The Public Health Burden of Diabetes: A Comprehensive Review

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The review of several diabetes epidemiological studies confirms that diabetes is one of the most prevalent non-communicable diseases globally, and it is the fourth or fifth leading cause of death in most developed countries. Diabetes prevalence ranges from nearly 0% in New Guinea to 50% in the Indians of Arizona. No modifiable risk factors have been clearly established in persons with type 1 diabetes, but major environmental determinants have been suggested. Impaired glucose tolerance, gestational diabetes, insulin resistance, obesity and lack of physical activity have been consistently identified as risk factors for type 2 diabetes. The prevalence of diabetes increases with age, but a sex-specific tendency has not been consistent. In addition, the prevalence of diabetes is higher in African-Americans and Hispanics when compared to other ethnic groups. Diabetes affects almost all organs of the body and is the leading cause of blindness and amputations of legs, imposing both clinical and economic costs to patients and society.

Key words: Diabetes mellitus, Puerto Rico, Prevalence, Epidemiology.

Diabetes has been recognized as a major public health problem in westernized countries, but the magnitude and impact of the problem remains unclear in Puerto Rico. The lack of comparable data in Puerto Rico has contributed to the inability to track diabetes mellitus effectively on a population basis.

Diabetes mellitus is a physiological disorder of carbohydrate metabolism. It is characterized by hyperglycemia and glycosuria, which results from the body's inadequate insulin production or response (1). Diabetes occurs when the body cannot make use of the glucose in the blood for energy because either the pancreas is not able to make enough insulin or the insulin that is available is not effective (2).

There are two main types of diabetes mellitus. In 1997, The American Diabetes Association Expert Committee recommended a new classification system. The type of diabetes that was known as type I, juvenile-onset diabetes, or insulin-dependent diabetes mellitus (IDDM) is currently classified as type 1 diabetes. The type of diabetes that was known as type II, non-insulin-dependent diabetes mellitus (NIDDM), or adult-onset diabetes is classified as type 2 diabetes. This new classification is an attempt to move away from basing the names on treatment or age at onset. This new system identifies two additional types of diabetes: other specific types (genetic defects of beta cell function, genetic defects in insulin action, diseases of the exocrine pancreas, endocrinopathies, drug or chemical induced, infection, uncommon forms of immune-related diabetes and other genetic syndromes) and gestational diabetes. The Expert Committee also establishes new criteria for diagnosis (3).

Diabetes can be associated with serious complications and premature death; however, persons with diabetes can take measures to reduce the likelihood of such occurrences (4).

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This project was supported by the Centers for Disease Control and Prevention, Program Development Branch, Division of Diabetes Translation, NCCDPHP, CDC, 4770 Buford Highway, NE, MS K-10, Atlanta, GA 30341.

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Risk Factors

No modifiable risk factors have been clearly established in persons with type 1 diabetes. However, changes in incidence over time, geographic patterns, twin studies, and seasonality are all suggestive of major environmental determinants. Orchard and colleagues have expressed that 70% to 95% of type 1 diabetes may be attributed to environmental causes including dietary practices and viral

exposures. For example, about 20% of people born with congenital rubella develop diabetes later in life (5). However, it seems that the seasonality factor is not a determinant in all countries or geographic areas. A study designed to describe the seasonal pattern of incident cases of type 1 diabetes, aged 17 years or less, at the University Pediatric Hospital in Puerto Rico demonstrated no significant seasonal differences See Table 1, p.128 (6).

Epidemiological studies have consistently identified a group of risk factors associated with type 2 diabetes. These risk factors have been classified in two major categories. The first category includes genetic factors and the second comprises medical and lifestyle risk factors such as: impaired glucose tolerance, gestational diabetes, hyperinsulinemia and insulin resistance, obesity and physical inactivity (7). Studies performed in several countries are consistent in associating a high body mass index (BMI), family history of diabetes, hypertension, high levels of cholesterol, history of gestational diabetes and dyslipidemia with increasing odds of developing diabetes (8-11).

Obesity is a major risk factor for type 2 diabetes and depends not just on overall weight, but also on the distribution of the weight excess (7). In terms of nutrition, substitution of refined-grain for whole-grain products may decrease the risk of diabetes mellitus. A prospective study of whole-grain intake and the risk of type 2 diabetes mellitus in U.S. women conducted by Liu and colleagues reported that age and energy-adjusted relative risks (RR) were 0.62 (95% CI= 0.53, 0.71) for whole-grain and 1.31 (95% CI= 1.12, 1.53) for refined-grain (12). It is estimated that between 20% and 90% of type 2 diabetes may be associated with obesity and much of this may be attributable to abdominal adiposity. Twenty-four percent of the incidence may be attributable to a sedentary-life (5).

Other important risk factor is age. The prevalence of diabetes increases with age with peak prevalence in the sixth decade of life, followed by a decline in the seventh decade. This decline is probably attributed to greater mortality in older diabetics. In some improved survival populations (i.e. some American populations) prevalence is highest in the oldest age-group (13). In a cross-sectional study designed to quantify the health status of the elderly population in some municipalities of Puerto Rico, Suárez and colleagues reported a diabetes prevalence of 23.2% (95% CI: 19.6%, 27.1%) in the elderly population (≥65 years old) (14).

The sex-specific prevalence of diabetes varies among geographic areas. Some studies have revealed a male excess in most ethnic groups living in Singapore, whereas a female excess has been reported in Pacific populations (13). Most studies have failed to establish statistically significant sex differences in all age groups, thus a sex-specific genetic tendency has not been consistent (13, 15).

Analysis of genetic risk factors has revealed that race or ethnicity increases the likelihood of diabetes. Several studies have reported that African Americans, Alaskan Natives, American Indians, Asian Americans, Hispanic Americans and Pacific Islander Americans are at higher risk of diabetes (4). The risk of type 1 diabetes is higher among Whites than among people of other races (RR = 1.4). In contrast, the risk for type 2 diabetes is higher among races other than Whites, such as African Americans (RR = 1.3), Hispanics (RR = 3.1) and Native American Indians (RR = 10.1) (5).

Investigation of risk factors among children living in Australia has found that the development of type 1 diabetes mellitus was significantly associated with higher paternal age and neonatal jaundice (16).

Prevalence Estimates

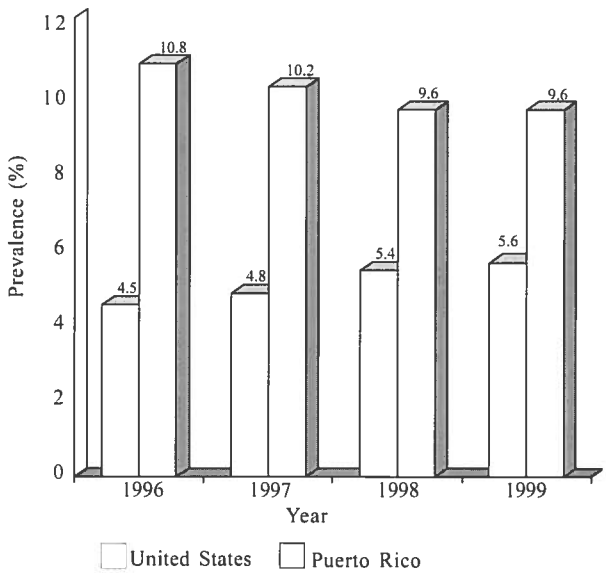
The review of several diabetes prevalence studies confirms that diabetes is one of the most prevalent non-communicable diseases globally, specially in developing and newly industrialized countries. It is estimated that 2.1% of the total world population may have diabetes, with type 2 diabetes accounting for 85 to 90% of all cases (17).

Analysis of the global estimates shows wide variations in the prevalence of diabetes in African, Asian, American, European and Pacific populations of the world. The age-adjusted type 2 diabetes prevalence estimates range from virtually 0% in Papua, New Guinea to over 50% in the Pima Indians of Arizona (18).

In the Americas, diabetes is also one of the most important public health concerns. Approximately 10% of cases are type 1 diabetes. The prevalence of type 1 diabetes is highly variable in the Americas. For example, the lowest rate is observed in Perú (0.7 per 100,000 population) and the highest rate in Prince Edward Island, Canada (27 per 100,000 population). The distribution of type 2 diabetes prevalence is also variable ranging from 1.4% in the natives of Mapuche, Chile to 17.9% in Jamaica (19). Table 1 summarizes clinical and epidemiological data of diabetes in Puerto Rico from 1966 through 2000.

In the United States non-Hispanic whites, black men and upper income Hispanic populations have a prevalence ranging from 3% to 10%. However, a high prevalence estimate (11-20%) has been observed in black women and most Hispanic groups residing in the U.S. (13). The Behavioral Risk Factor Surveillance System reported a nationwide median prevalence of 4.4%, 4.5%, 4.8%, 5.4%

and 5.6% for the years 1995, 1996, 1997, 1998 and 1999, respectively [See Figure 1] (20). This makes evident that diabetes prevalence has been increasing during the past years. According to the Centers for Disease Control and Prevention, it is estimated that about 5.4 million people have undiagnosed diabetes in the U.S., therefore the estimates provided by the BRFSS are probably underestimated (21).

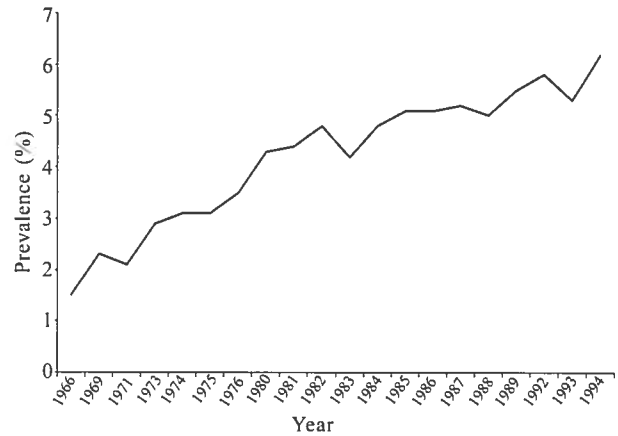


Source: Behavioral Risk Factor Surveillance System (BRFSS) data: 1996-1999. Centers for Disease Control and Prevention, Atlanta, Georgia

Figure 1. Self-reported prevalence of diabetes in the United States and Puerto Rico, 1996-1999

Diabetes in Hispanic Americans is a serious health challenge because of the increased prevalence of diabetes in this population, the greater number of risk factors for diabetes in Hispanics, the greater incidence of several diabetes complications, and the growing number of people of Hispanic ethnicity in the U.S. Diabetes is two to three times more common in Mexican Americans and Puerto Ricans than in non-Hispanics whites (7).

The Household Health Interview System, a population-based survey conducted in Puerto Rico, has shown that the prevalence of diabetes varies from 1.5 cases per 100 population in 1966 to 6.19 per 100 population in 1994, a four-fold increase during a 28 year period [See Figure 2] (22, 23). The Behavioral Risk Factor Surveillance System reported a weighted prevalence of 10.8% (95% CI: 9.2%-12.4%), 10.3% (95% CI: 9.1%-11.9%), 9.6% (95% CI: 8.2%-10.6%) and 9.6% (95% CI: 8.4%-10.7%) for the years 1996, 1997, 1998 and 1999, respectively [See Figure 1] (20). Frazer de Lladó and colleagues found a mean incidence of type 1 diabetes in Puerto Rican children from 1985 to 1994 of 18



Source: Household Health Interview Survey, Puerto Rico Health Department, 1966-1994

Figure 2. Self-reported prevalence of diabetes by year, Puerto Rico, 1966-1994

cases/100,000 children (95% CI: 17.6/100,000-18.3/100,000) with a slight female rather than male predominance (24).

Diabetes has increased sharply in many countries and by the year 2010 the total number of people with diabetes is projected to reach 221 million. It has been suggested that the prevalence may increase two to three-fold in regions such as Asia and Africa (17). In fact, countries such as Japan and Korea have experienced increases during the past decades with estimated prevalences as high as 8% in Koreans 30 years or older and 10% in Japanese over 40 years (25-26).

Complications

Diabetes affects almost all organs of the body. Complications of diabetes include: heart attack, stroke, peripheral artery diseases, kidney failure, blindness, cataracts, retinopathy, leg amputation, needle sensation and pain in the feet, poor circulation, diarrhea, impotence, urinary incontinence, dementia, excessive sweating, special risks to the fetus in pregnant diabetic women, diabetic ketoacidosis, coma, and life-threatening infections (27-28).

Diabetes is the leading cause of blindness (especially in the 20 to 60 age group), non-traumatic amputations of legs, renal failure, heart attack, stroke and impotence in the United States (27,29). Nearly 8,000 new cases of blindness and 50,000 foot or leg amputations are diabetes complications occurring in the United States every year (30).

People with diabetes are 17 times more prone to kidney disease; have two- to eighth- fold excess in cardiovascular disease, twice the prevalence of hypertension and about

twice the incidence of stroke compared to non-diabetics. However, neuropathy is probably the most common complication, being present in about 30 to 40% of diabetics (17). From January 1970 to October 1994, about 42% of patients under dialysis treatment in Puerto Rico had a diabetes diagnosis (31,32). From 1993 to 1998 the proportion of end-stage renal disease cases with diabetes as a primary diagnosis ranged from 34.8% to 44.0% (33).

Characteristics such as age, income and level of education affect the risk of diabetes complications. A two-year follow-up study (1991-1993) with data from a population-based survey in the Netherlands found that people with diabetes with a low level education have lower utilization rates of medical checkups and services relevant for diabetes care, and worst outcome in terms of complications (34). Also, the amputation rates in diabetic individuals increase with age and are higher in males than in females (35).

Clinical studies, based on medical records, conducted in Puerto Rico have shown an elevated frequency of diabetes mellitus in patients with cardiac anomalies. Colón and colleagues observed that a history of diabetes mellitus was present in 31.6% of octogenarian patients with coronary artery disease (36). Similar studies conducted among cardiac patients in the island have reported prevalences that range from 34% to 47% (37-39).

Complications from diabetes are resulting in increasing disability, reduced life expectancy and enormous health cost for virtually every society (17).

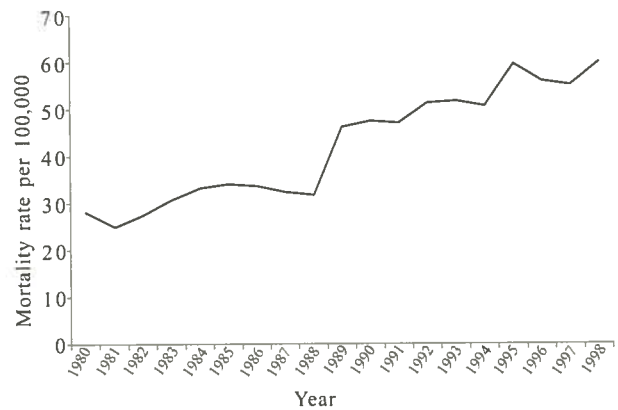
Mortality

A review of the global burden of diabetes reveals that it is the fourth or fifth leading cause of death in most developed countries, and there is substantial evidence that it is epidemic in many developing and newly industrialized nations (17).

A significant number of deaths in the United States each year can be attributed to diabetes. In 1993, approximately 400,000 deaths from all causes were reported in people with diabetes (40). Several studies have found deaths rates to be twice as high among middle-aged people with diabetes as among middle-aged people without diabetes.

Based on death certificate data, diabetes contributed to 193,140 deaths in 1996 in the United States. Diabetes was the seventh leading cause of death listed on U.S. death certificates in 1996, according to the CDC's National Center for Health Statistics. Diabetes is believed to be underreported on death certificates, both as a condition and as a cause of death (40).

Factors that influence the risk of early death in type 2 diabetes, which are similar for people with type 1 diabetes, includes the following: duration of diabetes, lack of blood glucose control, and cardiovascular risk factors such as smoking, hypertension, abnormal lipid levels, physical inactivity, and central obesity (40).



Source: Puerto Rico Vital Statistics Annual Report, Puerto Rico Health Department, Planning, Evaluation, Statistics, and Information System Auxiliary Secretary, San Juan, Puerto Rico, 1998.

Figure 3. Crude mortality rates of diabetes by year, Puerto Rico, 1980-1998

In Puerto Rico, diabetes has been consistently reported as the third cause of death from 1989 thru 1998, and crude death rates have been increasing from 46.1 per 100,000 population to 59.9 per 100,000 population [See Figure 3] (41).

Suárez and colleagues reported that the largest death rate in patients under dialysis treatment in Puerto Rico between January 1970 and October 1994 was attributed to diabetes (45.8%). In addition, the estimated median survival time for dialysis patients in Puerto Rico was significantly higher for males when compared to females (31.3 months versus 27.6 months for males and females, respectively) ($p < 0.01$). The largest estimated survival time (40.4 months, 95% CI: 32.1-52.0) was observed in the age group of <40 years and the lowest (23.8 months, 95% CI: 21.9-26.3) in people aged 60 years or older ($p < 0.01$) (31).

Diabetes Cost

Diabetes imposes both clinical and economic costs to patients and society (42). The economic burden of diabetes varies by region probably due to differences in disease burden and in economic and society structure. The total economic impact of diabetes in the U.S. increased from $92 billion in 1992 to $98 billion in 1997 (42-44).

Direct medical expenditures attributable to diabetes in 1997 in the United States was estimated to be $44.1 billion,

with $7.7 billion for diabetes and acute glycemic care, $11.8 billion due to related complications and $24.6 billion due to general medical conditions. Attributable indirect costs totaled $54.1 billion; $17.0 billion resulting from premature mortality and $37.1 billion from disability (42). Ford and colleagues reported that in 1994 diabetes cost for Wisconsin residents was $545 million or $150 per person (45). During 1988 and 1999 charges for diabetes-related hospitalizations in North Carolina was estimated to be $490 million or $73 per resident. In 1996 a study conducted in Texas estimated that $2.4 billion in indirect costs and $1.6 billion spent in direct costs were clearly or probably attributable to diabetes (15). Based on CDC data, the total cost of diabetes in North Carolina during 1990 was estimated at $1.2 billion (46).

The two most costly complications of type 2 diabetes are cardiovascular disease and renal disease, with two-thirds of diabetes-related expenditures spent by elderly people (42, 47). Economic cost of type 1 diabetes peak at time of disease diagnosis and at development of complications (48).

Diabetes patient education is an essential strategy for disease prevention but is expensive. A patient management study to discuss the cost of ambulatory education programs at the Children's Diabetes Management Center of the University of Texas found that outpatient education services require per patient, 2 to 4 hours from the physician, 10 to 12 hours from the nurse educator, and 2 to 4 hours from the dietitian. Using a conservative estimate, the total costs of these education services range from $500 to $800 per patient (49).

Another factor that contributes to the increase in diabetes-related costs is the labor productivity loss. A retrospective study conducted in Argentina found that the average productivity loss attributable to patients with temporary and permanent disability induced by diabetes was 11 years (50).

Prevention

Two basic approaches to primary prevention can be used. First, the population approach seeks to alter or eliminate lifestyle and environmental characteristics that are know risk factors for diabetes from whole communities or populations. Second, the high-risk approach narrows the focus to particular individuals or groups with a special high risk for developing diabetes (5).

Population screening for type 1 diabetes is not recommended because of the low frequency of disorder and the short time between the onset of the hyperglycemia and the onset of symptoms. In contrast, early control of hyperglycemia in type 2 diabetes may prevent or delay chronic complications (5). Preventive efforts in type 2 diabetes have focused on prevention of heart disease, stroke and other macrovascular events (51).

Community-based interventions must emphasize a low fat, high-fiber diet, cessation or prevention of cigarette smoking and promote regular physical activity, which is a protective factor against type 2 diabetes (5,7).

Conclusions

Diabetes is widely recognized as one of the leading causes of death and disability in the United States and its territories. It is also associated with long-term complications that affect almost every body organ. Diabetes is associated with very high rates of health care resource utilization, poor quality of life, increased work and school absenteeism, and increased mortality at younger ages.

Recent advances in diabetes research have led to improvements in patient management and treatment. Healthy eating, physical activity, oral hypoglycemic drugs, insulin via injection or an insulin pump, and blood glucose testing are the basic therapies and management tools for diabetes.

People with diabetes must take responsibility for their daily care, including keeping blood glucose levels from going too low or too high. People with diabetes should seek medical advice in order to learn to manage and self-monitor their condition. Intensive management with near normal blood glucose levels reduces and may prevent development of diabetes complications. Better ways of managing diabetes in pregnant women should improve chances of successful outcomes.

Health care providers and people with diagnosed diabetes need continuous education on the latest treatments, care and self-management of diabetes. The approach that will reach the largest number with people with diabetes and have the greatest impact on reducing cost involves working with health care systems to adopt state of the art diabetes education and treatment practices. Education on the psychosocial aspects of the disease must be also integrated into this effort to maximize its effectiveness.

Acknowledgment

We wish to thanks Dr. Myriam Allende-Vigo, Endocrinologist and Professor at the School of Medicine at the Medical Sciences Campus of the University of Puerto Rico, for reviewing the manuscript.

Table 1. Summary of Clinical and Epidemiological Data of Diabetes in Puerto Rico, 1966 – 2000

Author	Relevant Findings
Diabetes complications	
Suárez E, Pérez R, Burgos R et al., 1998 (31)	• Diabetics and the elderly had the lowest survival rates in patients under dialysis treatment due to end stage renal disease in the Puerto Rican population.
Pérez R, Suárez E, Burgos R et al., 1997 (32)	• 41.7% of people treated for dialysis in Puerto Rico between 1970-1994 had diabetes.
Aguiló F, Allende M, Altieri P, 1985 (28)	• A prospective study of 34 type 2 diabetics over a 14 year period revealed that 22 patients (62%) had clinical and/or ECG-VCG abnormalities compatible with coronary artery disease (CAD).
Clinical studies based on medical records	
Colón G, Pérez C, Guzmán M, 2000 (36)	• A history of diabetes mellitus was present in 31.6% of octogenarian patients with coronary artery disease.
Viruet E, Cox R, Pérez C, et al., 2000 (37)	• A history of type 2 diabetes was documented in 39.5% males and 46.7% females who underwent coronary stenting.
Pérez C, Guzmán M, Cox R, 1998 (38)	• The medical history of patients aged 20 to 80 years who underwent cardiac catherization and coronary agiography revealed that the prevalence of diabetes mellitus was 34.8%. • In patients with angiographic evidence of coronary artery disease, diabetes mellitus (41.3%) was a predominant risk factor.
Guzmán M, Pérez C, 1998 (39)	• A history of type 2 diabetes was observed in 46.5% of patients undergoing coronary artery bypass grafting (CABG).
González de Pijém L, Cintrón C, Carrión F, et al., 1986 (6)	• On average, there were 27 (SD: 5.3) newly diagnosed type 1 diabetes cases per year. • Sex distribution fails to demonstrate a male predominance. • No significant seasonal differences in the prevalence of type 1 diabetes were noted.
Diabetes prevalence studies	
Centers for Disease Control and Prevention (CDC), 1998 (4)	• Weighted prevalence of diabetes, reported by the Behavioral Risk Factor Surveillance System, in Puerto Rico was 9.6%.
Suárez E, Oliver M, De Andino R et al., 1999 (14)	• The self-reported diabetes prevalence was 23.2% (95% CI: 19.6%, 27.1%) in the elderly (≥65 years) population residing in the University Region of Puerto Rico.
Oliver M, Suárez E, De Andino R et al., 1999 (53)	• Sex-specific prevalence of diabetes for the elderly was 22% and 23.5% for males and females, respectively.
Frazer de Lladó T, González de Pijém L, Hawk B, 1998 (24)	• Mean incidence of IDDM, in children ≤14 years of age living in Puerto Rico, from 1985-1994 was 18/100,000 children per year (95% CI: 17.6/100,000-18.3/100,000). • No significant differences were found in the incidence rates in different areas or seasons of the island.
Haddock L, Torres de County I, 1991 (23)	• Diabetes prevalence, obtained from the Household Health Interview Survey, showed an increasing trend from 3.1% in 1975 to 5.1% in 1986.
Villavicencio E, Badillo C, Morales P, 1966 (52)	• Data from a screening program from the Department of Health of Puerto Rico, based on persons who voluntary go for testing, revealed a prevalence of 7.6%, 12.1%, 6.1% and 9.6% in 1959, 1960, 1961 and 1962, respectively.
Diabetes mortality studies	
Pérez R, Pérez C, Suárez E, 2001 (54)	• From 1980 through 1997 diabetes mortality has been markedly increasing in Puerto Rico, primarily in persons aged 65 years or more.

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