Dyslipidemia in type 2 diabetes mellitus (T2DM): Pathophysiology, pattern and management

Dhanya A V1, Sanjiv Karale2*, Priya Varkey3, Amruthakrishna Anil4, Abhijith K5

1PG Student, 2Associate Professor, 3-5PG Student, Dept. of Pharmacology, Shree Devi College of Pharmacy, Mangalore, Karnataka, India

*Corresponding Author: Sanjiv Karale
Email: sanjiv.karale@gmail.com

Abstract
Type 2 diabetes mellitus (T2DM) is related with severe cardiovascular morbidity and mortality throughout the worldwide. Dyslipidemia, high blood glucose level, and coronary artery diseases are well linked with each other in T2DM and it has been demonstrated that higher prevalence of cardiovascular disease (CVD) in T2DM is due to chronic uncontrolled hyperglycemia. Dyslipidemia, which affects almost 50% of patients with T2DM, is a cardiovascular risk factor and characteristic features of dyslipidemic diabetes are elevated plasma triglyceride level, decline in high density lipoprotein cholesterol (HDL-c) level, and raised level of small dense low density lipoprotein (LDL) particles. An adequate availability of many lipid-lowering agents and nutritional supplements provides novel and effective treatments in control of lipid levels in diabetes patients. Several hypolipidemic drugs, such as statins, fibrin acid derivatives, niacin, and bile acid sequestrants, are available to target normalization of the entire lipid profile in T2DM patients. This review highlights the prevalence, underlying pathogenesis, patterns and various management approaches of dyslipidemia in patients with T2DM.

Keywords: Type 2 diabetes mellitus, Dyslipidemia, Cardiovascular disease, statins, Triglycerides.

Introduction
“Sweet is Sweet but until it is not too Sweet”. As the diabetes a major healthcare concern and challenges the global population, diabetic organizations worldwide call for unanimous resonance of Diabetes Voice to tackle diabetes with healthy living. With an emerging of new pathophysiology linked with diabetes, patients are receiving access to the newer therapeutic category agents.1 Diabetes is a common endocrine metabolic disorder which can leads to complications in various parts of our body and might results in premature death. The increase in the persuasiveness of this disease is quite distressing. According to the latest 2016 data from the WHO, 422 million adults are suffering with diabetes mellitus (DM).2 Dyslipidemia is a major risk factor for macroversal complications in patients with Type-2 DM (T2DM) and affects 10% - 73% of the population. Dyslipidemia is prominent in DM which causes death of about 80% of the patients due to cardiovascular disease (CVD).3 Although, both diabetes and dyslipidemia represent different genetic disorders, there is a chance of concurrence in same individual.4

DM is a group of metabolic disease characterized by hyperglycemia, glucosuria, hyperlipidemia, negative nitrogen balance and sometimes ketonemia.5 Dyslipidemia is defined as elevated total cholesterol, low-density lipoprotein (LDL) cholesterol, or triglycerides (TG); low high-density lipoprotein (HDL) cholesterol; or a combination of these abnormalities.6 Diabetic dyslipidemia is manifested as raised LDL, decreased HDL, and elevated TG. Elevated TG level is a significant risk factor for coronary heart diseases.7

DM if left untreated can leads to several life threatened macrovascular and microvascular complications. The microvascular complications are retinopathy, nephropathy, and neuropathy, while the macrovascular complications of diabetes include angina, myocardial infarction, transient ischemic attack, and stroke.8 The objective of this paper is to provide a comprehensive datum to summarize the various pathophysiology, patterns and management involved in diabetic dyslipidemia.

Pathophysiology
Several mechanisms are involved in the development of dyslipidemia in T2DM. Hepatic glucose and metabolism of lipids are varied in metabolic disorders like T2DM. The normal lipid metabolism is shown in Fig. 1. There exist typical patterns of dyslipidemia in T2DM, which reveal an elevated TG and LDL and decreased level of HDL. Insulin resistance or deficiency in T2DM can lead to altered normal lipid metabolism, which in turn leads to raised production of TG, VLDL, LDL and diminished production of HDL.4

Raised VLDL Levels
The mechanism for increased VLDL levels are: overproduction, increased secretion & reduced catabolism.9, 10

Overproduction
Raised production of VLDL-TG and VLDL Apolipoprotein B (Apo B) resulting in increased formation of VLDL. Normally, insulin inhibits the expression of Microsomal Transfer Protein (MTP) and thus blocks the lipidaion of Apo B and reduces the secretion of Apo B. But in T2DM, insulin resistance leads to the activation of MTP.

Increased Secretion
Insulin fails to arrest lipolysis in adipose tissue and Forkhead Box Protein 01 (Fox 01) in liver due to resistance in T2DM. This results in the activation of MTP and Apolipoprotein CIII (Apo CIII). These mechanisms cause the increased secretion of Apo B in the form of VLDL particles.
Reduced Catabolism
Defective catabolism of VLDL shows the suppressed activity of LPL. Since insulin is the activator of LPL, the activity will be declined in T2DM.

Increased small dense LDL (sdLDL)
Increased level of VLDL in plasma results in the formation of sdLDL. The sdLDL is produced through the following steps: 12
1. CETP eases the movement of TG from VLDL to LDL (TG-rich LDL).
2. Hepatic lipase enzyme acts on this TG-rich LDL.
3. Raised lipolysis of TG-rich LDL leads to the generation of sdLDL.

Decreased HDL
Hepatic lipase enzyme hydrolyses TG and phospholipids and produce small dense HDL particles. In T2DM, the activity of hepatic lipase increases. It leads to accelerated HDL metabolism resulting in diminished levels of HDL.13

Pattern of Dyslipidemia in T2DM Patients
The best time to go through the prevalence and pattern of dyslipidemia with DM is at the time of the diagnosis of diabetes as subsequent management with pharmacological drugs or non-pharmacological measures can modify the both pattern as well as the prevalence of dyslipidemia.14 The recent literature surveys demonstrate that various studies have been performed to identify the difference in the pattern of dyslipidemia in T2DM patients in different population.

Table 1: Study in Indian population

| Parameters          | Punjab        | Madhya Pradesh | Odisha        | Mangalore     | Southern India |
|---------------------|---------------|----------------|---------------|---------------|----------------|
| Year                | 2016          | 2015           | 2017          | 2015          | 2012           |
| Recruitment period  | Mar 2015-Aug  | Mar 2013-Oct 14| May 2015-Jan  | Dec 2014      | March 2010 to April 2012 |
| Study design        | Cross-sectional study | Cross –sectional study | Cross- sectional study | Cross -sectional study | Cross sectional study |
| Age                 | 45-60         | >30 yrs        | ≥40           | >18           | >18            |
| Subjects            | Men & women- 285 | M:29           | M:362         | M:50          | M:533          |
|                     |               | F:21           | F:41          | F:50          | F:287          |
| Lipid levels        | TG↑           | TG↑            | TG↓           | TG↑           | TG↑            |
|                     | LDL↑          | LDL↑           | LDL↑          | LDL↑          | LDL↑           |
|                     | HDL↓          | HDL↓           | HDL↓          | HDL↓          | HDL↓           |

Table 2: Studies conducted at different countries

| Parameters          | Nepal   | Pakistan | Sri-Lanka | South Africa | Ethiopia |
|---------------------|---------|----------|-----------|--------------|---------|
| Year                | 2017    | 2016     | 2016      | 2017         | 2015    |
| Recruitment period  | July –Dec 2014 | 2014-2015 | January 2012- July 2013 | July – August 2012 | Mar – Nov 2014 |
| Study design        | Cross –sectional study | Cross- sectional study | Cross-sectional study | Cross-sectional study | Cross-sectional study |
| Age                 | NA      | >40 or<40 | <45 or>45 | >18          | Not mentioned |
| Subjects            | M:84    | M:120    | M:289     | M:86         | M:172   |
|                     | F:64    | F:80     | F:114     | F:114        | F:123   |
| Lipid levels        | ↑TG     | ↑TG      | ↓TG       | ↑TG          | ↑TG    |
|                     | ↑HDL    | ↑HDL     | ↑HDL      | ↑HDL         | ↑HDL   |
|                     | ↑LDL    | ↑LDL     | ↑LDL      | ↑LDL         | ↑LDL   |

Studies conducted in Indian population were listed in Table 1,15-18 and studies conducted in different parts of the world were mentioned in Table 2,14,19-22

Management of Dyslipidemia
The management of dyslipidemia diabetes needs a comprehensive strategy to regulate the levels of lipid and to discuss over associated metabolic complicated disorders and modifiable risk factors like hypertension, diabetes, obesity, and cigarette smoking. There are mainly 2 principal approaches for dyslipidemia, lifestyle intervention and lipid modifying drug therapy.23

Non Pharmacological Treatment:23
Diet
Dietary approaches extend from one extreme to another regarding fats, sugar, and protein content. Caloric intake should be reduced and it include five servings per day of fruits and vegetables and six servings per day of grains together with one- third of whole grains, fish and lean meat. Reduce the intake of saturated fats, trans fats, and cholesterol.

Exercise
Intensity of the exercise should be for 30 minutes. It is beneficial in patients with diabetic dyslipidemia as it prevents development and progression of atherosclerosis and improvements are seen in all parameters of dyslipidemia including HDL, TG and LDL with regular physical activity.
Table 3: Guidelines for statin therapy by different associations

| Names of the associations | High intensity statin therapy | Moderate intensity statin therapy |
|---------------------------|------------------------------|----------------------------------|
| American Diabetes Association Standards of Medical Care In Diabetes | -DM and ASCVD any age -DM, age 40-75 and 1 risk factor -DM, age <40 or >75 and risk factors. | -DM, age <40 or >75 and 1 risk factor -DM, age >40 and no risk factors |
| American College of Cardiology/American Heart Association Blood Cholesterol Guidelines for ASCVD Prevention. | -DM and LDL >190 mg/dL -DM, age 40-75 year, LDL 70-189 mg/dL and 10 year ASCVD risk >7.5%. | -DM, age 40-75, LDL70-189 mg/dL -10 year ASCVD risk <7.5%. |

Table 4: Effects of glucose lowering drugs on lipid profile

| Sl. No | Antidiabetic Agents | Effects of antidiabetic agent on lipids profile |
|--------|---------------------|---------------------------------------------|
| 1      | Metformin[28]       | ↓LDL ↔↑HDL ↓Total Cholesterol (TC) ↔↓TG   |
| 2      | Pioglitazone[29]    | ↓LDL ↑HDL ↑TC ↓TG                          |
| 3      | Rosiglitazone[29]   | ↑LDL ↓HDL ↓TG                               |
| 4      | Saroglitazar[30]    | ↓LDL ↓TC ↓VLDL                              |
| 5      | Sitagliptin[31]     | ↔↑HDL                                       |
| 6      | Linagliptin[32]     | No effect                                    |
| 7      | Teneligliptin[33]   | ↓LDL ↑HDL ↓TC ↓TG                           |
| 8      | Canagliflozin[34]   | ↑LDL ↑HDL ↑TC ↑TG                           |
| 9      | Empagliflozin[31]   | ↔↑LDL ↔↑HDL ↔↑TC                          |
| 10     | Exenatide[35]       | ↔↑LDL ↔↑HDL ↔↑TC ↑TG                       |
| 11     | Dulaglutide[36]     | ↓LDL ↓TC ↓TG                               |

↓: decrease, ↑: increase, ↔: no effect

Fig. 1: Normal lipid metabolism

Pharmacological Treatment

Cholesterol Lowering Agents

Statins
The initial therapy which is used in the treatment of diabetic dyslipidemia is that statin therapy. AACE, ADA and ACC/AHA guidelines for statin therapy is given in Table 3.23-25 For patients with LDL level between 100 and 129 mg/dl, the treatment strategy that could be considered should include statin. High intensity statin therapy includes atorvastatin 80 mg/day and rosuvastatin 20-40 mg/day.25 Moderate-intensity statin therapy includes atorvastatin 10-20 mg once daily, fluvastatin 40 mg twice daily, lovastatin 40 mg once daily, pravastatin 40-80 mg once daily, rosuvastatin 5-10 mg once daily, simvastatin 20-40 mg once daily and pitavastatin 2-4 mg once daily.26

Fibrates
Fibrates are peroxisome proliferator activated receptor (PPAR)-α agonists, they reduces TG level and are capable of slightly increasing the level of HDL cholesterol and are
evidenced with decreased cardiovascular mortality. LDL lowering can also be achieved by these agents at very high dose fibric acid derivatives.\textsuperscript{27} Ezetimibe
This is a selective cholesterol absorption inhibitor as well as a lipid-lowering agent when used as monotherapy and it is useful in patients who are unable to tolerate statin therapy. Ezetimibe can also be used in combination with statin therapy for greater lipid-lowering efficacy.\textsuperscript{28}

| Antidiabetic Agents |
|---------------------|
| In addition to their glucose-lowering properties, antidiabetic agents that directly improve insulin resistance may have effects on lipid levels, especially TG levels. The effect of antidiabetic drugs on lipid profile is depicted in Table 4.\textsuperscript{1,29-36} |

Bile Acid Sequestrant
Colesovelam, the bile acid sequestrant has been used in practice to reduce LDL levels as well as improve blood glucose levels in T2DM patients.\textsuperscript{37}

| Conclusion |
| In the current study, various mechanisms and hypotheses are proposed to explain the pathophysiology of diabetic dyslipidemia. All these data suggest that, overproduction of VLDL is the core of all other events occurs in diabetic dyslipidemia. The common pattern of diabetic dyslipidemia is hypertriglyceridemia, high levels of LDL cholesterol and low level of HDL cholesterol. Different methods are preferred for the control and treatment of diabetic dyslipidemia and are described in nutshell. Individualization of therapy is important for better outcomes. |

**Conflict of Interest:** None.

**References**

1. Maladkar M, Sankar S, Kamat K. Teneligliptin: Heraldings Change in Type 2 Diabetes. J Diabetes Mellitus 2016;6(2):113-31.
2. Roglic G. WHO Global report on diabetes: A summary. Int J Non-Commun Dis 2016;1(1):3.
3. Mithal A, Majhi D, Shumugavelu M, Talwarkar PG, Vasnavala H, Raza AS. Prevalence of dyslipidemia in adult Indian diabetic patients: A cross sectional study. Indian J Endocrinol Metab 2014;18(5):642.
4. Khan M, Sakuntala P, Siddeswari R, Sudessi B. Pattern of Dyslipidemia in Diabetes Mellitus. Int J Sci Res Public 2015;5(5):1849-61.
5. Tripathi KD. Essentials of Medical Pharmacology 7th Ed. New Delhi: Jaypee brothers’ medical publisher; 2013:558.
6. Wells BG, DiPiro CV, DiPiro JT, Schwinhammer TL. Pharmacotherapy Handbook. 7th Ed. New York: The McGraw-Hill Companies; 2009:98.
7. Bali K, Vij AS. Pattern of dyslipidemia in type 2 diabetes mellitus in Punjab. Int J Res Med Sci 2016;4(3):809-12.
8. Fowler MJ. Microvascular and macrovascular complications of diabetes. Clin Diabetes 2008;26(2):77-82.
9. Haas ME, Attie AD, Biddinger SB. The regulation of ApoB metabolism by insulin. Trends Endocrinol Metab 2013;24(8):391-7.
10. Sørensen L, Andersen I, Søndergaard E, Gormsen L, Schmitz O, Christiansen J et al. Basil and Insulin Mediated VLDL- Triglyceride Kinetics in Type 2 Diabetic Men. Diabetes 2010;60(1):88-96.
11. Vergès B. Pathophysiology of diabetic dyslipidaemia: where are we? Diabetologia 2015;58(5):886-99.
12. Hirano T. Pathophysiology of Diabetic Dyslipidemia. J Atheroscler Thromb 2018;25(9):771-82.
13. Labadzhyana A, Cui J, Pétery M, Guo X, Chen Y, Hsuew H et al. Insulin Clearance Is Associated with Hepatic Lipase Activity and Lipid and Adiposity Traits in Mexican Americans. Plos One 2016;11(11):e0166263.
14. Sarfraz M, Sajid S, Ashraf MA. Prevalence and pattern of dyslipidemia in hyperglycemic patients and its associated factors among Pakistani population. Saudi J Biol Sci 2016;23(6):761-6.
15. Børkø AL, Chhiari N, Gupta G, Batthma V. Study of prevalence and pattern of dyslipidemia in type 2 diabetes mellitus patients attending rural health training centre of medical college in Bhopal, Madhya Pradesh, India. Int J Community Med Public Health 2017;3(1):140-4.
16. Samantaryar R, Bal AK, Das D. Pattern of Dyslipidemia in Type 2 Diabetic Patients in Southern Odisha. Sch J App Med Sci 2017;11(1):4397-4401.
17. Faseeh KM, Pasha SW, Maryam Z, Thunga MV. The Pattern of dyslipidemia among type 2 Diabetes Mellitus patients of Mangalore. Indian J Basic Appl Med Res 2015;4(2):254-7.
18. Jayarama N, Reddy M, Lakshmaia V. Prevalence and pattern of dyslipidemia in type 2 diabetes mellitus patients in a rural tertiary care centre, southern India. Glob J Med Public Health 2012;1:24-8.
19. Shrestha HK, Khanal L. Prevalence and Pattern of Dyslipidemia among Type 2 Diabetes Mellitus Patients in a Tertiary Center Hospital of Nepal. Endocrinol Metab Int J 2017;4(3):54-6.
20. Herath HM, Weerarathna TP, Weerasinghe NP. Prevalence and pattern of Dyslipidaemia among Type 2 Diabetes Mellitus Patients in a rural tertiary care hospital. Indian J Endocrinol Metab 2015;4(2):254-7.
21. Daya R, Bayat Z, Raal FJ. Prevalence and pattern of dyslipidaemia in type 2 diabetes mellitus patients at a tertiary care hospital. J Endocrinol Metabol Diabetes South Africa 2017;22(3):31-5.
22. Ambachew H, Shimelis T, Lemma K. Dyslipidemia among diabetic patients in Southern Ethiopia: Cross-sectional study. J Diabetes Endocrinol 2015;6(4):19-24.
23. Jellinger PS, Smith DA, Mehta AE, Ganda O, Handelsman Y, Rodbard HW et al. American Association of Clinical Endocrinologists Guidelines for Management of Dyslipidemia and Prevention of Atherosclerosis. Endocr Pract 2012;18(suppl1):S1-78.
24. 2013 Prevention Guideline Tools: CV Risk Calculator. American Heart Association Available from: http://my.american.heart.org/cvriskcalculator. Accessed 28/12/2016.
25. American Diabetes Association. Standards of medical care in diabetes—2015. Diabetes Care 2015; 38(suppl 1):S1-99.
26. Stone NJ, Robinson JG, Lichtenstein AH, Bairey Merz CN, Blum CB, Eckel RH et al. 2013 ACC/AHA guideline on the treatment of blood cholesterol to reduce atherosclerotic cardiovascular risk in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guide-lines. Circ 2014;129:S1-S45.
27. Lalloyer F, Staels B. Fibrates, glitazones, and peroxisome proliferator–activated receptors. Arterioscler Thromb Vasc Biol 2010;30(5):894-9. 
Dhanya A V et al. Dyslipidemia in type 2 diabetes mellitus (T2dm): Pathophysiology, pattern and management

28. Chan DC, Watts GF, Gan SK, Ooi EM, Barrett PH. Effect of ezetimibe on hepatic fat, inflammatory markers, and apolipoprotein B-100 kinetics in insulin-resistant obese subjects on a weight loss diet. Diabetes Care 2010;33(5):1134-9.
29. Xu T, Brandmaier S, Messias AC, Herder C, Draisma HH, Demirkan A et al. Effects of metformin on metabolite profiles and LDL cholesterol in patients with type 2 diabetes. Diabetes Care 2015;38(10):1858-67.
30. Simo R, Rodriguez A, Caveda E. Different Effects of Thiazolidinediones on Cardiovascular Risk in Patients with Type 2 Diabetes Mellitus: Pioglitazone vs Rosiglitazone. Curr Drug Saf 2010;5(3):234-44.
31. Pai V, Paneerselvam A, Mukhopadhyay S, Bhansali A, Kamath D, Shankar V et al. A multicenter, prospective, randomized double-blind study to evaluate the safety and efficacy of saroglitazar 2 and 4 mg compared to pioglitazone 45 mg in diabetic dyslipidemia (PRESS V). J Diabetes Sci Technol 2014;8(1):132-41.
32. Roden M, Weng J, Eilbracht J, Delafont B, Kim G, Woerle HJ et al. Empagliflozin monotherapy with sitagliptin as an active comparator in patients with type 2 diabetes: a randomised, double-blind, placebo-controlled, phase 3 trial. Lancet Diabetes Endocrinol 2013;1(3):208-19.
33. Zimman B, Ahren B, Neubacher D, Patel S, Woerle HJ, Johansen OE. Efficacy and cardiovascular safety of linagliptin as an add-on to insulin in type 2 diabetes: a pooled comprehensive post hoc analysis. Can J Diabetes 2016;40(1):50-7.
34. Forst T, Guthrie R, Goldenberg R, Yee J, Vijapurkar U, Meininger G, et al. Efficacy and safety of canagliflozin over 52 weeks in patients with type 2 diabetes on background metformin and pioglitazone. Diabetes Obes Metab 2014;16(5):467-77.
35. Schwartz EA, Koska J, Mullin MP, Syoufi I, Sachwenke DC, Reaven PD. Exenatide suppresses postprandial elevations in lipids and lipoproteins in individuals with impaired glucose tolerance and recent onset type 2 diabetes mellitus. Atherosclerosis. 2010; 212(1):217-22.
36. Edwards KL, Minze MG. Dulaglutide: an evidence-based review of its potential in the treatment of type 2 diabetes. Core Evid 2015;10:11-21.
37. Fonseca VA, Handelsman Y, Staels B. Colesevelam lowers glucose and lipid levels in type 2 diabetes: the clinical evidence. Diabetes Obes Metab 2010;12(5):384-92.

How to cite this article: Dhanya AV, Karale S, Varkey P, Anil A, Abhijith K. Dyslipidemia in type 2 diabetes mellitus (T2dm): Pathophysiology, pattern and management. Int J Comprehensive Adv Pharmacol 2019;4(2):34-8.