of these deaths occurred in children under age 5. Malaria was responsible for 19% of all recorded deaths in Ghana in 2015 [23].

In 2003, the Ghana Health Service in cooperation with local governments and UNICEF distributed Insecticide Treated Nets (ITNs) to more than 20% of children under age 5 and pregnant women. The use of ITNs increased from 3.5% in 2003 to 21.8% in 2006. As it shown in Figure 4 there is a huge reduction in the number of deaths in 2003. The distribution of 2 million ‘long lasting’ nets for children under age 5 was started in 2006.



**Figure 4.** Progress of the number of deaths caused by malaria for children under age of 5 in Ghana

Diarrhea is the second leading cause of the deaths in the world. Access to unimproved water and sanitation among children under 5 years old is a serious public health problem in many developing countries [24]. Globally, almost a billion people still do not have access to improved sources of drinking water, and about 2.5 billion lack improved sanitation [25].

Unimproved water and sanitation have been identified as a major cause of diarrhea for children in the public health literature, which globally accounts for approximately 1.4 million child deaths each year. The majority of these deaths occur in sub-Saharan Africa where nearly half the population does not have access to clean water (Figure 5) [26]. Drinking clean water is more important for vulnerable groups such pregnant women and children under the age of 5 [27]. Many children also play in contaminated areas [28]. Previous studies have shown that access to clean water and sanitation can reduce child diarrhea and consequently reduce child mortality [29,30]. There has been great improvement over time showing a decline from 77,858 deaths to 19,623 from 1990 to 2016 (Figure 6).



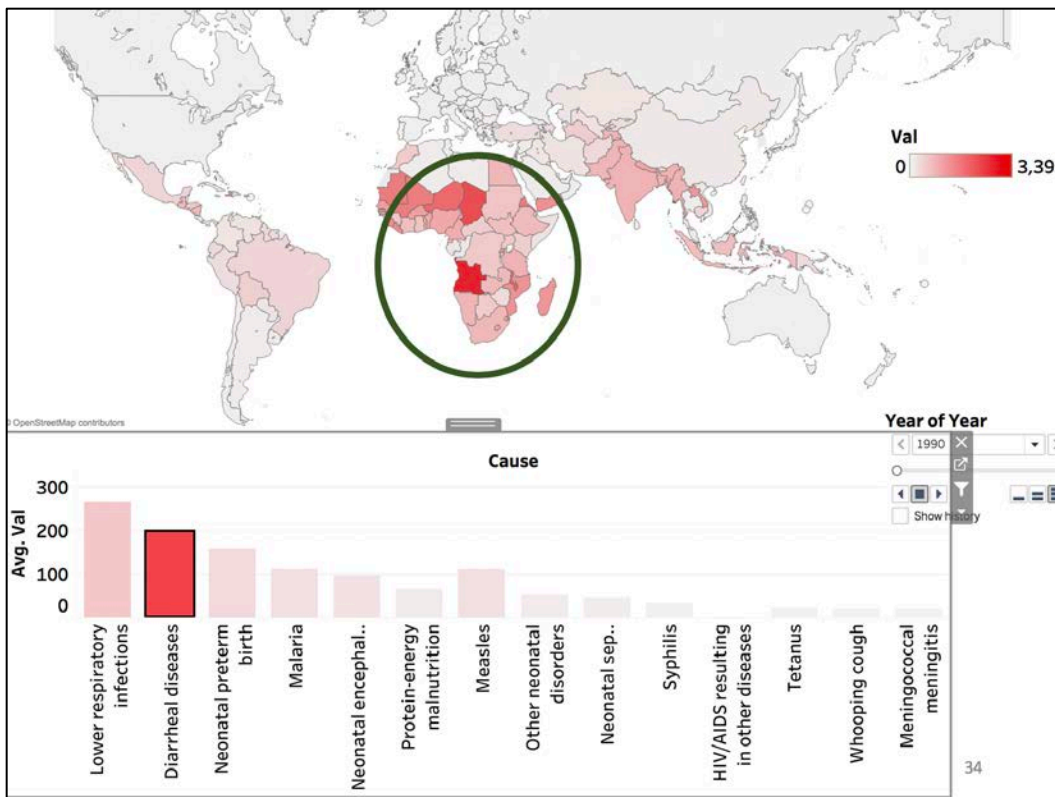


Figure 5. global map and chart visualization for children under age 5 mortality caused by diarrheal

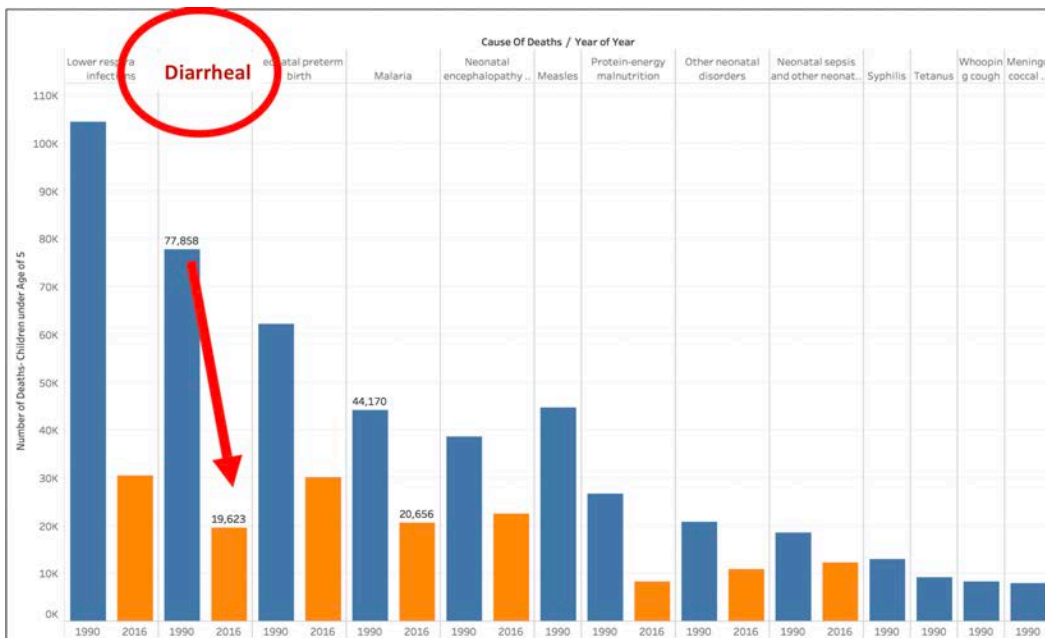


Figure 6. Child under 5 mortality caused by diarrhea progress



## **Data Visualization Challenges**

Barriers to progress have included the lack of easily accessible, understandable and reliable data, easy-to-use statistical methods for analyses of these data, difficulties in plotting real-time data, effective data analysis tools, and discovering the right tools to visualize the data and precisely targeting effective interventions to meet the needs of a particular community.

Many different disciplines will need to use these data visualization tools to identify causes of death ranging from disease, nutrition, water, education, transportation, communication, access to healthcare, and even the care itself. So, connecting and communicating between these disciplines is challenging. Another major challenge is connecting the visualization team with leaders throughout the world who have built or are building similar databases and visualization tools focused on reducing maternal and child mortality.

Identifying the best practices for reducing deaths from the most common reasons of death will be categorized in order to facilitate implementing best practices in similar situations.

## **5. Discussion and Conclusion**

Maternal and child mortality are two of the most important challenges in the world today. Despite many efforts, unacceptably high maternal and child mortality rates persist in the world, with large racial and ethnic disparities. Almost half of all maternal deaths are preventable.

This research uses the data from the most trusted and accurate databases for maternal and child mortality as well as the reasons for these deaths. Malaria was found as one the main causes of deaths for children under age 5 in many countries especially in the African region, but by implementing several of the discovered best solutions the number of deaths caused by malaria dropped over 50 percent from 1990 to 2017. Diarrhea was another cause of death and the data show a significant decline in many countries since 1990. In India there has been a substantial decline in the number of maternal deaths caused by infection from 1990 to 2017, but India still has the highest number of maternal mortalities caused by infection. Using the data that available, we have identified the countries and regions with highest and lowest mortality. But do we really know what exactly they have done in those countries to reduce the number of deaths? What are those solutions? Are these solutions applicable to other countries with high rates of mortality that have similar causes of death?

We are still investigating and identifying proven best practices used throughout the world in reducing maternal and child mortality. This research identified different barriers in using data visualizations to support reducing maternal and child mortality. Barriers to progress including collecting reliable data, plotting real-time data, effective data analysis, and discovering the right tools to visualize the data.

To begin addressing these problems, we will continue working in this project to create a dynamic interactive data visualization and utilization lab for monitoring maternal and child health in the world and discovering the effectiveness of best practices for reducing mortality. The lab will require integrative innovations in data collection, analysis and visualization. With the improved understanding we gain, we will know which interventions and approaches to implementation work better, and what changes are needed for sustainable solutions. This research can be extended by further analysis of in-depth

learning on the best practices to find out why some solutions are effective in specific countries and explore if they can then be implemented into other countries' practices.

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