

Studying the combined effects of risk factors via mathematical model on heart attack chances using clinical data

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(Received February 14, 2024, Revised May 27, 2025, Accepted May 28, 2025)

Abstract. In this paper, a framework that constructs risk factor differential equations and probability functions for heart attack patients, enabling the perception of a patient's heart attack probability is developed. The model has been generalized for n risk factors, but focused on the major three: cholesterol, triglycerides, and sugar levels. The main cause of blockages and clots in heart compartments are the identified risk factors, which increase the likelihood of blockage occurrence. By utilizing 12-patient clinical data, the differential equations and probability functions that accurately predict heart attack probability is constructed using the identified major risk factors.

Keywords: blockage; cholesterol; framework; heart attack; likelihood; sugar levels; triglycerides

1. Introduction

Nowadays sciences and medicines are intertwined. Indeed, many applications of mathematical sciences are used to make tremendous improvements in the medical field (Sun *et al.* 2025, Xu *et al.* 2020). Mathematical biology is one of the forerunners in the field of cardiovascular diseases to provide effective predictive models and treatments (Liu *et al.* 2024). In mathematical biology, the study of biomechanics is very important due to its ability of modeling biological phenomena (Zhou *et al.* 2022a, b). The mathematical models of blood flows in the arteries in order to demonstrate the relevance and uses of biomechanics in biological systems is studied. The relationship between fat and blood flow in stenosis arteries is discussed. The main cause of blood flow decreases are blockage in the arteries. The normal and deceased artery as shown in Fig. 1. Atherosclerosis is the most common type of arteriosclerosis. Atherosclerosis is hardening of arteries due to blockage (plaque). Due to atherosclerosis many heart attack risk factors appear like high cholesterol level, high triglycerides and high sugar level etc (Qian *et al.* 2024).

Process of atherosclerosis is shown in Fig. 2. Li *et al.* (2019a) and Jiang *et al.* (2020) explored the cardiac fibroblasts senescence and cardiac fibroblasts activation via mediating. Alharbi and Rambely (2018) concluded that the immune system could be able to dynamically eradicate aberrant cells, in which case the functionality moves

through the response stage, the interaction stage, and the recovery stage. The immune system's primary job is to protect the body from the development of cancer. Ding *et al.* (2025) and Zhang *et al.* (2024a) used machine Learning model for perioperative Neurocognitive and subcutaneous implantable cardioverter defibrillator intervention for patients. Previous studies have indicated that some bad diets, including a Western-style diet, can hinder the immune system's capacity to engage with aberrant cells and cause cancer and with micellas. The effect of VEGF with Synergistic (Yang *et al.* 2022) and Puerarin (Li *et al.* 2019b) is conducted. Using the thermostated kinestates technique, Bianca and Brézin (2018) developed a simple model with three cell types-cancer cell, immune cell, and normal cell in 2016. The results show that the model is capable of simulating cancer cell eradication, equilibrium, and immune system evasion. Wei *et al.* (2020) and Sun *et al.* (2021) used ROS/NLRP3 Inflammasome Signaling and isoprenaline-induced cardiac hypertrophy. Thermostated kinetic theory helps one to establish the linkages between the immune system and a tumor at cell scales. A large amount of sterol level in the arteries caused interruption in blood supply (Palma *et al.* 2015). Fang *et al.* (2024) and Li *et al.* (2025) investigated the Clinical features and predictors of cardiovascular mortality of patients. Heart attack occurs due to congeal of blood in coronal arteries (Zulkepli and Eldabi 2015). Jiang *et al.* (2024) and Zhang *et al.* (2025) investigated the low-frequency ultrasound sensitive piezo1 channels and association between serum vitamin D level. There are two types of blockage: one is full blockage and second is partial. The full blockage is called ST-elevation myocardial infarction (STEMI) (Esensoy and Carter 2015) and secondly, non-ST elevation myocardial infarction (NSTEMI) is partially blockage. Another cause may be

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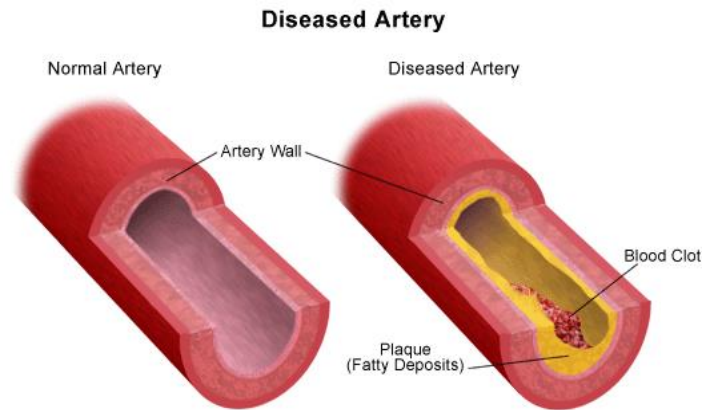


Fig. 1 Blood clots and blockage in normal and disease artery (Image Credit: Stanford Medicine Health Care)

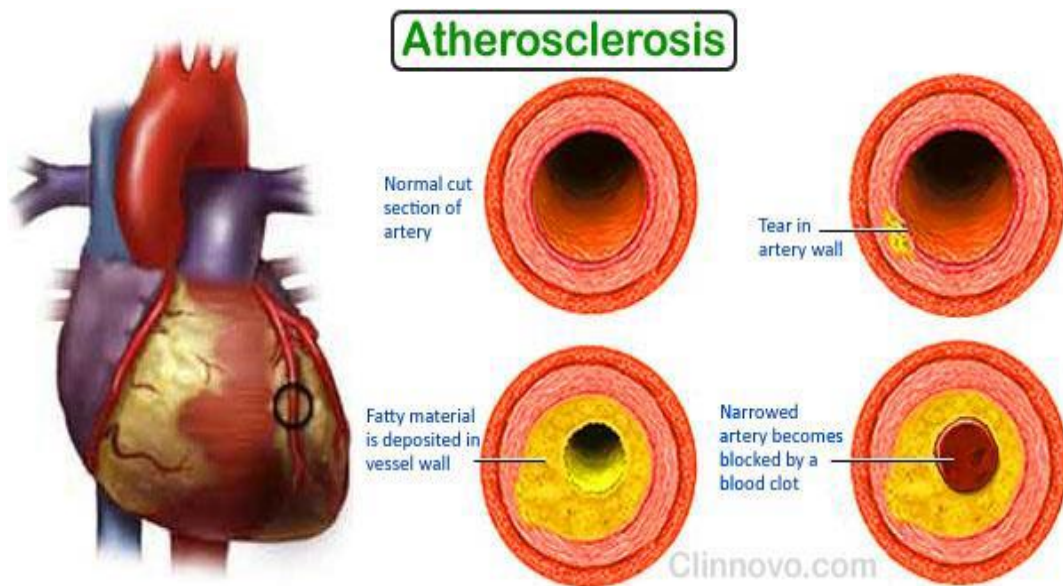


Fig. 2 Process of atherosclerosis (Image Credit: Medline Plus)

spasm of coronary arteries that abandon the blood flow to a part of heart muscle (Yu *et al.* 2015). Zhang *et al.* (2021) and Li *et al.* (2024) used Image-Guided Para-Corticospinal Tract Approach and aldosteronism on and off interfering medications for patients. Lyons and Duggan (2015) presented some heart abnormal conditions as Heart rhythm variability: Heart rhythm does not work properly due to electric short circuits SA-nodes and AV- nodes. Heart failure: Heart failure occurs, when heart tissues are not pumping blood from heart. Heart arrest without warning: Sudden heart arrest condition is very dangerous. This condition occurs, when SA-nodes and AV-nodes electric circuits are breakdown and heart does not receive properly message. Zhang *et al.* (2024b) and Li *et al.* (2025) protected mice from CVB3-induced myocarditis and amplification probe for miRNAs detection.

Wodarz and Nowak (2002) inspected the elements of HIV/AIDS with treatment and vertical transmission. A nonlinear deterministic mathematical model for the issue is proposed and investigated subjectively utilizing the strength hypothesis of differential conditions. The elements between infection contaminations and the immunesystem include a

wide range of parts and are multifactorial. In such a scenario, the standards overseeing the dynamics and the result of disease can't be perceived by verbal or graphical reasoning. Mathematical models give a fundamental instrument to catch a series of expectations and to follow them to their exact coherent conclusions. They permit us to create new speculations, propose experiments, and measure urgent parameters. Pei *et al.* (2024) and Xiao *et al.* (2025) developed multitargeted immunomodulatory therapy and novel predictive model for dementia risk with different ages. Their negligible model proposed in (Hamer, 1906, Pacini and Bergman 1986) used an arrangement of customary differential conditions (ODEs) to address the joint impact of insulin discharge and affectability on glucose resistance. The full ODE model is made out of two subsystems: the first portrays glucose leeway by means of the conditions relating glucose and interstitial insulin and the second depicts plasma insulin action. The glucose model just as other comparative ODE frameworks are utilized as investigatory demonstrating devices measure insulin discharge and insulin affectability in singular patients. Recently some researcher used different methods for

different modeling (Safaei *et al.* 2019, Hussain 2024, Benmansour *et al.* 2019, Asghar *et al.* 2020a, b, Akbaş 2020, Sharif *et al.* 2020, Forsat *et al.* 2021, Iqbal *et al.* 2020, Luo *et al.* 2022, Moradi *et al.* 2023, Liu *et al.* 2025, Khadimallah *et al.* 2020, Hussain 2021).

In addition, a generalized independent risk factors recovery model, which allows for the prediction of a heart-infected patient's recovery time based on food intake is studied. The targeted mathematical modeling in system dynamics to calculate heart attack recovery time is used. Furthermore, to accelerate recovery by modeling the suggested system of equations for a heart attack patient is studied. By controlling the patient's glucose and sterol levels through S.D. (system dynamics), achieved a significant reduction in cardiovascular disease in the patient is achieved. This heart attack recovery model is a contribution to the field of translational research and is beneficial to the medical field. It can reduce the risk of heart attack and promote a healthy lifestyle. In this paper, the heart attack simulation modeling for heart patients by using cholesterol level and blockage (plaque) in arteries is discussed. First, the knowledge related to artery blockage is shared. The discussion about recovery simulation of heart attack using two risk factors, cholesterol and triglycerides is achieved.

2. Mathematical model for two independent risk factors

The differential equation for two independent risk factors for heart attacks is given as (Wazwaz 2002).

$$u_{x_1x_1} + u_{x_2x_2} = \text{Source},$$

$$0 < x_1 < b_1, 0 < x_2 < b_2$$

$$u_{x_1x_1} + u_{x_2x_2} = \text{Source}, \tag{1}$$

$$0 < x_1 < b_1, \quad 0 < x_2 < b_2$$

$$u(0, x_2) = 0, \quad u(b_1, x_2) = 0,$$

$$u(x_1, 0) = 0, \quad u(x_1, b_2) = f(x_1).$$

Let $u(x_1, x_2) = f(x_1, x_2)$ is the solution of heart attack differential equation with two risk factors. Here b_2 is the terminal value of heart attack risk factor x_2 .

2.1 Heart attack differential equation probability function for two independent risk factors

The probability function for two independent risk factors heart attack is given by

$$\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} u(x_1, x_2) dx_1 dx_2 = 1 \tag{2}$$

where

$$u(x_1, x_2) = \begin{cases} kf(x_1, x_2), & a_1 < x_1 \leq b_1, \\ & a_2 < x_2 \leq b_2 \\ 0, & \text{elsewhere} \end{cases} \tag{3}$$

Using the probability density function in equation (2),

we get

$$k \int_{a_2}^{b_2} \int_{a_1}^{b_1} f(x_1, x_2) dx_1 dx_2 = 1,$$

To find probability constant, we consider

$$h(x_2) = \int_{a_1}^{b_1} f(x_1, x_2) dx_1,$$

we get

$$k \int_{a_2}^{b_2} h(x_2) dx_2 = 1.$$

Let

$$M = \int_{a_2}^{b_2} h(x_2) dx_2,$$

we get

$$k [M(b_2) - M(a_2)] = 1,$$

$$k = 1 / [M(b_2) - M(a_2)].$$

is probability constant. Thus Eq. (3) is called the generalized heart attack probability function for two independent risk factors.

2.2 Special case of Laplace equation for two independent risk factors

The Laplace differential equation for two independent risk factors for heart attacks is given by

$$u_{x_1x_1} + u_{x_2x_2} = 0, \quad 0 < x_1 < b_1, \quad 0 < x_2 < b_2,$$

$$u(0, x_2) = x_2 - (a_1 + a_2), \quad u_{x_1}(b_1, x_2) = 1, \tag{4}$$

$$u(x_1, 0) = x_1 - (a_1 + a_2), \quad u_{x_2}(x_1, b_2) = 1.$$

Now we solve this equation by using the linear operator

$$L = \frac{d^2}{dx_1^2}.$$

we get

$$u(x_1, x_2) = Ax_1 + B,$$

where

$$A = 1,$$

$$B = x_2 - \sum_{i=1}^2 a_i.$$

We take the initial guess

$$u_0(x_1, x_2) = \sum_{i=1}^2 (x_i - a_i).$$

Using Homotopy perturbation equation

$$(1-p)[Lu - Lu_0] = p[Lu + u_{x_2x_2}],$$

where P is perturbation parameter

$$Lu - Lu_0 - pLu + pLu_0 + pu_{x_2x_2} = 0,$$

$$Lu - Lu_0 + pLu_0 + pu_{x_2x_2} = 0,$$

Let

$$u = u_0 + pu_1 + p^2u_2 + \dots$$

be the solution of Homotopy perturbation equation, so that

we get

$$L(u_0 + pu_1 + p^2u_2 + \dots) - Lu_0 + pLu_0 + pu_{x_2x_2} = 0,$$

By comparing coefficients of p

$$p^1: Lu_1 + Lu_0 + u_{0x_2x_2} = 0,$$

$$p^2: Lu_2 + u_{1x_2x_2} = 0,$$

so

$$u_1 = -L^{-1}(Lu_0 + u_{0x_2x_2}),$$

$$u_2 = -L^{-1}(Lu_1 + u_{1x_2x_2}),$$

Consequently, the exact solution of heart attack Laplace equation with two independent risk factors is given by

$$u(x_1, x_2) = \sum_{i=1}^2 (x_i - a_i).$$

Here a_2 is the initial value of risk factor x_2 .

Table 1 Analysis of 12 patients

Patients	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Cholesterol level of 12 patients	141 mg/dl	181 mg/dl	178 mg/dl	110 mg/dl	224 mg/dl	238 mg/dl	210 mg/dl	224 mg/dl	249 mg/dl	209 mg/dl	170 mg/dl	226 mg/dl
Triglycerides level of 12 patients	145 mg/dl	140 mg/dl	205 mg/dl	200 mg/dl	193 mg/dl	335 mg/dl	240 mg/dl	119 mg/dl	303 mg/dl	437 mg/dl	193 mg/dl	430 mg/dl
Sugar level of 12 patients	140 mg/dl	140 mg/dl	140 mg/dl	159 mg/dl	104 mg/dl	140 mg/dl	140 mg/dl	145 mg/dl	88 mg/dl	101 mg/dl	140 mg/dl	169 mg/dl
Heart attack probability by cholesterol and triglycerides	-	-	0.0046	-	0.0095	0.0999	0.0209	-	0.0845	0.1416	0.0024	-
Heart attack probability by triglycerides and sugar	-	-	-	0.0015	-	-	-	-	-	-	-	-
Heart attack probability by cholesterol and sugar	-	-	-	-	-	-	-	0.0017	-	-	-	-
Heart attack probability by cholesterol, triglycerides and sugar.	-	-	-	-	-	-	-	-	-	-	-	0.0186

2.3 Special case of heart attack Laplace equation probability function for two independent risk factors

The probability function for two independent risk factors heart attack is given by

$$\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} u(x_1, x_2) dx_1 dx_2 = 1 \tag{5}$$

where

$$u(x_1, x_2) = \begin{cases} k \sum_{i=1}^2 (x_i - a_i), & a_1 < x_1 \leq b_1, a_2 < x_2 \leq b_2 \\ 0, & \text{elsewhere} \end{cases} \tag{6}$$

Using u in Eq.(2), we get

$$k \int_{a_2}^{b_2} \int_{a_1}^{b_1} \sum_{i=1}^2 (x_i - a_i) dx_1 dx_2 = 1$$

where

$$k = 2/[-1]^2(a_1-b_1)(a_2-b_2)(b_1+b_2-a_1-a_2).$$

is probability constant. Thus equation (6) is called the generalized heart attack probability function for two independent risk factors.

2.4 Mathematical model for three independent risk factors

The differential equation for three independent risk factors for heart attacks is given as

$$\begin{aligned} &u_{x_1x_1} + u_{x_2x_2} + u_{x_3x_3} = \text{source}, \\ &0 < x_1 < b_1, 0 < x_2 < b_2, 0 < x_3 < b_3 \\ &u(0, x_2, x_3) = 0, u(b_1, x_2, x_3) = 0, \\ &u(x_1, 0, x_3) = 0, u(x_1, b_2, x_3) = 0, \\ &u(x_1, x_2, 0) = 0, u(x_1, x_2, b_3) = f(x_1, x_2). \\ &\text{Let } u(x_1, x_2, x_3) = f(x_1, x_2, x_3) \end{aligned} \tag{7}$$

be the solution of heart attack differential equation with three independent risk factors. Here b_3 is the terminal value of heart attack risk factor x_3 .

The probability function for three independent risk factors heart attack is given by

$$\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} u(x_1, x_2, x_3) dx_1 dx_2 dx_3 = 1 \tag{8}$$

where

$$u(x_1, x_2, x_3) = \begin{cases} a_1 < x_1 \leq b_1, a_2 < x_2 \leq b_2, \\ a_3 < x_3 \leq b_3 \\ 0, & \text{elsewhere} \end{cases} \tag{9}$$

Using u in equation (8), we get

$$k \int_{a_3}^{b_3} \int_{a_2}^{b_2} \int_{a_1}^{b_1} f(x_1, x_2, x_3) dx_1 dx_2 dx_3 = 1,$$

let

$$h(x_2, x_3) = \int_{a_1}^{b_1} f(x_1, x_2, x_3) dx_1,$$

we get

$$k \int_{a_3}^{b_3} \int_{a_2}^{b_2} h(x_2, x_3) dx_2 dx_3 = 1.$$

Let

$$z(x_3) = \int_{a_2}^{b_2} h(x_2, x_3) dx_2,$$

we get

$$k \int_{a_3}^{b_3} z(x_3) dx_3 = 1,$$

$$k [M(b_3) - M(a_3)] = 1,$$

$$k = 1/[M(b_3) - M(a_3)].$$

is probability constant. Thus equation (9) is called the generalized heart attack probability function for three independent risk factors.

The Laplace equation for three independent risk factors for heart attacks is given by

$$\begin{aligned} &u_{x_1x_1} + u_{x_2x_2} + u_{x_3x_3} = 0, \\ &0 < x_1 < b_1, 0 < x_2 < b_2, 0 < x_3 < b_3, \\ &u(0, x_2, x_3) = \sum_{i=2}^3 x_i - \sum_{i=1}^3 a_i, \end{aligned}$$

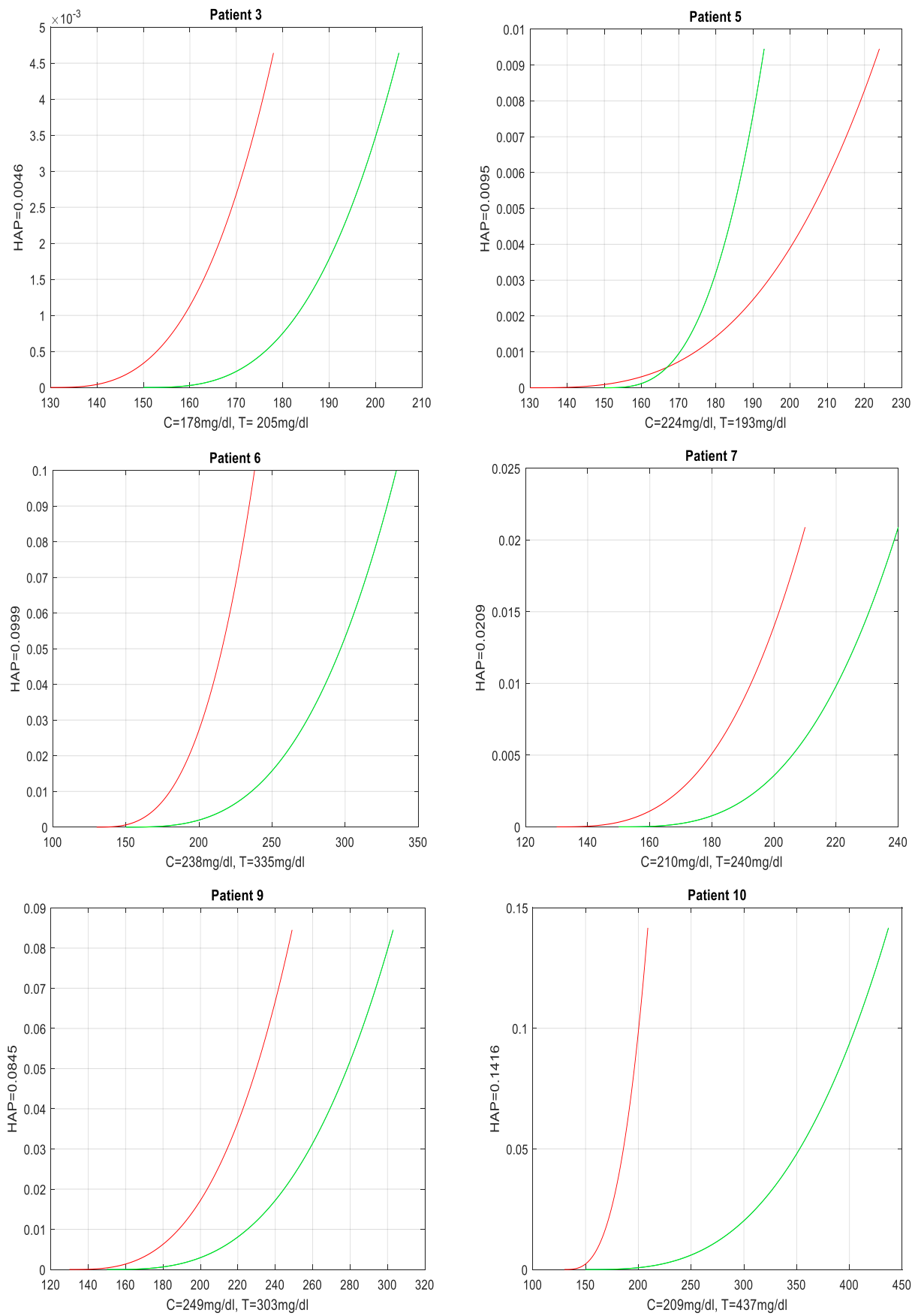


Fig. 3 The simulated probability of heart attacks in seven patients

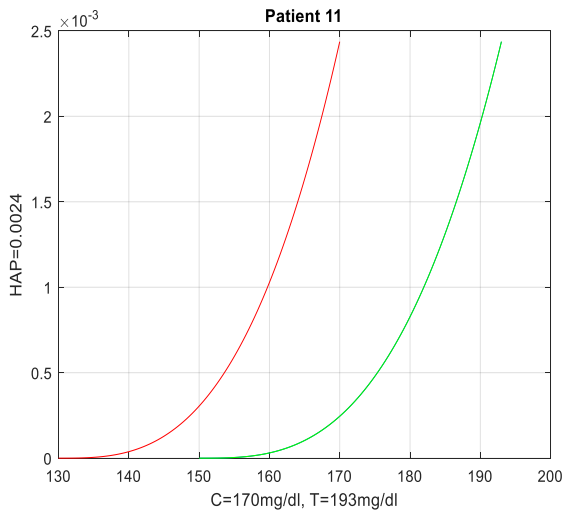


Fig. 3 Continued

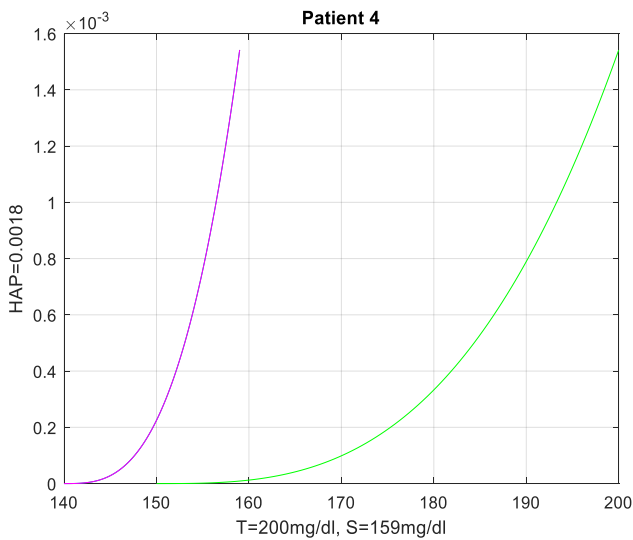


Fig. 4 The simulated probability of a heart attack for a patient

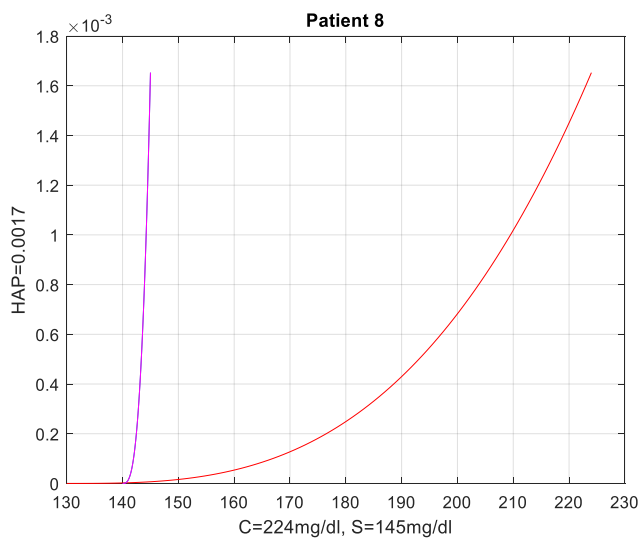


Fig. 5 The simulated probability of a heart attack

$$u_{x_1}(b_1, x_2, x_3) = 1, u(x_1, 0, x_3) = (x_1 + x_3) - \sum_{i=1}^3 a_i,$$

$$u_{x_2}(x_1, b_2, x_3) = 1, u(x_1, x_2, 0) = \sum_{i=1}^2 x_i - \sum_{i=1}^3 a_i,$$

$$u_{x_3}(x_1, x_2, b_3) = 1.$$

Now we solve this equation by using the linear operator

$$L = \frac{d^2}{dx_1^2},$$

we get

$$u(x_1, x_2, x_3) = Ax_1 + B.$$

where

$$A = 1,$$

$$B = \sum_{i=2}^3 x_i - \sum_{i=1}^3 a_i.$$

We take the initial guess

$$u_0(x_1, x_2, x_3) = \sum_{i=1}^3 x_i - \sum_{i=1}^3 a_i.$$

Using Homotopy perturbation equation

$$(1-p)[Lu - Lu_0] = -p[Lu + u_{x_2x_2} + u_{x_3x_3}],$$

$$Lu - Lu_0 - pLu + pLu_0 + pLu + pu_{x_2x_2} + pu_{x_3x_3} = 0,$$

$$Lu - Lu_0 + pLu_0 + pu_{x_2x_2} + pu_{x_3x_3} = 0,$$

Let

$$u = u_0 + pu_1 + p^2u_2 + \dots$$

be the solution of Homotopy perturbation equation, so that we get

$$L(u_0 + pu_1 + p^2u_2 + \dots) - Lu_0 + pLu_0 + p(u_{0x_2x_2} + pu_{1x_2x_2} + p^2u_{2x_2x_2} + \dots) + p(u_{0x_3x_3} + pu_{1x_3x_3} + p^2u_{2x_3x_3} + \dots) = 0,$$

By comparing coefficients of p

$$p^1: Lu_1 + Lu_0 + u_{0x_2x_2} + u_{0x_3x_3} = 0,$$

$$p^2: Lu_2 + u_{1x_2x_2} + u_{1x_3x_3} = 0,$$

so

$$u_1 = -L^{-1}(Lu_0 + u_{0x_2x_2} + u_{0x_3x_3}),$$

$$u_2 = -L^{-1}(Lu_1 + u_{1x_2x_2} + u_{1x_3x_3}),$$

Consequently, the exact solution of heart attack Laplace equation with three independent risk factors is given by

$$u(x_1, x_2, x_3) = \sum_{i=1}^3 x_i - \sum_{i=1}^3 a_i.$$

Here a_3 is the initial value of risk factor x_3 .

The probability function for three independent risk factors heart attack is given by

$$\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} u(x_1, x_2, x_3) dx_1 dx_2 dx_3 = 1 \quad (10)$$

where

$$u(x_1, x_2, x_3) = \begin{cases} k \sum_{i=1}^3 (x_i - a_i), & a_1 < x_1 \leq b_1, a_2 < x_2 \leq b_2, a_3 < x_3 \leq b_3 \\ 0, & \text{elsewhere} \end{cases} \quad (11)$$

Using u in Eq. (11), we get

$$k \int_{a_3}^{b_3} \int_{a_2}^{b_2} \int_{a_1}^{b_1} \sum_{i=1}^3 (x_i - a_i) dx_1 dx_2 dx_3 = 1,$$

where

$$k = 2 / [(-1)^3 (a_1 - b_1)(a_2 - b_2)(a_3 - b_3)(b_1 + b_2 + b_3 - a_1 - a_2 - a_3)].$$

is probability constant. Thus Eq. (11) is called the generalized heart attack probability function for three independent risk factors.

The differential equation for n -independent risk factors for heart attacks is given by

$$u_{x_1x_1} + u_{x_2x_2} + \dots + u_{x_nx_n} = \text{source}, \quad (12)$$

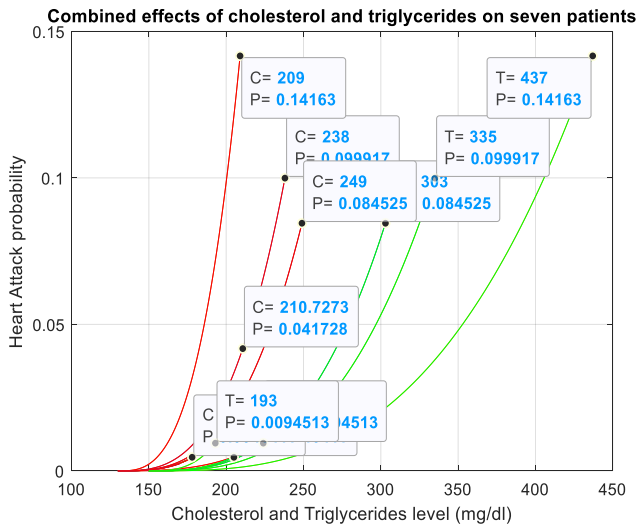


Fig. 6 Analysis of seven patients probability in one graph

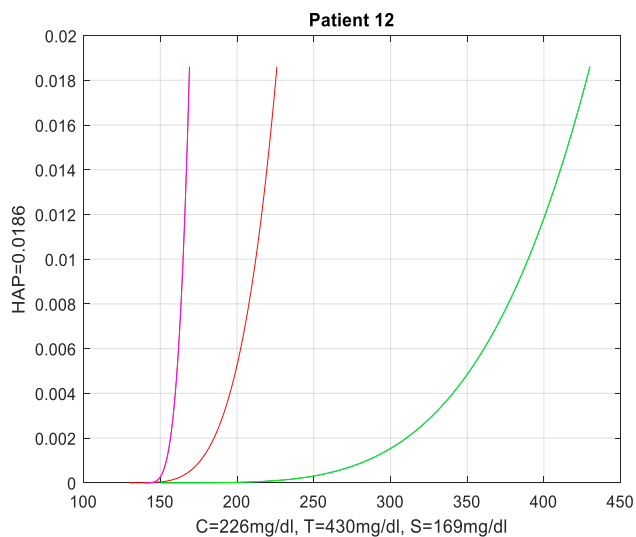


Fig. 7 The simulated probability of a patient

$$\begin{aligned}
 &0 < x_1 < b_1, 0 < x_2 < b_2, \dots, 0 < x_n < b_n \\
 &u(0, x_2, \dots, x_n) = 0, u(b_1, x_2, \dots, x_n) = 0, \\
 &u(x_1, 0, x_3, \dots, x_n) = 0, u(x_1, b_2, x_3, \dots, x_n) = 0, \\
 &u(x_1, x_2, \dots, x_{n-1}, 0) = 0, \\
 &u(x_1, x_2, \dots, x_{n-1}, b_n) = f(x_1, x_2, \dots, x_{n-1}). \\
 &\text{Let } u(x_1, x_2, x_3, \dots, x_n) = f(x_1, x_2, x_3, \dots, x_n)
 \end{aligned}
 \tag{12}$$

be the solution of heart attack Laplace differential equation for n -independent risk factors. Here b_n is the terminal value of heart attack risk factor x_n

We analyzed the clinical data of 12 patients to investigate the combined effects of cholesterol, triglycerides, and sugar on the probability of heart attack. To examine these effects, we utilized a mathematical models (4) and (6) for two risk factors and (10), (11) for three risk factors.

Table 1 analyzed the data of 12 patients and determined the probability of heart attack based on their cholesterol level, triglycerides level, and sugar level. Our observation clearly shows that when these levels increase, the chances of a heart attack also increase. It is observed that each

patient has a different heart attack probability due to different risk factors. Specifically, out of the 12 patients, seven patients have an increased risk of heart attack due to their cholesterol and triglycerides levels, one patient due to their triglycerides and sugar levels, one patient due to their cholesterol and sugar levels, and one patient due to their cholesterol, triglycerides, and sugar levels. So, all 12 patients have varying rates of heart attack chances due to different risk factors. Fig. 3 shows the simulated probability of heart attacks in seven patients by analyzing the red and green color lines, which were based on the levels of cholesterol and triglycerides as risk factors. From our analysis, it is found that only these seven patients had an increased likelihood of suffering a heart attack due to high cholesterol and triglyceride levels. The red and green lines depicted the variation in heart attack probability with the progression of these risk factors. Fig. 4 shows the simulated probability of a heart attack for a patient by considering triglycerides and sugar as risk factors. The green and purple lines represent the variations in the likelihood of a heart attack with the increase in these risk factors. Fig. 5 shows the simulated probability of a heart attack for one patient using cholesterol and sugar as risk factors. The red and purple lines indicate how the risk of heart attack varies with changes in these risk factors. Fig. 6 depicts the analysis of seven patients probability in one graph. Fig. 7 shows the simulated probability of a patient experiencing a heart attack using cholesterol, triglycerides, and sugar as risk factors. Our findings revealed that only one patient had an elevated risk of heart attack due to these factors. The red, green, and purple lines depicted the changes in heart attack risk as the levels of the risk factors varied.

3. Conclusions

In this paper, the connection between blockage in arteries and high levels of cholesterol and triglycerides in the blood is found. It is noted that if these major risk factors increase, the chances of having a heart attack also increase. However, it is noted that by making certain lifestyle changes such as eating a healthy diet on a daily basis that decrease the recovery time and lower the risk of experiencing a heart attack. Therefore, it is essential for us to take the necessary steps to maintain a healthy diet and lifestyle in order to reduce the risk of cardiovascular diseases.

Acknowledgment

The Authors extend their appreciation to the Deanship Scientific Research at King Khalid University for funding this work through large group Research Project under grant number: RGP2/649/46.

Funding

This research work was supported by the Deanship of Scientific Research at King Khalid University under grant number: RGP2/649/46.

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