**Option 1: Capstone Project Final Report: U.S. Organization**

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# Abstract

The opioid health crisis in the United States has claimed over 450,000 lives (Centers for Disease Control and Prevention, 2020) and drug poisoning is now the number one cause of mortality from injury, surpassing motor vehicle accidents (National Center for Health Statistics, 2018). The National Institute on Drug Abuse (NIDA) is the lead government organization focused on researching the causes, consequences, treatment, and prevention of drug abuse and the disease of addiction (National Institutes of Health, 2018), making NIDA central in the fight against opioid addiction. Even as some gains have been made with prescription opioid and heroin death rates decreasing slightly, illicitly manufactured opioid related mortalities are on the rise (Centers for Disease Control and Prevention, 2020). NIDA’s work fighting the opioid health crisis can be accelerated through data analytics, determining trends, making predictions and ultimately informing future treatment and prevention efforts. This study will focus on understanding the geographic disparities in synthetic opioid overdose mortality rates between HHS Regions in order to provide insights to NIDA for the distribution of resources to highly affected and at risk locations.

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# National Institute on Drug Abuse: Regional Analysis of Synthetic Opioid Overdoses

The National Institute on Drug Abuse (NIDA), established in 1974, is one of 27 research institutes and centers within the National Institutes of Health (NIH). NIDA focuses on advancing research on the prevention, treatment, and the underlying causes of the disease of addiction (NIH, 2018). Substance Use Disorder (SUD) is a challenging disease to understand, treat, and prevent. SUD is complicated by comorbidities, including neurological and mental health disease factors; environmental and behavioral aspects; and treatment is often complicated by negative social stigmas attached to those with the disease (NIDA, 2016). Due to the ongoing opioid health crisis, the U.S. life expectancy has started to decline and drug poisoning has become the leading cause of injury related mortality (National Center for Health Statistics [NCHS], 2018; Saloner, et. al., 2018; Zoorob, 2019). With over 20 million people in the United States suffering from SUD (Substance Abuse and Mental Health Services Administration [SAMHSA], 2019), and drug overdose deaths again on the rise due to the rapid entry of illicit synthetically manufactured opioids into the drug market (Centers for Disease Control and Prevention [CDC], 2020), the work of NIDA is more critical than ever.

## NIDA Background

### History

NIDA originated in 1935 as part of the U.S. Public Health Service in Lexington, KY and was later renamed the Addiction Research Center in 1948 (NIH, 2018). NIDA was formalized in 1974 as the Federal lead for data collection and research on the prevention, treatment, training, and services on drug abuse and continues today as an institute within NIH (NIH, 2018).

### Current Characteristics

Today, NIDA is headquartered in North Bethesda, Maryland and has 382 full time federal employees on staff with an enacted fiscal year 2020 budget of $1,462,016,000 (NIDA, 2020a). The budget is divided between seven different divisions, special research programs, and research management and support services.

NIDA has four primary goals:

1. Identifying the causes and consequences of long-term addiction and drug use;
2. Developing effective drug abuse prevention strategies;
3. Developing new treatments for SUD; and
4. Increasing the impact of its research programs to improve public health (NIDA, 2020b).

NIDA is broken down into six different research centers and has an additional seven cross-cutting research teams dedicated to specific areas of interest such as analytics, brain development, and nicotine and tobacco research, to name a few.

In addition to NIDA’s research focus, the institute also provides public education services on the science of addiction, prevention, recovery, treatment and facts about specific drugs such as opioids, methamphetamines, and other illicit drugs as well as legal drugs such as nicotine, alcohol, and marijuana (NIDA, n.d.). NIDA also provides science-based resources and training to healthcare professionals to help promote best practices for screening, treating, and preventing addiction (NIDA, n.d.). Additionally, NIDA offers research grants and funding opportunities to support basic and clinical research on SUD and related research priorities (NIDA, n.d.).

### Rational for Use in Capstone Project

In 2018, opioid related poisoning deaths started to drop, with a 2% decrease overall, a 13.5% decrease in prescription opioid-involved overdoses, and a 4% decrease in heroin death rates, however fentanyl related fatal overdoses increased by 10% **(**CDC, 2020).The increase in deaths is attributed to Illicitly Manufactured Fentanyl (IMF) sold as counterfeit pills, mixed with cocaine, and sold in place of heroin (CDC, 2020). The opioid crisis has always had geographic disparities, with 2011-2016 fentanyl related death rates highest in the Northeast (Spencer, Warner, Bastian, Trinidad, & Hedegaard, 2019). In order to effectively respond and deploy prevention to communities most in need, geographic and demographic disparities must be well understood. The research in this Capstone project will focus on identifying the regional differences in fentanyl overdose death rates in order to inform future NIDA resource allocations.

### Multiple Cause of Death Dataset

In order to better understand the geographic trends in fentanyl use, overdose data can be analyzed. The CDC Wide-ranging Online Data for Epidemiologic Research (WONDER) research system provides public access to data regarding public health, including mortality data. The Multiple Cause of Death (MCD) database can be accessed and queried through WONDER, providing detailed data gathered from death certificates, including a primary cause of death, any additional causes, and demographic data (NCHS, n.d.). This dataset, alone or in combination with other data, can be used by NIDA to understand trends and discover patterns in drug related overdose deaths to help focus its prevention and research priorities.

## Study Overview, Objectives, and Hypothesis

In order to effectively respond and deploy prevention to the communities most in need and most at risk, geographic disparities must be well understood. The purpose of this study is to understand differences in fentanyl overdose rates between the 10 U.S. Department of Health and Human Services (HHS) organizational Regions in order to better inform future research and funding decisions within NIDA. The hypothesis of this research is that *there are statistically significant differences in fentanyl related overdose deaths between at least one pair of HHS Regions for the time period 2013 through 2018.*

To test the hypothesis, fentanyl related fatal overdose data was downloaded from the MCD database for each HHS Region for the years 2013 through 2018. One-way Analysis of Variance (ANOVA) was performed, followed by post-hoc testing to determine which Regions had statistically significant differences in fentanyl overdose mortality rates.

## Literature Review

The opioid crisis has continued to evolve, with three distinct phases identified so far: 1) prescription opioid overdose deaths from 1990 to 2010; 2) heroin overdose deaths from 2010 to 2013; and 3) synthetic opioid overdose deaths starting in 2013 to present (CDC, 2020). Each phase of the opioid crisis has been interrelated with the preceding phase and has led to new and rapidly evolving challenges. Many studies have correlated the prescription opioid crisis to the increased use of non-medical prescription opioids and then subsequently to heroin, in essence catalyzing phase two of the epidemic (Unick & Ciccarone, 2017). Currently the crisis is in phase three, and started with the inception of synthetic opioids – fentanyl or fentanyl derivatives – into the illicit drug market. Fentanyl is a manufactured prescription drug used to treat patients with extreme pain, and is similar to morphine but is 100 times more potent and potentially deadly (NIDA, 2019). IMF is made in labs and mixed with other drugs such as heroin, cocaine, and methamphetamines (NIDA, 2019) and its presence is often unknown to drug users (Mars, Rosenblum, & Ciccarone, 2019).

Synthetic opioid overdoses are closely tied to the changes in the illicit drug market. Zoorob (2019) identifies fentanyl exposure, identified by drug seizure data, as an indicator of overdose risk and contends that geographic and demographic changes in the opioid crisis can be attributed to differences within regional illicit drug supplies. Historical regional drug availability patterns have also been correlated with differences in fentanyl overdose rates across the United States. Mars et al., describe geographic differences in availability of heroin types between East and West coast drug users, with Colombian produced powder heroin dominating the East market and Mexican produced “black tar” dominating the West market (Mars et al., 2016). With differences in the textures of these different drug supplies, fentanyl is more difficult to detect in powder-based East coast heroin supplies, which the authors theorize has led to a higher proportion of fentanyl related deaths in the Northeastern population of heroin users (Zoorob, 2019; Mars, Rosenblum, & Ciccarone, 2019). These studies highlight the importance of differences in overdose risk based on geographic location and available drug supplies.

# Materials & Methods

## Methodology

This study follows the basic scientific method and relies on a quantitative research approach using deductive reasoning to drill down from a theory to specific hypotheses, which are rejected or supported based on the statistical analysis of different study variables (O’Leary, 2017). The null hypothesis, written as H0, tests the idea that the researcher believes to be false and the alternative hypothesis, written as Ha, is the idea that the researcher believes to be true (Guthrie, 2020). Statistical analysis can be performed to reject the null hypothesis, providing supporting evidence for the alternative hypothesis.

## Data Analysis Tools

For this study the JupyterLab framework was used with a Python 3 kernel. For the data preparation, exploration, and descriptive analysis of the data, the Python pandas library, designed for efficient structured data wrangling and analysis, was used (McKinney, 2018). For data plotting, the Python seaborn statistical data visualization library was utilized (Waskom, 2020). For the data visualization of results, Tableau Public was used to create maps and animated graphs (Tableau Software, 2020).

## Data Source Overview

### HHS Regions

The HHS is broken down into ten regional jurisdictions, which include U.S. Territories and Tribal Nations, however this study only includes the U.S. States in each Region, see Figure 1.

**Figure 1**

*HHS Organizational Regions.*

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*Note.* HHS organizational regions in the United States starting from the Northeast with Region One moving west towards Region Ten in the pacific northwest (HHS, 2018).

### 

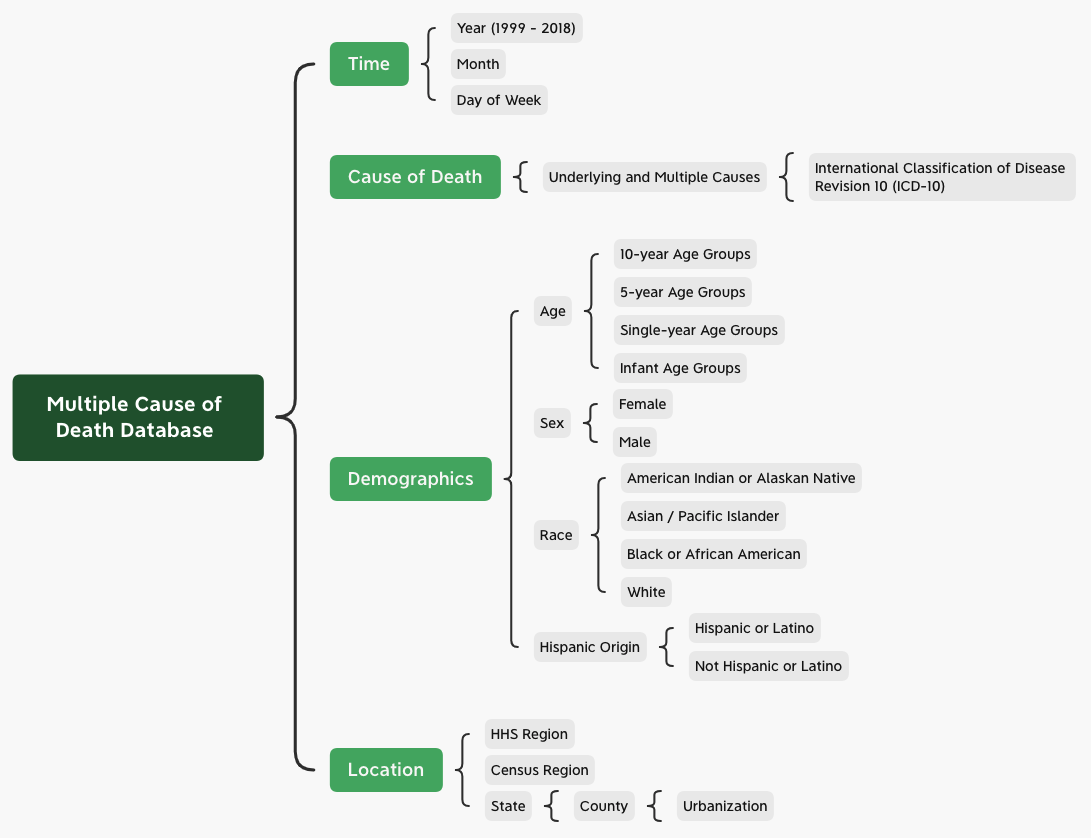
### MCD Data

The MCD data holdings include national mortality information and population statistics from 1999 through 2018 collected from the death certificates of U.S. residents. Data include a primary cause of death, with a listing of up to twenty additional causes, and demographic information on decedents that includes age, race, sex, Hispanic ethnicity, location of death, year, month, weekday of death, and autopsy information (NCHS, n.d.). Data can be queried by cause of death codes, including drug related causes and can be broken down by specific contributing drugs such as heroin, methadone, synthetic narcotics, and many others. This dataset, alone or in combination with other data, can be used by NIDA to understand trends and discover patterns in drug related overdose deaths to help focus its prevention and research priorities.

#### Data Model and Variables. The MCD database contains a variety of variables that can be used to subset data and perform analysis on specific causes of death to determine correlations, patterns, and trends based on locational or demographic data. Figure 2 provides an overview of the MCD data fields that can be queried through the CDC WONDER information system.

**Figure 2**

*MCD Data Model*



*Note.* This chart was produced based on the information provided by the Multiple Cause of Death 1999-2018 database summary (NCHS, 2020a).

The CDC WONDER system provides a nice graphical user interface to query and group data by different variables prior to downloading. The system saves the researcher’s time, eliminating the need to download and then sub set a large volume of data prior to analysis. For this project, the following variables were examined: year, HHS Region, International Classification of Diseases (ICD) codes, number of deaths, age adjusted death rate per 100,000 people, and percent of total deaths. Categorical variables included year, HHS Region and ICD code. Numeric variables include number of deaths, age adjusted death rate per 100,000 people, and percent of total deaths (NCHS, 2020a).

Query Criteria. In order to drill down to the level of specific drug overdose data, the codes within the International Classification of Diseases and Related Health Problems Tenth Revision (ICD-10) (World Health Organization, 2019), can be used to identify drug poisonings and the specific substances that contributed to the fatal injury (NCHS, 2020a). The hierarchy of codes can be very complex, and are important to understand in order to retrieve the appropriate data for analysis. The SAMHSA Center for the Application of Prevention Technologies produced a guide with instructions on how to “crack the code” and properly query fentanyl related drug overdose data within the MCD database (SAMHSA, 2018).

For this study, queries of the MCD database were performed with the following parameters: HHS Region, Underlying Cause of Death ICD-10 code, Multiple Cause of Death ICD-10 codes, and year. See Figure 3 to examine the detailed query performed for HHS Region Ten.

**Figure 3.**

*Example Query from the MCD Database.*

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*Note.* Query parameters from the MCD database for fentanyl related overdose age adjusted rates for HHS Region Ten. (NCHS, 2020b).

### Understanding the Challenges of Working with Mortality Data

Mortality data is important for analysis of population health and can be crucial for prioritizing funding, research, public health initiatives, and timely prevention efforts. Analysis of mortality data comes with challenges to ensure that data are secure, adhere to privacy laws, and are ethically used.

Security. The MCD database is covered under the Health Insurance Portability and Accountability Act (HIPAA) *Security Rule* which operationalizes the privacy protections through a set of security standards and requirements to safeguard Electronic Protected Health Information (ePHI) (Center for Medicare & Medicaid Services, 2018; HHS, 2017). However, the HIPAA regulations only cover the following entities and their business associates: health plans; healthcare clearinghouses; and health care providers. This means that non-affiliated researchers who utilize ePHI must adhere to data use agreements where specific security and privacy protocols are outlined by the data provider. In the case of the MCD database, users must agree to specific data use restrictions prior to requesting and using data (NCHS, n.d.). Figure 4 shows the data use agreement and sanctions for violating the rules.

**Figure 4**

*Multiple Cause of Death Database Use Restrictions.*

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*Note.* Violation penalties include fines of up to $10,000 and/or 5 years in prison (NCHS, n.d.).

Privacy. The HIPAA *Privacy Rule*, established a set of regulations for the use and disclosure of ePHI (Center for Medicare & Medicaid Services, 2018; HHS, 2017). These privacy regulations also pertain to the health information of deceased individuals, requiring that data be protected for fifty years following the date of death (HHS, n.d.). As part of the data use agreement for the MCD database, researchers must agree to not try to identify anyone and cannot *“present or publish death counts of 9 or fewer”* in order to comply with the HIPAA Privacy Rule (NCHS, n.d., para 2.).

Ethics. While HIPAA laws provide legal regulations that researchers must follow, there are also ethical standards which should be applied when using mortality data to maintain a level of reverence and respect for the lives of the decedents and their families. Data should only be used for the purposes of health statistical reporting and analysis, and the identity of decedents must never be investigated. The data use restrictions provided by the CDC outline the legal and ethical guidelines for the use of MCD data. Data use restrictions include:

* Data may only be used for the analysis and reporting of health information;
* Death counts of 9 or fewer may not be reported or published;
* Investigation of personal identities or establishments are not allowed; and
* Accidently discovery of identity information must be reported to the NCHS Confidentiality Officer and should not be disclosed (NCHS, n.d., para 2.).

Beyond adherence to data use restrictions, care must also be taken with how data analysis results are presented in figures, graphs, and through other visual mediums. Ethical guidelines should be utilized during visualization development and empathy must be given to those individuals and families affected by fatalities caused by SUD. Cogley advises that *“If you are visualizing human lives, you have the capacity to do harm”* and care must be taken to craft a compassionate message that goes beyond presenting numbers and instead educates, informs, and promotes ideas that can be used to support positive change (2019, Learn Section, para 3).

## Methods

The hypothesis for this study is: *There are statistically significant differences in fentanyl related overdose deaths between at least one pair of HHS Regions for the time period 2013 through 2018.*  To test the overall hypothesis the following hypotheses were evaluated:

* Null Hypothesis: H0 : = = = = = : There is no statistically significant difference between the fentanyl overdose death rate means of each HHS Region during the time period 2013 – 2018.
* Alternative Hypothesis: Ha : : There is a statistically significant difference between the fentanyl overdose death rate means with at least one pair of HHS Regions during the time period 2013 – 2018.

Data from each HHS Region were downloaded as tab separated files from the MCD database and then imported into a Python 3 Jupyter Lab notebook. Data was then combined into a pandas DataFrame with the following fields: year, total deaths, population, age-adjusted death rates per 100,000 people, percentage of total deaths, and the HHS Region. Basic descriptive statistics were performed and exploratory visual analysis was completed using kernel density estimate plots and boxplots to identify the characteristics of the death rates variable.

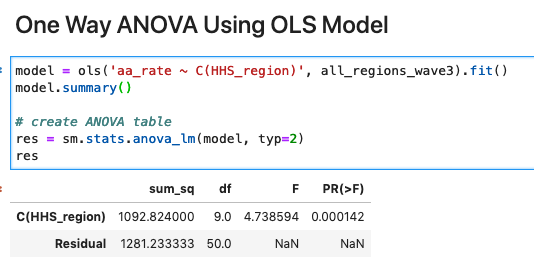
In order to test the null and alternative hypotheses, a one-way ANOVA analysis was performed using the Python statsmodel OLS method. A Shipiro-Wilks test was then performed to test the model residuals for normality. Next a Levene’s test was performed to confirm homogeneity of variances. Finally, a post hoc Tukey’s Honestly Significant Difference (HSD) test was used to determine which pairs of Regions had statistically significant differences between age adjusted death rates. The JupyterLab notebook code and data files can be viewed on GitHub at <https://github.com/janice-gordon/Regional-Disparities-in-Overdose-Death-Rates>.

# Results

The ANOVA analysis results are available in Figure 5. The p-value of the F-statistic was 0.000142, well below the 0.05 threshold, enabling the rejection of the Null Hypothesis that all HHS Regions have equal mean death rates.

**Figure 5**

*Python Code and Results for the One-way ANOVA Analysis of Overdose Death Rates*



*Note.* Screenshot of Jupyter Lab notebook Python code and results of the one-way ANOVA for death rates by HHS Region.

Because the Null Hypothesis was rejected, further analysis was done to determine which Regions had statistically significant differences. The Tukey’s HSD test was completed with the statsmodel Python library. Results of the test showed that the following pairs of Regions showed statistically significant differences in overdose death rates: Regions One and Ten (p-adj: 0.0012); Regions One and Six (p-adj: 0.0011); Regions One and Seven (p-adj: 0.0011); Regions One and Eight (p-adj: 0.0017); and Regions One and Nine (p-adj: 0.001), see Figure 6.

**Figure 6**

*Tukey’s HSD Python Code and Results*

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*Note.* Screenshot of Jupyter Lab notebook Python code and partial results of the Tukey’s HSD test.

Figure 7 shows a bar chart comparing the average fentanyl related death rates from 2013 through 2018 which highlights the difference between Region One and Regions Six, Seven, Eight, Nine, and Ten.

**Figure 7**

*Bar Chart Comparing Region One with Regions Six, Seven, Eight, Nine, and Ten*

A picture containing chart

Description automatically generated*Note.* This bar chart highlights the statistically significant differences in fentanyl related overdose death rates between Region One and Regions Six, Seven, Eight, Nine, and Ten. An animated version of this chart can be viewed on Tableau Public, see <https://public.tableau.com/profile/janice.gordon#!/vizhome/Capstone-OverdoseRatesbyHHSRegion/HHSFentanylOverdoseDeathRates>

# Discussion

## Results Analysis

The statistically significant regional differences found for fentanyl related overdose deaths in this study support the findings of Zoorob (2019) and Mars, Rosenblum, & Ciccarone (2019), which emphasize regional differences in fentanyl availability due to different illicit drug supply chains found in Northeastern and Western states. The different regional patterns in fentanyl related overdose death rates between the northeastern United States (Region One) and the west (Regions Six, Seven, Eight, Nine and Ten) are highlighted in Figure 8.

**Figure 8**

*Comparison of Regional Differences in Fentanyl Overdose Rates in 2013 and 2018.*

Map

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*Note.* The upper map shows the age adjusted average fentanyl related overdose death rates per 100,000 residents in 2013, highlighting only minor regional differences. The lower map shows the same data for 2018 showing the disparities between the northeastern HHS Regions and the Western Regions. These maps were created using Tableau Public and an interactive versions can be viewed at <https://public.tableau.com/profile/janice.gordon#!/vizhome/Capstone-Map/RegionsbyYear>

## Limitations

There are several limitations identified within the current study. First, the currency of data is lacking, as the MCD database contains data that is already two years old by the time it is vetted and shared with researchers and the public. More current data sources should be sought in order to do more timely analysis and make predictions to inform NIDA policy and research efforts. Second, death certificate data can have questionable accuracy unless an autopsy was performed, and are often reliant on medical opinion and differing state requirements (SAMHSA, 2018). Third, geographic analysis performed on the basis of artificial organizational boundaries which may not be the most informative method, as state, county, and urban areas may offer more detailed information.

## Recommendations

With the results of the analysis showing statistically significant differences between Region One and Regions Six, Seven, Eight, Nine, and Ten but no significant differences between any other pairs of Regions, further analysis of Region One is warranted. Region One contains states in New England (CT, ME, MA, NH, RI, & VT) and has had the highest overall fentanyl related overdose death rates in 2018 (24.8), 2017 (23.1), and 2016 (20.5). Future research could include more detailed state and county level analysis of both fatal and non-fatal overdose rates, demographic analysis, and analysis of drug seizure and trafficking data. Additional insights from highly affected areas could help identify risk factors and inform prevention efforts in other areas.

# Conclusion

Fentanyl related overdose deaths have rapidly increased, with over 31,000 deaths in 2018 alone (National Center for Injury Prevention and Control, 2020), making the work of NIDA critically important in the fight against opioid addiction. More research is required to understand the geographic disparities within the current wave of the opioid crisis. The goal of this research project was to determine if there were statistically significant differences in fentanyl involved overdose death rates between the ten different HHS Regions in the United States. ANOVA analysis results allowed the rejection of the null hypothesis, supporting the alternative hypothesis that statistically significant differences are found between Regions. A follow-up Tukey’s HSD test found that there were statistically significant differences between HHS Region One and Regions Six, Seven, Eight, Nine, and Ten. These results indicate that further analysis of fentanyl overdoses within Region One should be performed, with current and varied data sources in order to inform future research, funding, and overdose prevention efforts within NIDA.

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