



## A STUDY ON RISK OF COVID-19 INFECTION IN COMPLICATIONS OF DIABETES PATIENTS USING BAMs\*

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Article History: Received: 22.04.2023

Revised: 05.06.2023

Accepted: 26.07.2023

### Abstract

COVID-19 is an infectious disease which was identified in the year 2019 as a life-threatening disease by World Health Organization (WHO). It is been identified that about 15-25 percent of the people who is affected by COVID-19 are diabetes patients. Evidence says that diabetes patients have more risk of severe COVID-19 complications. From the study of WHO about 8-9 percent of the world population has diabetes in the year 2019. In this article, we analyze the complications of diabetes with the medical conditions that can increase the risk of corona virus infections using Bidirectional Associative Memory (BAMs).

**Keywords:** Fuzzy logic, synaptic connection matrix, fuzzy neural network, Bidirectional Associative Memory, COVID-19, Diabetes.

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DOI: 10.31838/ecb/2023.12.s3.753

### 1. Introduction

COVID-19 was recognized in Wuhan in the year 2019. In March 2020, WHO declared it is pandemic. It is caused due to the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). COVID-19 is most likely to affect the persons with

chronic obstructive pulmonary disease, diabetes, cardiovascular disease, kidney disease, and overweight or obesity. The earlier study tells that about 25 percent of people who affected by covid-19 had diabetes. The diabetes patients has high danger for COVID-19 complications. Because the diabetes weakens the immune system in our body and it makes our body weak to fight with infections [7]. One get COVID-19, the infection could put him at larger risk for diabetes difficulties like diabetic ketoacidosis (DKA). DKA occurs if the high levels of acids called ketones build up in our blood. Awadhesh Kumar pursued to analysis the data concerning the relation among diabetes and COVID-19, pathophysiology of the disease in diabetes

and supervision of affected role with diabetes who grow COVID-19 infection [7]. Peric stated that the diabetes mellitus influences to a severe course of the disease and increase the COVID-19 death because of pulmonary and cardiac participation [14]. Alireza reviewed the indication about diabetes and COVID-19 outbreak over an efficient evaluation and meta-analysis method [9].

## **2. Diabetes**

Diabetes mellitus is generally named as diabetes, is a metabolic illness. Which is the high blood sugar lever for a prolonged period of time. The hormone insulin transports sugar from the blood into our cells which is deposited or used for energy [5]. But for a person with diabetes the body fail to make enough insulin or doesn't use the insulin effectively. The different types of diabetes and causes are as follows:

### **Type 1 diabetes**

type 1 diabetes is known as a autoimmune disease. Around 10 percent of persons with diabetes having this type of diabetes. The cells in pancreas are destroyed by the immune system reasons type 1 diabetes.

### **Type 2 diabetes**

Type to diabetes happens if our body becomes resistant to insulin, and sugar develop in our blood. Obesity, genes and physically inactive will cause this type 2 diabetes [6].

### **Prediabetes**

If our blood sugar level is greater than its usual level and it is not high enough to diagnose diabetes, then it is called prediabetes.

### **Gestational diabetes**

During pregnancy the blood sugar level increases and higher than the normal level for certain women this medical condition is called gestational diabetes.

### **Diabetes Insipidus**

If the human body cannot produce ADH (Antidiuretic hormone), which leads to an imbalance of fluid in the body. This leads to an enormous amount of urine in the kidney.

### **2.1 General Symptoms Associated to Diabetes**

The symptoms associated to the diabetes patients are as follows:

- Increased thirst
- Increased hunger
- Extreme tiredness
- Loss of weight
- Blurred vision
- Sores that do not heal.

The child with diabetes has the following symptoms:

- Difficult in sleeping
- Fever
- Vomiting sensation
- Constipation
- Slow growth
- Weight reduction
- Bed-wetting

### **2.2 Complications of Diabetes**

High blood sugar level cause damage organs and tissues in our body. Complications of diabetes develop gradually in our body and damages eye, kidney, heart, skin condition, nerve problem etc.. It is a life threatening disease at some level [9]. The major complications are given as follows:

#### **• Neuropathy**

High sugar level wound the capillaries that nourish our nerves. This can cause pain in the tips of the toes and fingers. The sense of feeling in the affected limbs will reduce if it is left without treatment. Which can also damage the nerves related to digestion and leads to digestion problems.

#### **• Kidney Damage**

Diabetes may damage the blood vessels in the kidneys that separate the waste in our

blood. This can lead to kidney disease such as kidney failure.

- **Retinopathy**

Diabetes can damage the blood vessels of retina can be affected by diabetes. This may cause blindness. And diabetes may also cause other vision problems like cataracts and glaucoma.

- **Cardiovascular disease**

Diabetes patients have more risk in heart disease or a stroke than the people do not have diabetes. It also leads to chest pain, stroke and atherosclerosis.

- **Skin Problems**

Diabetes increases the risk level of skin complications like bacterial infections, fungal infections, itching diabetic dermopathy, etc.

- **Ketoacidosis DKA and Ketones**

If our blood glucose level is very low, our body start to burn fat for energy and which will produce ketones. when the ketons level is high in the blood it makes acidic. The high level of ketons affect out body like a poison do and it will develop Diabetes Ketoacidosis. This may lead to comma and even death.

### 2.3 Test of Diabetes

- **Fasting blood sugar test**

This test is effective test used to test the blood glucose level in the body. It is done after overnight fasting. If the blood sugar level is less than 100 mg/dL then, the sugar level is normal. Blood sugar level from 100 to 125 mg/dL then, it is called prediabetes. If the blood sugar level is greater than or equal to 126 mg/dL then, it is diabetes.

- **HbA1C test**

HbA1C test measures the rate of glucose joined to hemoglobin and the protein that transfer oxygen in red blood cells. If one has a higher glucose level then, there are more hemoglobin with sugar attached to it.

A1C level of more than 6.5% has diabetes. An A1C level from 5.7 to 6.4 percent results prediabetes. less than 5.7 is said to be normal.

- **Complete Blood Count test (CBC):**

This test is used to identify different health issues, anemia, leukemia and blood sugar. It analyses several components of the blood, including WBC, RBC hemoglobin, hematocrit, the ratio of plasma in one's blood that plays a vital role in clotting blood. The notable change in the cell count showed in the CBC test may result that the person is under a medical condition that needs to be diagnosed.

- **Cholesterol test:**

diabetes patients to be tested for cholesterol level in more frequently since they have the risk of heart disease.

- **PPBS test (Post Prandial Glucose Test):**

One can usually take this test after meal. It measures the blood glucose level in the blood, which is a particular type of sugar. Blood glucose level increases after having food. This causes the pancreas to release insulin that helps in expelling the glucose from our blood and gives energy to our body. The people with diabetes, their blood may cannot react to insulin. This can affect the kidney, nerves, eyes and increase tension.

The above are the major test used to identify the diabetes. The other test that can be advisable for the diabetes patients are:

- **Triglycerides test**

It is a fat which is present in the blood. If the triglycerides level is less than 150 then, it is normal. And if it is greater than 200 then, it is high level. In women, if this level is high, it increases the possibility of coronary artery disease. We calculate this triglycerides level in the blood test. This usually occurs because of the lack of exercise, having obesity, smoking,

consuming alcohol and because of the genetic disorders.

- **Creatinine Blood Test**

This test calculates the creatinine level in the blood and it is a waste which shapes when creatine separates. This is found in our muscle and it gives the information about the level of kidneys function.

- **Electrolytes**

sodium, potassium, CO<sub>2</sub> and chloride are the major electrolytes in our body. The Electrolytes calculate the level of these electrolytes. Which helps in finding the symptoms of cardiac disease and inspect the effect of the medical care for high BP, kidney damage and heart failure.

- **Insulin Auto Antibodies (IAA):**

This test identifies the type I diabetes it identifies the antibodies attack the insulin and the beta cells [6].

- **C-Peptide:**

The insulin level in the body matches the peptide level in the body. C-Peptide test identifies the type 1 diabetes. This test calculates the amount of insulin produced by the body. If the C-Peptide level is very low, in the body, then it identifies the type 1 diabetes.

### 3 COVID-19

The first study in Wuhan published on COVID-19 infected people conveyed that nearly 32% out of 41 cases was combined with other diseases, including diabetes (20%), hypertension (15%), and heart disease (CVD; 15%). A study on COVID-19 persons proves that 52% of the affected persons had more blood glucose levels. A retrospective study of 138 patients with COVID-19 resulted that around 64 patients also had other diseases out of which one disease shows 10% similarity is diabetes. And 6 patients out of 38 are admitted to ICU had diabetes.

Wuhan Jin Yin Tan Hospital given a result that, among COVID-19 patients in ICU, 17% patients were testified to have chronic illnesses, among which 17% were patients with diabetes. During ICU treatment, 35% patients were reported to have hyperglycemia as comorbidity and the death rate in diabetics was more as 77.7% among the critically unhealthy patients. [15].

COVID-19 is identified in 2019, however it continues as a life-threatening disease. Diagnosis of COVID-19 at the right time helps to avoid the complications this disease in greater level. The most related symptoms of COVID-19 in given in Fig. 1.

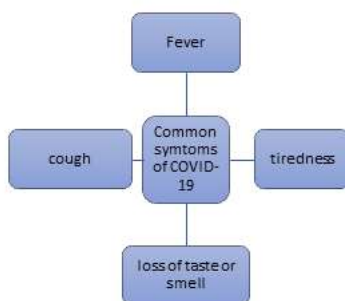


Fig. 1. Common symptoms of COVID-19

Some symptoms are very common in COVID-19 patients. However, there are symptoms which are less common, and not

easily identified as symptoms of COVID-19 which are given in Fig. 2.

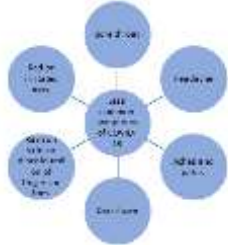


Fig. 2. Less common symptoms of COVID-19

The critical symptoms of COVID-19 includes the breathing suffering, confusion chest pain. Early identification of the disease can avoid these kind of complications. Some of the symptoms are common to the Influenza disease. One can be tested for COVID-19 if they have the above mentioned symptoms.

### 3.1 Diagnosis of COVID-19

In the coronaviridae family, Corona viruses are the positive single-stranded RNA genome viruses. Alpha, beta, gamma and delta are the four different types of genera found up to date. The novel SARS-CoV-2 belongs to the genera of  $\beta$ -coronavirus [10]. The following are the different diagnosis techniques of COVID-19:

- **Nucleic Acid Amplification Testing (NAAT)**

The diagnosis of SARS-CoV-2 is based on the detection of viral RNA by nucleic acid amplification tests similar to Real-time reverse transcriptase-polymerase chain reactions and cartridge-based nucleic acid amplification test. Various genes targeted still have E, N, S, ORF and RdRp as a portion of broadcast and validation of cases.

- **Viral Sequencing**

This test does not used in the initial stage to diagnose COVID-19. However, it helps in identifying the virus, monitor for viral genome mutations and counter measures.

- **Viral Cultures**

This test can research such as isolation of virus, and to find the characteristic of the virus to develop the vaccination.

- **Serology of COVID-19**

It detects the serum antibodies in contradiction of S proteins in the coronavirus spike. The further protein which is necessary antigenic site to expand serological assays to find the COVID-19 is the N protein, which is a structural module of the helical nucleocapsid.

- **CRISPR based assay**

CRISPR based assay functions by programming a CRISPR molecule to find a specific genetic signature for SARS-CoV-2 [11].

### 4. Bidirectional Associative Memories BAMs

Bi-directional associate memory behaves like a hetero-associative memory. The BAM is a non-adaptive, additive and bivalent neural network. It was introduced by Bart Kasko in 1988. The field is the set of neurons and Neural network is the set of fields that contains the neurons. Let  $U$  is the neuron field along with  $m$  neurons and let  $V$  denotes a neuron field with  $n$  neurons. In BAM the neurons are arranged in double layers  $U$  and  $V$ . The second layer  $V$  is interconnected to the neurons of the first layer  $U$ . The neurons in the same layer have no connection among themselves. The time evaluation of the neuronal activation's is monitored by the first order differential equation in the neuronal dynamical system. Let  $t$  indicate the activation time and the activation time function of the  $i^{\text{th}}$  neuron in  $U(t)$  and the  $j^{\text{th}}$

neuron in  $V(t)$  are denoted by  $u_i$  and  $v_j$  respectively. Where  $U(t) = (u_1(t), u_2(t), \dots, u_m(t))$ ,  $V(t) = (v_1(t), v_2(t), \dots, v_n(t))$ . Which defines the government of the neuronal dynamical system at time  $t$ . Additive bivalent Models presents stochastic and asynchronous behavior. Each neuron can change the state of activation and can omit a new signal in the present activation state. This process can be done randomly.

### Synaptic Connection Matrix

The  $n$  neurons in the field  $U$  and the  $m$  neurons in the field  $V$  are synoptically connected. Let  $m_{ij}$  denote the synapse where the axon from the  $i^{\text{th}}$  neuron field terminates.  $m_{ij}$  can be positive, negative or zero. The synaptic matrix is denoted as  $M$  which is an  $m \times n$  matrix. The entries of  $M$  are the synaptic connection  $m_{ij}$ . The matrix  $M$  denotes the forward projections from the neuronal field  $U$  to the neuronal

field  $V$ . And  $M^T$  denotes backward projections from  $V$  to  $U$  [4].

### Bidirectional Associative Memory

In Unidirectional network the neurons interconnect itself synoptically and the synoptic connection matrix is a square matrix. And in Bidirectional network  $M = N^T$  and  $N = M^T$ . If the initiation of the neuronal fields  $U$  and  $V$  tends to complete stable behavior, the bi-directional systems are said to be Bi-directional Associative Memories (BAM). If  $M$  is a symmetric matrix then the unidirectional network defines a Bidirectional Associative Memory [3].

### Working Pattern of BAM

BAM model in Neural Network is defined earlier with signal function  $S$ , Connection matrix  $M$  and input function  $I$  is defined as follows:

$$x_i^{r+1} = \sum_{j=1}^n S_j(y_j^r) m_{ij} + I_i$$

$$y_j^{r+1} = \sum_{i=1}^m S_i(x_i^r) m_{ij} + I_j$$

The BAM system  $(U, V, M)$ , if it attains the fixed point equilibrium then it is bidirectionally stable. The same signal of information flows in two direction in a bidirectional fixed point. Let  $X$  denotes a

binary  $n$  vector and  $Y$  denote the binary  $m$  vector. If we initially give  $X$  as an input to BAM system, then:

$$\begin{aligned} X &\rightarrow M \rightarrow Y \\ X' &\leftarrow M^T \leftarrow Y \\ X' &\rightarrow M \rightarrow Y' \\ X'' &\rightarrow M^T \rightarrow Y' \dots \\ X^k &\rightarrow M \rightarrow Y^k \\ X^k &\leftarrow M^T \leftarrow Y^k \end{aligned}$$

$X, X' \dots X^k$  denotes the transient state vector between  $X$  and  $X^k$ . And  $Y, Y' \dots Y^k$  represents the transient state vector between  $Y$  and  $Y^k$ . The invariant point of the BAM is depend on time and it varies depends on the synopsis connection matrix.

### 4.1 Complications of COVID-19 in Diabetes Patients

Person with diabetes have more complications of COVID-19 because of their body condition. In this section, we analyze the complications of diabetes with the medical conditions that can increase

the risk of COVID-19 using BAM. In the Domain space  $X$ , we take the complications of diabetes and in the range space  $Y$  we take the medical condition which increases the risk of COVID-19 [1]. Let  $M$  denotes the synaptic connection matrix between  $X$  and  $Y$ .  $M$  is obtained by collecting the various health organization earlier study and the statistical data. Obesity increases the chance of getting cardiovascular disease and heart failure [2]. High blood pressure decreases the oxygen supply to our heart and tends to heart diseases. Obesity increases the chance of getting chronic kidney disease.

High blood pressure may narrow the blood vessels, which finally damages the kidney. High blood pressure damages the retina's blood vessels and causing vision problems.  $X = \{ \text{Neuropathy, Kidney Damage, Retinopathy, Cardiovascular disease, Skin Problems, Depression} \}$   
 $Y = \{ \text{Cardiovascular Disease, Liver disease, Kidney disease, Diabetes, Obesity, High blood pressure} \}$ . The mapping between the complications of diabetes and the medical condition increases the risk of COVID-19 is given in Fig. 3.

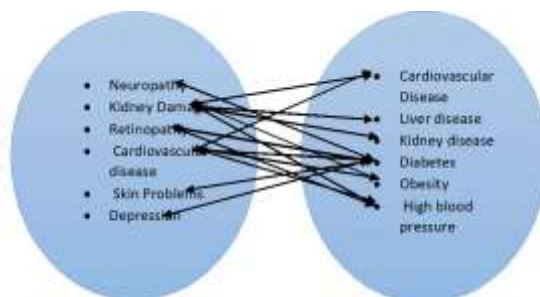


Fig. 3. The mapping between the complications of diabetes and the medical condition increases the risk of COVID-19

The synoptic connection matrix which represent the relation between  $X$  and  $Y$  are given below:

$$M = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}, M^T = \begin{bmatrix} 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 \end{bmatrix}$$

We turn on the Neuropathy, the first complication of Diabetes and allow it to pass on the synoptic connection matrix. For that, take  $X = [1 \ 0 \ 0 \ 0 \ 0 \ 0]$

$$XM = [0 \ 0 \ 0 \ 1 \ 0 \ 0] = Y$$

$$YM^T = [1 \ 1 \ 1 \ 1 \ 1 \ 1] = X'$$

$$X'M = [1 \ 1 \ 1 \ 1 \ 1 \ 1] = Y'$$

$$Y'M^T = [1 \ 1 \ 1 \ 1 \ 1 \ 1] = X''$$

$$X''M = [1 \ 1 \ 1 \ 1 \ 1 \ 1] = Y''$$

When we turn on the diabetes complication Neuropathy, all medical condition which increases risk of COVID-19 is in on state. Similarly we allow each complications of diabetes to pass on  $M$ , we get the following result:

$$\begin{aligned} [0 \ 1 \ 0 \ 0 \ 0 \ 0] &\rightarrow [1 \ 1 \ 1 \ 1 \ 1 \ 1] \\ [0 \ 0 \ 1 \ 0 \ 0 \ 0] &\rightarrow [1 \ 1 \ 1 \ 1 \ 1 \ 1] \\ [0 \ 0 \ 0 \ 1 \ 0 \ 0] &\rightarrow [1 \ 1 \ 1 \ 1 \ 1 \ 1] \\ [0 \ 0 \ 0 \ 0 \ 1 \ 0] &\rightarrow [1 \ 1 \ 1 \ 1 \ 1 \ 1] \end{aligned}$$

$$[0 \ 0 \ 0 \ 0 \ 0 \ 1] \rightarrow [1 \ 1 \ 1 \ 1 \ 1 \ 1]$$

We can see that when we turn on each complications of diabetes and allow it to pass on synoptic connection matrix it result in the on state of all the risk of COVID-19. And hence in this COVID-19 pandemic situation it is important to keep the diabetes in control by taking necessary measures.

### **5 Impact And Treatment For Patients With Diabetes And Covid-19**

A remarkable proportion of hospitalized COVID-19 patients were Diabetes patients [5]. Diabetes mellitus multiplies death rate of the COVID-19 patents due to cardiac involvement. A diabetes patient with other medical conditions further makes clinical outcomes more worsen [8]. Glycemic control is difficult in such a case and antidiabetic drugs together with insulin therapy have to be adapted if required. On the other hand, chances for diabetes patients going to outpatient clinics became limited during the COVID-19 situation urged for alternative ways of treatment, particularly the implementation of telemedicine strategies. Hence, to avoid mortality rate of diabetes patients during COVID 19 crisis much care should be taken [14].

The COVID-19 pandemic has driven significant changes in the healthcare sector and interrupting best treatment for diabetic. A large number of diabetic patients were left without proper treatment and pampering [12]. The impact of COVID-19 on diabetes complications is difficult to quantify, due to lack of any forms of data. No special recommendations on treating people with diabetes regarding COVID-19 and its complications were found till date. With insufficient facilities on glycemic control leading to increased length of hospitalization, rate of complications and mortality of patients. Some suggestions include initiated antidiabetic therapy for patients who repeatedly have high blood

glucose levels greater than 180 mg /dl. Owing to its well-established efficacy and safety profile insulin is the therapy of choice for these patients, preferably as multiple doses daily as injections or, treating in intensive care units, continuous intravenous infusion by syringe pump.

In order to control infection spreading many hospitals have reduced their outpatient clinic capacities to a bare minimum for emergencies. To minimize direct patient visits many licensed physicians have reduced patients seeking to their offices. With restrictions on people to come out of home likely reduced the amount of physical exercise leading to increase in calorie balance in considerable proportion of subjects. These aspects may lead to a deterioration in glycemic control. All patients were advised to increase the frequency of blood glucose measurement checks. Those with COVID-19 should furthermore be educated in recognition and handling of diabetic since infection is one of its most frequent triggers [13]. However, telemedicine with improved instruments could complement personal contact in standard diabetes management. Notably, access to insulin, oral antidiabetics and glucose management supplies will be required with extensive care.

Thus, in case a person with diabetes finds to have symptoms of COVID-19, he/She is needed to approach a proper health advisor and get isolated as per the regulations of the country. Through tele-medication the glucose level has to be maintained with periodic glucose level check and corresponding changes in dosage of medicine. Hydration must be properly taken care. Sick Patients are to be hospitalized and insulin to be taken as directed by physician Hence it is concluded [14], Diabetes patients are vulnerable to COVID-19 with



increased rate of mortality. Therefore, diabetes patients and particularly those with comorbidities must be urged to comply with social isolation, proper medication, extensive care and together with preventive measures for COVID-19 infection. Moreover, patients must be made aware of hyperglycemia by stress and infection, and be counselled on how to adapt glucose lowering therapy. Diabetes patients are more of other people in danger of severity of COVID-19 and mortality. Best function is prevention and then usage of evidence-based treatments.

## 6. Conclusion

In this article, we have studied the risk of COVID-19 in complications of diabetes patients using Bidirectional Associate memory. And the results show that any of the diabetes complications such as cardiovascular disease, neuropathy, kidney damage, retinopathy, skin problems and depression may lead to the greater risk level of COVID-19 disease and can cause death. We have discussed the impact and the treatment measures that have to be taken for the patients with diabetes and COVID-19.

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