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Original Research

Calculating Cholesterol (C) and Triglyceride (TG) Levels in Very-Low-Density Lipoprotein (VLDL), Low-Density Lipoprotein (LDL), and High-Density Lipoprotein (HDL)

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Introduction

Cardiovascular disease is the leading cause of death, accounting for 17.3 million deaths per year which is approximately one death per 40 seconds[3]. As a result, medicine that helps to lower this risk is increasing in demand and is necessary to promote health and to ultimately reduce mortality and morbidity. One of the primary causes of cardiovascular disease results from excessive fats or lipids[3]; therefore, lipid-lowering drugs are a key component to reduce morbidity and mortality. However, drug development requires efficient and accurate approach to ensure that the benefits outweigh the risks. In medicine, a balance is often struck between efficiency and accuracy. Therefore, there is a focus on cholesterol (C), triglyceride (TG), very-low-density lipoprotein (VLDL), low-density lipoprotein (LDL), and high-density lipoprotein (HDL) to calculate a patient's risk of developing cardiovascular disease.

Lipoproteins, triglycerides, and cholesterol play important roles in maintaining homeostasis. LDL is known as the "bad" lipid and VLDL is synthesized in the liver to transport TG and cholesterol throughout the body. These two lipids will mainly be observed to calculate the risks of cardiovascular disease. There is LDL-C and LDL-P which are two different methods of measuring LDL in the body (note that VLDL or HDL can also be measured in the same way). LDL-C represents how much cholesterol is in one LDL molecule[4-5]. On the other hand, LDL-P represents how big the particle size is that contains cholesterol[4-5]. Therefore, there are essentially two ways of measuring how much cholesterol is present in the body: the size of LDL and the amount of cholesterol in one LDL. This concept also applies to triglyceride in other lipoproteins such as HDL and VLDL.

Clinical Applications

There are many emerging studies that utilize this concept of cholesterol and particle size of lipoproteins to assess risk for cardiovascular disease. In one study, Dr. Hoogeveen and his lab attempted to find a correlation between LDL-C and the risk of coronary heart disease[6]. Another study conducted by Dr. Roever determines the severity of coronary atherosclerosis using LDL-C and non-HDL-C[7]. However, it is still a difficult and daunting task to compare cholesterol and particle size as they are both calculated in different units. Currently, lab test yields cholesterol amount in (mg/dL) and lipoprotein particle sizes in (nmol/L). For example, if one data presents with 80 mg/dL of VLDL-C and 70 nmol/L of VLDL-P, it is difficult to compare the relationship between the two. To address this problem, there are many online resources such as MediCalculator[2] that can calculate the conversion, but there is no written mathematical explanation of how the conversion is done to measure the accuracy or the validity of the sources.

In this article, we derived various online conversion calculations to verify accuracy. In addition, we created a conversion formula as it can heighten the advancement of lipid-related drug development by reducing time and increasing accuracy of the calculation.

To decipher how much cholesterol or triglyceride is contained in one lipoprotein, we first need to convert all the units into one uniformed International Units (SI units) in mmol/L. The conversion factor that we used represents the amount of cholesterol in one particular lipoprotein (VLDL, LDL and etc. except for HDL because it is measured in μmol instead of nmol). This number is 25,863.2. This conversion factor takes into consideration units for cholesterol and the corresponding lipoprotein. In addition, we wanted to confirm if the conversion factor that is widely available online was accurate. To test this, we confirmed the accuracy of the conversion factor given online[2], which is 0.0259 using dimensional analysis shown later in the text. Next, we used our new formula and tested the validity on VLDL, and LDL. Currently, this equation is being used in Hospital of University of Pennsylvania by Dr. Dunbar in his current research[1]. In addition, the results that he finds from the research is being used to educate his patients to create healthy lifestyle and to promote health.

We will be explaining step by step the dimensional analysis conducted and to compare that result with the new formula to check the accuracy of the new formula in various examples shown below.

Equation I:

25,863.2 x {Cholesterol (mg/dL) / lipoprotein particle (nmol/L)}

Example I (CalculatingVLDL-C/VLDL-P): We wanted to demonstrate that the formula we acquired and the traditional route of unit conversion through dimensional analysis is matched. Starting with VLDL-C of 30 mg/dL and VLDL-P of 80 nmol/L, we took 30 mg/dL and multiplied by 1dL/0.1L to convert dL into L.

Next, we multiplied by 1 mol/386.65g (molecular weight of cholesterol) to convert grams to mol, then to convert mol to mmol, we multiplied by 1000 mmol/1mol to get

0.7759 mmol/L. We converted VLDL-P of 80 nmol/L to mmol/L by multiplying by 1e-9 to convert nmol to mol and then multiplying by 1000 to convert mol to mmol. As a result, we converted 80 nmol/L to 0.00008 mmol/L. Since we are looking for the ratio of VLDL-C and VLDL-P, we divided 0.7759 mmol/L and 0.00008 mmol/L to get 9,698.7 mmol (VLDL-C): 1 mmol (VLDL-P).

Now, to verify if our equation above can reproduce the same answer, we can substitute 30 mg/dL of VLDL-C and 80 nmol/L of VLDL-P to get the following:

The two results are identical, which proves that the new conversion equation is an accurate tool in finding cholesterol level in VLDL.

We derived the new conversion factor equation by taking the conversion factor of 0.0258632[2], which is used globally used to convert mg/dL to mmol/L, and multiplying by 1e6, which is used to convert nmol to mmol, to get the new conversion factor of 25,863.2.

Example II (Calculating LDL-C/LDL-P): Next we will be using LDL-C of 98 mg/dL and LDL-P of 1,400 nmol/L to further prove our formula's validity. We take 98 mg/dL and multiplied by 1 dL/0.1 L to convert dL into L. Next, we multiplied by 1 mol/386.65g (molecular weight of cholesterol) to convert grams into mol. To convert mol to mmol, we multiplied by 1000 mmol/1 mol to get 2.5346 mmol/L. Next, we converted 1,400 nmol/L to mmol/L by multiplying by 1e-9 to convert nmol into mol and then multiplying by 1,000 to convert mol into mmol. As a result, we converted 1,400 nmol/L as 0.0014 mmol/L. Dividing 2.5346 mmol/L and 0.0014 mmol/L, you get 1,810.423 mmol (LDL-C): 1 mmol (LDL-P). Using the same equation shown below, we obtained a very similar, reflecting accuracy and validity of our approach.

Finally, to determine the triglyceride content in one particle of lipoprotein, we must take a different approach because the conversion factor of triglyceride (mg/dL to mmol/L) is 88.57[2]. Using this reference number, we came up an equation to immediately convert , which will inform us how much triglyceride content is in one lipoprotein:

Equation II:

11,290.5 x {Triglyceride (mg/dL) / lipoprotein particle (nmol/L)}

Example III (Finding Total TG/VLDL-P): Other than LDL level, TG level is also important to determine the risks of various cardiovascular diseases. Starting with 200 mg/dL of Total-TG and 80 nmol/L of VLDL-P, we divided 200 mg/dL by the conversion factor of 88.57 to convert mg/dL to mmol/L. As a result, we got 2.2581 mmol/L.

Next, we took 80 nmol/L and multiplied by 1e-9 to convert from nmol to mol. To convert mol to mmol, we multiplied by 1000 mmol/1 mol to get 0.00008 mmol/L.

Taking the ratio of 2.2581 mmol/L and 0.00008 mmol/L, we got 28,226.25 mmol (VLDL-TG): 1 mmol (VLDL-P). Using the equation II, you get the exact same value shown below:

We derived this new conversion factor equation by using 1e6, which converted nmol to mmol, and dividing by the conversion factor of 88.57, which converted mg/dL to mmol/L, to get 11,290.5.

In addition to LDL and TG levels, determining HDL level can be an important tool to assess the reduced risk in cardiovascular disease as HDL is the only non-atherogenic lipoprotein our body. In other words, HDL is a good cholesterol in our body. Finding the cholesterol/particle size of HDL utilizes a different equation due to the fact that HDL-P is measured in micromole (μmol) instead of nanomole (nmol) used for other lipoproteins. The new equation that will be used to calculate cholesterol/particle (in mmol/L) of HDL is:

Equation III:

25.8632 x {Cholesterol (mg/dL) / HDL (umol/L)}

Example IV (Finding HDL-C/HDL-P): We started off with 41 mg/dL of HDL-C and 27.7 umol/L of HDL-P. We took 41mg/dL and multiplied by 1dL/0.1L to convert dL into L. Next, we multiplied by 1 mol/386.65g (molecular weight of cholesterol) to convert gram into mole. Finally, to convert mol to mmol, we multiplied by 1000 mmol/1 mol to get 1.06039053 mmol/L. Next, we converted 27.7 umol/L to mmol/L by multiplying by 1e-6 to convert umol to mol and then multiplying by 1000 to convert mol into umol. As a result, we converted 27.7 umol/L into 0.0279 mmol/L. Finally, taking the ratio of 1.06039053 mmol/L and 0.0279 mmol/L, you get 38.281 mmol (HDL-C): 1 mmol (HDL-P).

Using the equation III, we can visualize in the equation below that the two results are identical which proves that the HDL-specific conversion equation works and is accurate in finding cholesterol/particle level of HDL.

We derived this new HDL-specific conversion factor equation by taking the known conversion factor of 0.0258632, which converted mg/dL to mmol/L, and multiplying by 1e3, which is used to convert umol to mmol to get the new HDL-specific conversion factor of 25.8632.

There have been many studies done using LDL-P, total TG, and HDL-P to determine their role sin potential risks in various cardiovascular diseases. However, the role of apolipoprotein B is an ongoing area of research. Primary reason is the fact that there is only one apolipoprotein B in one LDL, which serves as an important marker to test for risks in cardiovascular diseases. Instead of having two variables of LDL-C and LDL-P, now we can only use apolipoprotein B to determine a similar result. However, this is an emerging field of research, thus the full significance is yet to be determined[8].

Apolipoprotein B (ApoB) is normally measured in mg/dL and LDL-P is measured in nmol/L. To compare the values between ApoB and LDL-P, we need both values to be under one concurrent unit; therefore, we decided to convert mg/dL to nmol/L. With this conversion, we can easily compare between ApoB and LDL-P to measure their effect on atherosclerosis patients.

To convert mg/dL to nmol/L for ApoB, we used the equation:

Equation IV:

19.5313 x {Apolipoprotein B (mg/dL)} = Apolipoprotein B (nmol/L)

Example V (Converting ApoB mg/dL to nmol/L):

Before we start our conversion, it is crucial to find the molecular weight of Apolipoprotein B as it is measured in g/mol, the unit that we desire. However, only the molecular mass of ApoB is given, so we must calculate the molecular weight. It is commonly agreed that the average molecular mass of ApoB is 512kDa[9]. To convert kDa to g/mol, we take 512 kDa and multiplied by 1000 Da/1 kDa and multiplied that value by 1 g/ 1 Da mol to get 512,000 g/mol. As a result, we now know that the molecular weight of 512 kDa of ApoB is 512,000 g/mol.

With the molecular weight, we can proceed with the conversion. We started with an initial value of 49 mg/dL of ApoB. We multiplied by 1dL/0.1L to convert dL into L. Next, we multiplied by 1mol/512,000g (molecular weight of ApoB). We then multiplied by 1g/1000mg to convert gram to mg and finally, we multiplied by 1e9 nmol/1mol to convert mol into nmol to get 957.03125 nmol/L.

Using the equation IV to verify our dimensional analysis, we get the exact same value:

We derived this conversion equation of mg/dL to nmol/L of ApoB by using the conversion factor of 19.5313. We took 1e9 nmol/1mol and multiplied by 1dL/0.1 L, 1mol/512,000g and 1g/1000mg to get 19.5313. By combining the conversion from dL to L, g to mg and mol to nmol, we increased the efficiency of conversion. The final conversion factor that we derived is 19.5313, which will aid in converting ApoB in mg/dL to nmol/L.

Conclusions

The formulas that have been created will guide future researchers and current researchers to obtain data more swiftly and efficiently and to draw more accurate conclusions to help patients with cardiovascular disease or simply to screen as a preventative measure. However, these formulas only serve as one compartment to lipid research. Calculating the ratios between different lipoproteins are important but it is just as important how to utilize the data to correctly interrupt the correlation amongst different lipids. Optimistically, we hope that easier and quicker calculations will alleviate physicians and researchers from superfluous and avoidable burdens so that they may more efficiently help patients to improve their mortality and morbidity.

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