Determinants for the persistence of canine rabies in the Sierra Madre Occidental of Sinaloa

Determinantes da persistência da raiva canina na Sierra Madre Ocidental de Sinaloa

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RESUMO
Para determinar as causas da persistência da raiva canina na área ocidental de Sierra Madre do Estado de Sinaloa, foram analisadas informações científicas e oficiais disponíveis de diferentes organizações e secretarias relacionadas à casuística de casos de raiva em cães e animais selvagens, apresentados no período compreendido entre os anos de 1993-2020. As informações sobre as características das áreas rurais foram integradas para identificar as condições geográficas, a biodiversidade da fauna, os aspectos culturais e a idiossincrasia dos habitantes dessas comunidades, caracterizadas por atividades ilícitas como plantio, colheita e tráfico de drogas, e foi realizado estudo descritivo. O registro de casos positivos de raiva canina e fauna silvestre durante o período 1993-2020 foi de 17 casos. A identificação e caracterização das variáveis do vírus da raiva tem sido alcançada de acordo com o avanço das técnicas de biologia molecular. A aplicação do biológico antirrábico para cães e gatos pelos Serviços de Saúde de Sinaloa, em determinadas áreas são de alto risco e até inacessíveis e animais vulneráveis à doença podem ser infectados com o consequente risco para os seres humanos.

Palavras-chave: Determinantes, raiva, cães, fauna.
ABSTRACT
To determine the causes of the persistence of canine rabies in the Sierra Madre Occidental in State of Sinaloa, scientific and official information available from the different organizations and Secretaries related to the cases of rabies in dogs and wildlife was analyzed, presented in the period between 1993-2020. Information on the characteristics of rural areas was integrated, to identify the geographical conditions, biodiversity of wild fauna, cultural aspects and the idiosyncrasy of the inhabitants of these communities characterized by illicit activities such as planting, harvesting and drug traffic. We carried out an analytical, cross-sectional, retrospective and descriptive study. The registry of positive cases of canine rabies and wildlife during the period 1993-2020 was 17 cases. The identification and characterization of the rabies virus variables has been achieved in accordance with the advancement of molecular biology techniques. The application of biological anti-rabies for dogs and cats by the Sinaloa Health Services, in certain areas are high risk and even inaccessible, animals vulnerable to the disease can become infected with the consequent risk to humans.

Keywords: Determinants, rabies, wildlife, canines.

1 INTRODUCTION
Rabies is a zoonotic disease, almost invariably fatal, once neurological symptoms appear, it presents as an acute viral encephalomyelitis that affects all homoeothermic mammals, rabies has a worldwide distribution in the continental regions of Africa, Asia and the Americas, but some countries are free of the disease (OMS, 2018). In Asia, are estimated 30,000 annual deaths from this cause and more than three million people are exposed to canine rabies each year. India, Nepal, Sri Lanka, Bangladesh and Pakistan are the most affected areas (Frantchez & Medina, 2018; Beck et al., 2017; Hampson et al., 2015; Wilde et al., 2013). In Africa, there are an estimated 24,000 annual deaths, most in impoverished rural communities with a high percentage of children. Angola, Namibia, Mozambique, Zimbabwe, South Africa and Zambia are considered high risk areas (Scott et al., 2015). The dog is the main source of human deaths from rabies, contributing to 99% of all rabies transmissions to humans, each year post-bite vaccines are administered to more than 29 million people worldwide; thousands of deaths from rabies are prevented in this way. The global economic burden of dog-mediated rabies is estimated at US $8.6 million per year (OMS, 2020). In Latin America, around 44 million dogs are vaccinated annually and approximately 1 million people at risk of contracting the disease are treated, of which 25% receive post-exposure treatment. For diagnosis and surveillance, more than 100 national and regional laboratories make up the network for diagnosing rabies (OMS, 2020). Approximately 5,000 cases of animal rabies are reported to the CDC annually, and more than 90% of those cases occur in wildlife. The main reservoirs of rabies in the United States today include bats, raccoons, skunks, and foxes (CDC, 2020). Rabies in Mexico continues to be priority in the Mexican Health System, the application of more than 18 million doses during the year 2020, the National Vaccination Campaigns for dogs and cats maintained uninterruptedly for more than 30 years contributed greatly to the certification of México as area free
of canine rabies in its variant V1 (dog), thus becoming the first country in the world to obtain this distinction, however, the circulation of rabies virus is perpetuated in wildlife, Until now, it continues without control despite efforts to vaccinate cattle and campaigns to control hematophagous bats. The first cases of human rabies transmitted by hematophagous bats, reported outside the island of Trinidad, were reported in April 1951 by Dr. H. Larín Landa, of the Coordinated Health and Assistance Services, in the state of Sinaloa (Malaga, 1956) “An angry bat attacked, at dawn, while they were sleeping, 13 people. Ten were bitten: nine children and one adult. Four children and the adult showed typical symptoms of paralytic rabies 2 to 4 weeks after the date of the bite. All died a few days after the onset of the disease”. The importance of continuing with the massive rabies vaccination campaigns in domestic animals and mainly in areas of difficult access in the Sierra Madre Occidental of the state of Sinaloa are essential for the control of the disease. The presentation of cases in domestic dogs and cats is of great relevance since humans have a close coexistence with these animals. In most other parts of the Americas, hematophagous bats are the main source of human rabies cases. Vampire bat rabies is also one of the main causes of livestock mortality, affecting both subsistence and commercial farmers throughout the range of this bat from Argentina and Uruguay to northern Mexico (OIE, 2016; Johnson et al., 2014). Rabies is caused by the virus, Rabies Lyssavirus, (family Rhabdoviridae) and is the only one reported in America (Johnson et al. 2010), nine antigenic variants of this genotype have been observed in Mexico (Constantine, 2009; Velasco et al., 2006), the disease is maintained in two epidemiological cycles, urban and wild, in urban dogs are the main reservoir host, while wild mammals mainly bats, skunks, foxes, coyotes and infected raccoons among others is common for hematophagous bats to cause disease in domestic species of economic interest, mainly cattle, causing bovine paralytic rabies, so contact with the saliva and offal of these animals can also cause disease in humans (Heymann, 2005), rabies occurs mainly in underserved populations, both rural and urban, and has been documented for more than 4,000 years (Tarantola, 2017), vaccination campaigns constitute the main strategy for rabies control by interrupting rabies transmission between dogs and reducing transmission to humans and other mammals.

2 MATERIAL AND METHODS

Location.- The state of Sinaloa is located northeast of the Mexican Republic and is located at the extreme geographic coordinates 27°02′32″ north, 22°28′02″ south latitude; to the east 105°23′32″, to the west 109°26′52″ of west longitude, its Capital is Culiacán de Rosales, its territorial percentage represents 2.9% of the surface of the country, it borders to the north with Sonora and Chihuahua; to
the east with Durango and Nayarit; to the south with Nayarit and the Pacific Ocean; to the west with the Gulf of California and Sonora (Figure 1) INEGI (2022a).

Its constituted for 18 municipalities that comprise an extension of 57,377 km2, the relief is divided into two large zones: the Pacific Coastal Plain and the Sierra Madre Occidental, the state area by type of climate and percentage indicates that 37.14% of the territory has a warm sub-humid type with summer rains A(w), 21.27% semi-dry very warm and warm BS1(h'), 18.56% dry very warm and hot BS0(h'), 11.02% semi-warm sub-humid with summer rains ACw, 9.75% very dry very hot and hot BW(h'), Temperate sub-humid with summer rains C(w) 2.26%, (Figure 2), INEGI (2022b). The annual temperature of the state is around 25 °C, the average minimum temperatures are around 10.5 °C in January and the average maximum can be higher than 36 °C during the months of May to July. The rains occur in the summer during the months of July to September, the average rainfall in the state is 790 mm per year. Under the criteria established in the classification system of the types of vegetation of the Sierra Madre Occidental in the state of Sinaloa, a series of plant communities can be found that are closely related to the type of climate that exists in the region, such as low deciduous forest, medium subdeciduous, oak forest, oak-pine forest, xeric scrub, grassland, mangrove and dunes (INEGI 2015).

Figure 1 - Sinaloa map of the United Mexican States
Obtaining the data. - Through the compilation and integration of information from scientific and official articles, available, from the different organizations and Secretaries related to the casuistry of rabies cases and their follow-up. The search period comprised the years from 1993 to 2020. The information on the cases and the characteristics of the rural areas in the Sierra Madre Occidental region in Sinaloa were analyzed to identify the geographical conditions, the variety of fauna, the cultural aspects and activities carried out by the population for their subsistence. This is an observational, cross-sectional, retrospective and analytical study.

3 RESULTS AND DISCUSSION

In the state of Sinaloa there have been no cases of human rabies transmitted by dogs (variable V1) since 1986, according to the information located during the period 1995-2020, two cases of human rabies were reported to the Sinaloa Health Services, one during the year 1999 and the second in the year 2008 (DGIS, 2021), both caused by wild animals. The last case of canine rabies was diagnosed in 2017, where two people were involved due to the aggression of the dog, the characteristics of the entity, its great variety of wildlife, the conditions of the ecosystems and illegal activities outside of control of all authorities such as the planting, harvesting, trafficking and processing of drugs make inaccessible mountain areas of the entity that are dedicated to this illicit, thus preventing pets from being vaccinated, by the personnel assigned for that purpose. by the State Health Services lay at risk the inhabitants of those areas where the anti-rabies vaccination of dogs
and cats is limited. According to the information reviewed during the search period, it is observed that during the period 1993-1999 no reliable records were found from the regional diagnostic laboratories of the Sinaloa Livestock Union, these were responsible for diagnosing rabies, in all the animal species, lack of equipment maintenance and financial support finally made them disappear.

During the period 2000-2020, records of positive cases of rabies were found by the National Epidemiological Reference Laboratory InDRE, identifying the antigenic variant of the virus, registering 17 cases of rabies in wild animals and dogs. The skunk represents the highest percentage of cases with 7 (41%), followed by dogs with 4 (23.5%), the lynx with 3 (17.6%), the fox with 2 cases (11.7%), and a positive sample of bat (5.8%) (Table 1).

<table>
<thead>
<tr>
<th>Number InDRE</th>
<th>Case number</th>
<th>Species</th>
<th>Date</th>
<th>Municipality</th>
<th>Variable</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1534</td>
<td>(9) VAR-106</td>
<td>lynx</td>
<td>03/05/2000</td>
<td>Sin dato</td>
<td>V-7</td>
<td>No</td>
</tr>
<tr>
<td>1535</td>
<td>(11) VAR-107</td>
<td>skunk</td>
<td>03/05/2000</td>
<td>Tamazula</td>
<td>V-1</td>
<td>No</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>lynx</td>
<td>10/01/2001</td>
<td>Mocorito</td>
<td>V-7</td>
<td>No</td>
</tr>
<tr>
<td>231</td>
<td>VAR-8</td>
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<td>30/01/2001</td>
<td>Culiacán</td>
<td>V-1</td>
<td>No</td>
</tr>
<tr>
<td>641</td>
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<td>21/02/2001</td>
<td>Mocorito</td>
<td>V-1</td>
<td>No</td>
</tr>
<tr>
<td>11</td>
<td>VAR-001</td>
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<tr>
<td>948</td>
<td>VAR-46</td>
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<td>V-7</td>
<td>No</td>
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<tr>
<td>5042</td>
<td>VAR-293</td>
<td>Humano</td>
<td>29/09/2004</td>
<td>Escuinapa</td>
<td>V-8</td>
<td>No</td>
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<tr>
<td>935</td>
<td>VAR-049</td>
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<td>24/02/2005</td>
<td>Ahome</td>
<td>V7</td>
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<tr>
<td>4192</td>
<td>2636</td>
<td>skunk</td>
<td>30/06/2005</td>
<td>El Fuerte</td>
<td>VI</td>
<td>No</td>
</tr>
<tr>
<td>7809</td>
<td>VAR-500</td>
<td>canideus</td>
<td>01/12/2005</td>
<td>Culiacán</td>
<td>V7</td>
<td>No</td>
</tr>
<tr>
<td>2053</td>
<td>VAR-140</td>
<td>Zorro</td>
<td>20/04/2006</td>
<td>Badiraguato</td>
<td>V-7</td>
<td>No</td>
</tr>
<tr>
<td>1384</td>
<td>13998</td>
<td>chiropteran</td>
<td>26/02/2008</td>
<td>Guasave</td>
<td>ND</td>
<td>sample is over</td>
</tr>
<tr>
<td>3985</td>
<td>VAR-348</td>
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<td>29/05/2008</td>
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<td>atypical</td>
<td>No</td>
</tr>
<tr>
<td>889</td>
<td>VAR-195</td>
<td>skunk</td>
<td>25/02/2009</td>
<td>Culiacán</td>
<td>V-1 del norte</td>
<td>No</td>
</tr>
<tr>
<td>1589</td>
<td>52-R</td>
<td>skunk</td>
<td>30/03/2010</td>
<td>El Fuerte</td>
<td>atypical</td>
<td>No</td>
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<tr>
<td>1549</td>
<td>SIN-15-47606</td>
<td>lynx</td>
<td>09/06/2015</td>
<td>Choix</td>
<td>V-7</td>
<td>sent by LESP Chihuahua</td>
</tr>
<tr>
<td>1243</td>
<td>SIN-2017013597</td>
<td>canideus</td>
<td>12/07/2017</td>
<td>Badiraguato</td>
<td>V-1 del norte</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: Institute of Epidemiological Diagnosis and Reference (InDRE), 2020.
Regarding this information, all the cases are related to contacts or aggressions against humans, in the case of the dogs they did not have an anti-rabies vaccine. In most cases additional information was obtained; In 2004, a case of a three month old puppy dog infected with variable V7 Arizona fox was recorded in the City of Culiacan, (CANACO subdivision north of the city), the origin of the infection could not be established and the owners reported that the puppy never left the city of Culiacán, no other puppy presented the disease, the pet remained in the courtyard of the house, so it is inferred that it could have been attacked by a chiropteran. In 2008 in the locality of San Antonio de las Juntas (Badiraguato) there was a case of rabies in an unvaccinated dog, in the Sierra Madre Occidental and can only be accessed by horse, mule walking. The last positive case for a dog in 2017 in the locality of Santa Cruz, municipality of Badiraguato. All cases of animal rabies have been diagnosed in rural areas of the Sierra Madre Occidental of Sinaloa, both in wild animals and in dogs, except for one registered in the CANACO subdivision within the peripheral area of the city of Culiacán. The air cycle of rabies in Sinaloa continues and has been evidenced by the identification of cases in bats, 2019 Los Zapotes locality, Mazatlán municipality, 2012 Cerro Cabezón locality, Guasave municipality, 2020 Limón de los Peraza municipality of San Ignacio, these diagnoses were made in the National Service of Health, Food Safety and Quality (SENASICA).

Zoogeographic Determinants.- In the Sierra Madre Occidental de Sinaloa there are canyons and hills, it is inclined with falls that go down to 1,000 meters and has mountains with a height greater than 2,500 meters above sea level. The Sierra Madre Occidental covers 59.5% of the state surface, covering a little more than the eastern half of the state, from the extreme north to the extreme south. It has 14 surface rivers that originate in the Sierra Madre Occidental and cross the entity to empty into the Gulf of California and others into the Pacific Ocean. There are also 11 dams and countless small bodies of water, it has a large number of caves and 98 registered mines where silver, gold, copper, kaolin, barite, gypsum, halite, talc, molybdenum, among others, are obtained, an indeterminate number of abandoned mines that serve as a refuge for various mammals. Sinaloa has a very important ecological value, because it is located in a transition zone between two biogeographic regions of America, the Nearctic and the Neotropical, causing a high wealth of animal species that converge in this region (Martínez, 2003; Reyna, 2003; Zunino y Zullini 2003). The wildlife inventory consists of 855 species, 117 mammal species (bats 52 species), 487 birds, 37 amphibians, 114 reptiles and 100 fish (INEGI, 2014; SERMANAT, 2022). It also has one of the five caves most populated by bats in Mexico, near the locality of Topolobampo, an approximate population of 3 million bats is estimated. Bats and small carnivores play a preponderant role in
maintaining the cycle of wild rabies. Sinaloa has the greatest diversity of bats for northern Mexico, since it is located between areas of great orographic heterogeneity with the coast and mountains, causing the existence of a great mosaic of habitats, since they exist from coastal plains to high parts of the Sierra Madre Occidental and all types of vegetation associated with them (Álvarez, 2000). According to these characteristics, some species of bats recorded in Sinaloa migrate from northern Mexico to the southern United States during the summer, in order to take advantage of the abundance of food and thus extend the chances of survival of the offspring, is estimated that 90% of individuals are pregnant females (Medellín et al., 2009). In temperate environments, the primary reservoirs that maintain rabies are carnivores and insectivorous bats (Belotto et al., 2005) however, in tropical environments, the vampire bat (Desmodus rotundus) is the main reservoir responsible for its transmission (Lee et al., 2012; Constantine, 2009). The main genera of bats in Sinaloa are: Anoura, Artibeus, Balantiopteryx, Centurio, Choeroniscus, Choeronycteris, Chiroderma, Desmodus rotundus (only of the genus), Dermanura, Eumops perotis (only of the genus). In Mexico, positive cases of rabies were reported between 1996 and 2002, with a total of 112 corresponding to: 52 in bats such as the species Desmodus rotundus, Lasurius cinereus and Tadarida brasiliensis mexicana (46.4%), 26 in skunks (23.2%) of the species Spilogale putorius and Mephitis mephitis, 7 in foxes (6.2%), 7 in raccoons (6.2%), 4 marsupials (3.6%), 4 deer (3.6%), 3 badgers (2.7%), 3 wild cats (2.7%), 2 coyotes (1.8%), 2 agouti (1.8%) 1 coati (0.9%) and 1 squirrel (0.9%) (SAPI, 2018; Jiménez 2009).

**Small carnivores.**- In the case of mammals, in Sinaloa there are 127 species and 141 subspecies, belonging to 77 genera, 30 families and 8 orders. Of which 2 genera and 24 species, which are endemic to Mexico, are distributed throughout the state (Hortelano et al., 2016; Álvarez, 2000). Among the most susceptible to rabies transmission are skunks with Mephitis macroura (striped skunk), Spilogale gracilis (spotted skunk), Spilogale pygmaea (pygmy skunk), Procyon lotor (raccoon), Pecari tajacu (collared peccary), Herpailurus yagouaroundi (jaju, ounce, leoncillo or breñero lion), Taxidea taxus (badger), Leopardus pardalis (ocelot), L. wiedii (tigrillo), Panthera onca (jaguar), Lynx rufus (american lynx), Nasua narica (coati), Urocyon cinereonigrorus (gray fox) Canis latrans vigilis (coyote) Canis lupus baileyi, (Mexican wolf), for the order Carnivora, diversity was 21 species (Wilson y Reeder, 2005; González et al., 2002; Gonzáles, & Sosa, 2001; Armstrong et al., 1972; Ramírez et al., 1986). This great variety of animal species are distributed in the Sierra Madre Occidental area, where human settlements are established in the most inaccessible areas.
Socioeconomic determinants.-State of Sinaloa has been identified in Mexico and many countries in the world for its association with drug production, the information found refers us to migrations which have facilitated the continuous flow of ideas, social practices, music, races in general, of everything that has to do with the human being. In that sense, to understand the current moment in Sinaloa, it is essential to consider Chinese migrations to the territory of that Mexican Pacific state (Fernández, 2010). Lai Chang Wong, a chinese immigrant who was born around 1869 in Hong Kong and who arrived in Mexico in 1911, is one of the precursors of the cultivation of poppy and other drugs in Sinaloa. He converted to Christianity and was baptized as José Amarillas, he had knowledge in medicine, he set up an consulting room in the location San José de la Puerta, Badiraguato and there he worked as a healer, for his 'remedies', he began to cultivate cabbage, radishes, lettuce, tomatoes and "those unknown flowers then", poppies were one of the raw materials for his natural medicine, he knew the narcotic and healing powers of opiates (Enciso, 2014). The origin of drug trafficking was due to the transmission of knowledge about opium from the chinese to peasants, the cultivation of the drug meant a real possibility to counteract unemployment. During the government of Porfirio Díaz (1876-1911) opium had already reached a high level of consumption and its figures ranged, only in the period 1888-1911, between 800 kilograms and 12 tons that were used in the form of laudanum (a mixture of alcohol tincture with opium) and other opiate compounds, which "was legitimate and usual" (Astorga, 2005). Cocaine was used for medicinal applications and was readily available without causing problems; Thus, the substances considered until today as prohibited drugs, were not distinguished from medicines, until the 1920s, there was no problem, pills, remedies and tonics, prepared with pure drugs, cocaine powder, opiates, among others (del Bosque et al., 2014).In the late 1930s and early 1940s, in addition to the chinese, the sinaloans were also involved in poppy planting, harvesting, and trafficking. The poppy began to be planted in the surroundings of Santiago los Caballeros, a community belonging to the municipality of Badiraguato, in the Sierra Madre Occidental, whose location offered a safe haven for poppy growers. The cultivation of the drug meant a real possibility to counteract the unemployment that afflicted the miners "El Prospecto" (mine located in El Tabachín, Badiraguato) was no longer enough (Fernández, 2010). During the conflict of the second world war (1940-1945), opium and its derivatives became scarce, causing consumer demand for opium, morphine, and heroin to increase, creating a very lucrative market, which in turn generated "many signs of speculative participation among mexicans." (Trujillo, 2017; Schantz, 2012), the United States had a very important participation in this conflict and Mexico got involved from two aspects: the military, and the cultivation of drugs for the pharmaceutical industry. This last aspect is the controversial one, since from those years a new stage in the history of drugs begins in Mexico and
especially in Sinaloa, it was directly involved in the cultivation of drugs to supply the international market, specifically the north American, the great economic profits from the sale of opium moved members of the "cosa nostra" to Mexico in order to convince the authorities to become the main producer and supplier of opium poppy in that nation, after visiting states such as Sinaloa, Sonora, Nayarit and Baja California and to distribute large amounts of money, they obtained the approval they wanted (Marino, 2003; Smith, 2013). The official fight against the opium trade began on January 8, 1925, when legal frameworks were established to restrict the use of opium, marijuana and cocaine, through the Geneva Agreements; but on July 3, 1940, the same agreements promoted with so much effort were violated and the decree was suspended, as a result of the war, promoting the production of opium in Badiraguato and Culiacán (Montoya, 2006). These historical events and their continuity to the present, together with the orographic characteristics of the state, make it difficult to access some areas, for the application of biological antirabies, together with the great variety of wild mammals distributed throughout the entire Sierra Madre Occidental that spread the infection.

As an alternative to reduce the number of unvaccinated dogs and cats, it has been to establish contact with City Councils, Municipal Trustees and Ejidal Commissioners in order to establish coordination to make antirabies biological available for application in those areas, however there is no certainty of that the vaccines reach their final destination and are applied.

4 CONCLUSIONS

After analyzing the exceptional characteristics of the Sierra Madre Occidental of the state of Sinaloa, there is a potential risk for the presentation of rabies cases in dogs and cats caused by viruses of wild animal species and with it a risk to humans, added to this direct attacks on humans by wild animals without requesting medical attention for the attack, fear of the authorities or ignorance of the possible transmission of rabies by wild animals. The last case of canine rabies was registered during the year 2017, adequate coverage of rabies vaccination in dogs and cats in these areas is difficult to do, represents risks for the physical integrity of health personnel and is beyond their reach to apply the vaccines.

No Conflicts of interest.
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