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Correlation between diabetic retinopathy and diabetic neuropathy in patients with diabetes mellitus: A systematic review and meta-analysis

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Abstract

Background & Objective: The early identification of microvascular complications associated with diabetes plays a crucial role in determining the disease's prognosis. This systematic review and meta-analysis aimed to investigate the correlation between diabetic retinopathy (DR) and diabetic neuropathy (DN) in patients with diabetes mellitus (DM). *Method:* An advanced literature search was carried out until February 18, 2024, and we accessed the relevant articles from databases including Google Scholar, PubMed, and Scopus. Related articles were extracted. Titles, abstracts, and full texts of the articles were screened. The quality of the included articles was assessed, and the data was extracted and analyzed. *Result:* We included 6 cohort and cross-sectional studies with a total population of 54,586. The primary outcome of this study was the interactions among the diabetic microvascular complications, including DR and DN. Our findings indicate DN is associated with increased risk of DR twofold (pooled effect: 2.08, 95% confidence interval (CI): 1.53-2.82، I^2: 81%, $p<0.01$). DR was related to DN (pooled OR: 2.67, 95% CI: 1.64–2.97, $p<0.01$).
Conclusion: This meta-analysis showed that DN is associated with increased risk of DR in patients with type 2 diabetes. Given the high heterogeneity observed in the studies, further large-scale randomized control trials are still required to prove this association.

Keyword: Diabetes, retinopathy, neuropathy, microvascular complications

INTRODUCTION

Diabetes mellitus (DM) refers to a group of metabolic disorders that share the phenotype of hyperglycemia. Different types of DM result from the interaction between genetics and environmental factors.[1] DM affects more than 240 million people worldwide.[2] DM can impact various organ systems and is responsible for the morbidity and mortality related to the disease.[3]

The two usual microvascular DM complications are diabetic retinopathy (DR) and diabetic neuropathy (DN).[4] Both microvascular complications have the exact pathogenesis.[5]

Approximately half of diabetic people experience some degree of DR at any given point.[6,7] Several risk factors have been linked to the onset and advancement of, including age, duration of diabetes, dyslipidemia, high blood pressure, anemia, blood sugar control,

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smoking and alcohol, pregnancy, type of DM, and renal disease.[6,7] Ocular risk factors include old chorioretinopathy, previous cataract surgery and posterior vitreous detachment. The duration of DM and the degree of blood sugar control are the most significant predictors of the progression of retinopathy.[8,9]

Peripheral neuropathy is the most prevalent and challenging complication of diabetes.[10] Its occurrence varies from 7% in the first year of diagnosis to 50% in individuals with diabetes for over 25 years.[11] DN initially affects the distal areas of the lower limbs. As the disease advances, sensory loss spreads up the legs and eventually reaches the hands, resulting in characteristic "stocking and glove" sensory loss.[3] Numerous articles have highlighted the associations between diabetic microvascular complications[12-22], emphasizing the necessity of screening for additional complications when one complication is present. Li *et al*.[20] Explored the correlation between microvascular complications of diabetes. Their findings suggest that routine screening for additional microvascular complications may be beneficial in cases where one complication is identified, particularly for patients with DR.[20]

Previous research unequivocally underscores the significance of the association between microvascular complications of diabetes. Thus, for the first time, this meta-analysis aims to determine the correlation between DR and DN in patients with diabetes mellitus.

METHODS

In this meta-analysis systematic review article, we intend to assess the correlation between diabetic retinopathy and diabetic neuropathy in patients with DM. The methodology of this article follows the PRISMA guidelines (approved Reporting features for Systematic Reviews and meta-analysis articles).[23]

Literature search

An advanced literature search was carried out until February 18, 2024, and we reclaimed applicable articles from databases including Google Scholar, PubMed, and Scopus. The search strategy involved three subgroups of keywords. Two subgroups included terms related to retinopathy and neuropathy. Also, the other subset was included (microvascular or micro-vascular). The subgroups were joined using the 'AND' agent, and no limitations were applied in terms of the date of publication, publication type, or any languages. The search strategy was revised, conforming to the question format for each database (Table 1). Furthermore, we evaluated the reference lists of relevant systematic review papers and comprised missed studies related to our research. Two reviewers did all phases separately, and any controversies were determined through discussion between the reviewers.

Criteria for selecting studies

For studies to be included in this meta-analysis article, the following criteria should be considered: (1) Observational methodology (to eliminate effects of any intervention); (2) The study aimed to assess the correlation between retinopathy and neuropathy. Studies performed using other types of methodology, such as animal models or cellular molecular studies, were excluded. Review articles, editorials, commentaries, and interventional studies were also excluded.

Data extraction and study quality assessment

Two earlier reviewers examined each study's

Table 1: Search Strategy

Search engine	Search strategy	Additional filter	Total result
Pubmed	"retinopathy"[Title/Abstract] AND "neuropathy"[Title/Abstract] AND "microvascular"[Title/Abstract]	17 February 2024	1276
Scopus	(TITLE-ABS-KEY (retinopathy) AND TITLE-ABS-KEY (neuropathy) AND TITLE-ABS-KEY (micro AND vascular) OR (microvascular))	17 February 2024	2500
Google Scholar	With all the words: retinopathy/ neuropathy/microvascular/ in title	17 February 2024	4
	With all the words: retinopathy/ neuropathy/in title		446

title and abstract to assess its qualification for inclusion in this review article. Studies that did not meet our standards were eliminated. The full texts of the other studies were screened, and acceptable studies were added to the data extraction process. Next, four sets of the following items were collected for extraction: 1. Study components (i.e., authors, year, location, and type of study), 2. patient-specific factors (i.e., the eligibility criteria for patients with DM, 3. Study design (i.e., number of participants, study method, definition of retinopathy and neuropathy), 4. Outcomes (i.e., rate of DR and DN). Former reviewers employ crucial assessment checklists for observational studies, such as cohort and analytical cross-sectional studies developed by the Joanna Briggs Institute (JBI) (https://jbi.global/critical-appraisal-tools). A third author participated in the process in case of inconsistency.

Statistical analysis

We utilize STATA 13.1 software promoted by StataCorp LP in College Station, USA, TX, for data analysis. Results were recorded as pooled odds ratios (ORs) with a 95% confidence interval, and featured in a forest plot (Figure 2). We assessed heterogeneity among the acceptable studies using the I2 statistic.[24] And used the random effects model when consequential heterogeneity was identified (I2 > 50%).[25] Additionally, we organized a sensitivity analysis, excluding one study for a while and repeating the meta-analysis process(Figure 4). This permitted us to ensure the stability of our reports. Eventually, to examine the potential for publication bias, we approved a visual inspection of funnel plot symmetry and Egger's regression analysis.[26]

RESULTS

Study selection

A thorough search was performed on PubMed, Scopus, and Google Scholar to locate pertinent articles. At first, 4226 articles were found. Following the elimination of 3,079 duplicates, 1,147 distinct articles were left. These were assessed based on titles and abstracts, and 184 articles were chosen for full-text evaluation. Ultimately, 6 articles that met the inclusion criteria were included in the systematic review. (Figure 1).

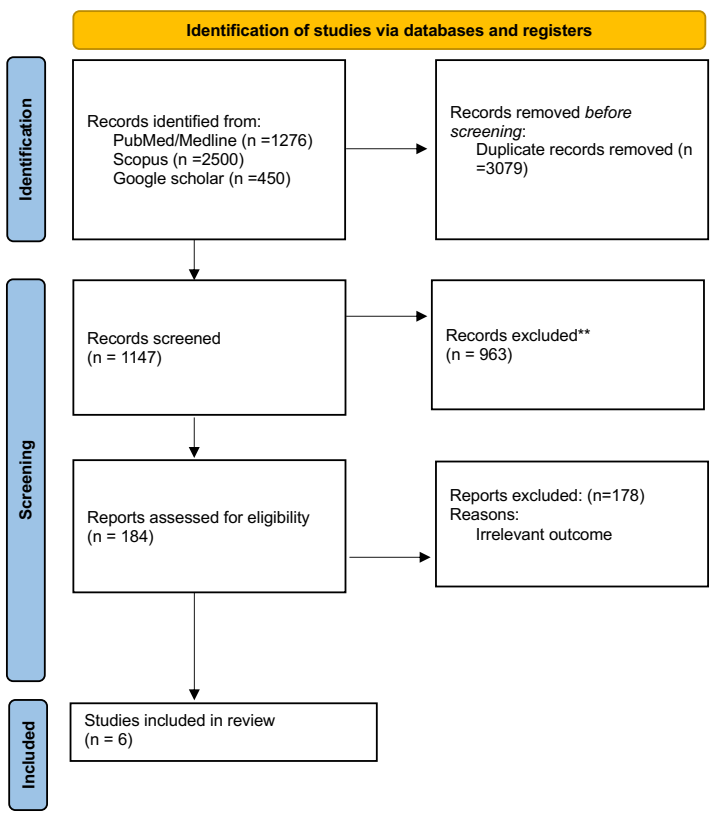

Figure 1. PRISMA flow chart.

Baseline characteristics

This systematic review encompassed 6 articles involving a total population of 54,586 patients with diabetes mellitus. Studies were conducted in multiple countries, including the USA[13], China[27], Saudi Arabia[14], India[12,28], and the United Arab Emirates.[15] All of the studies were either cohort or cross-sectional studies. The primary objective was to evaluate the correlation between DR and DN in patients with DM (Table 2).

Meta-analysis

Our meta-analyses all together show that DN is associated with increased risk of DR by twofold (pooled effect: 2.08, 95% CI: 1.53-2.82, I^2: 81%, $p<0.01$). The funnel plot chart is symmetric and shows low publication bias (Figure 3). With the increase in changes, all three parameters (OR, CI lower, and CI upper) exhibit an upward trend. This indicates that the changes significantly impact the OR and its confidence intervals, which may reflect your model's robustness or the data's sensitivity to variations.

DISCUSSION

Diabetes mellitus is a persistent medical condition marked by concurrent vascular and neurological complications that develop progressively. DR and DN are the two most prevalent complications associated with diabetes mellitus. DR has long been recognized as a disorder impacting the microvasculature and is diagnosed based on microvascular alterations.[29,30] The loss of pericytes, endothelial cell apoptosis, and thickening of the basement membrane collectively contribute to the disruption of the blood-retinal barrier, capillary blockage, and ischemia.[31]

DN involves the gradual loss of nerve fibers, leading to symptoms like pain, paresthesia, and reduced sensation. This loss follows a pattern where nerve damage starts proximally and extends distally, often linked to microvascular changes in peripheral nerves. Distal nerve fiber loss can begin in individuals with impaired glucose tolerance before impacting the lower extremities.[32,33] The condition's complexity arises from metabolic processes triggered by prolonged high blood sugar, including increased polyol pathway activity, advanced glycation end-product formation, cytokine release, protein kinase C activation, and oxidative stress.[32,33] These factors primarily damage distal nerve fibers, suggesting that targeting multiple metabolic pathways may be more effective for treatment than addressing individual factors alone.[32-34] On

Table 2: Summary of the included studies

Author/ Reference	Year	Country	Study design	Participants	Sex(female)	Mean age	Relation between neuropathy and retinopathy (Yes/No)
Fatma Al-Maskari *et al*.[15]	2007	United Arab Emirates	Cross-sectional	513 patients with DM2	249(48.5%)	53±13.01	Yes
Khalid Al-Rubeaan *et al*.[14]	2015	Saudi Arabia	Cross-sectional	50464 patients with DM2	22226(44%)	59.7±12.78	Yes
Barbara E. Klein *et al*.[13]	2018	USA	cohort	414 patients with DM1	–	–	Yes
Rehna Rasheed *et al*.[28]	2021	India	Cross-sectional	500 patients with DM2	197(39.4%)	58.89 ± 10.57	Yes
Rajendra Pradeepa *et al*.[12]	2010	India	Cross-sectional	1736 patients with DM2	-	-	Yes
Wei WW [27]	2017	China	Cross-sectional	959 patients with DM2			Yes

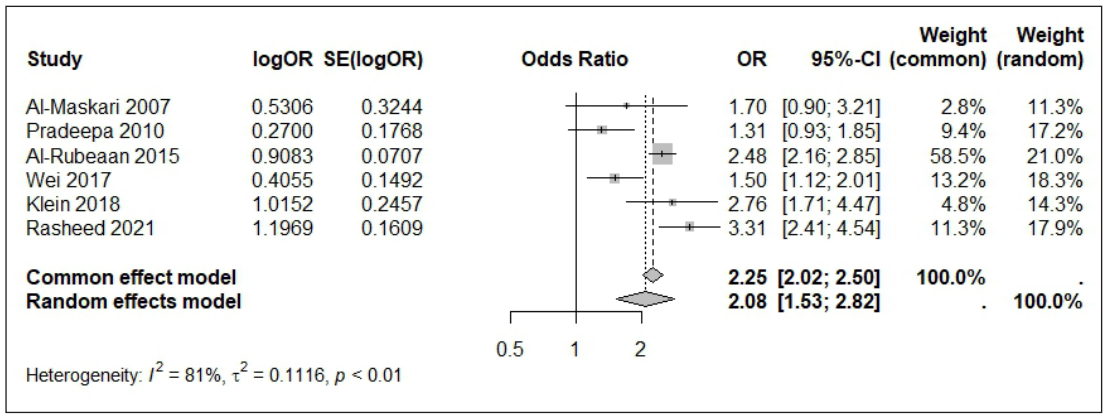

Figure 2. The forest plot demonstrates the results of this meta-analysis study. OR & 95%-CI for the random effect model confirm that it is significant in our study. OR: odds ratio, CI: confidence interval

the other hand, DR involves complex mechanisms related to diabetes microvascular complications.[35] Hyperglycemia is central, leading to advanced glycation end products, endothelial damage, and microaneurysms. Inflammation and vascular permeability contribute to diabetic macular edema.[35,36] Ischemia triggers pro-angiogenic factors like VEGF, causing neovascularization and severe complications in proliferative DR. Management involves regulating blood sugar, lipids, and blood pressure, alongside laser surgery, injections, and eye surgery.[34-36]

Rasheed *et al*.[22] study suggested that the average length of time the 500 patients had diabetes was 14.19 years. At this point, 48% of them had DR and 71.8% had DN. In our study group, the occurrence of DPN was 1.5 times higher than that of DR. They found a substantial likelihood of developing DPN with the duration of diabetes being 5.34 times as compared to 3.94 for DR in their study. These findings indicate that DPN becomes more prevalent than retinopathy as the duration of DM increases.[22] In a case-control study by Ayad *et al*.[37], the potential association between cardiac autonomic neuropathy and hypertension and its impact on diabetic complications was examined in 310 patients, comprising 138 individuals with type 1 diabetes and 172 with type 2 diabetes. The prevalence of hypertension was 20% in the overall population, with a notably higher occurrence in patients with type 2 diabetes compared to those with type 1 diabetes.[37] Retinopathy was detected in 25.8% of the patients, with a greater prevalence in type 1 diabetes patients. Peripheral neuropathy affected 33.2% of the patients, with a higher incidence in those with Type 2 diabetes. Symptoms indicative of dysautonomia were present in 26.2% of the patients, showing no significant disparity between type 1 and type 2 diabetes patients.[37] In a cross-sectional study conducted by Wei *et al*.[27], involving 959 patients with T2DM, it was found that DN was prevalent

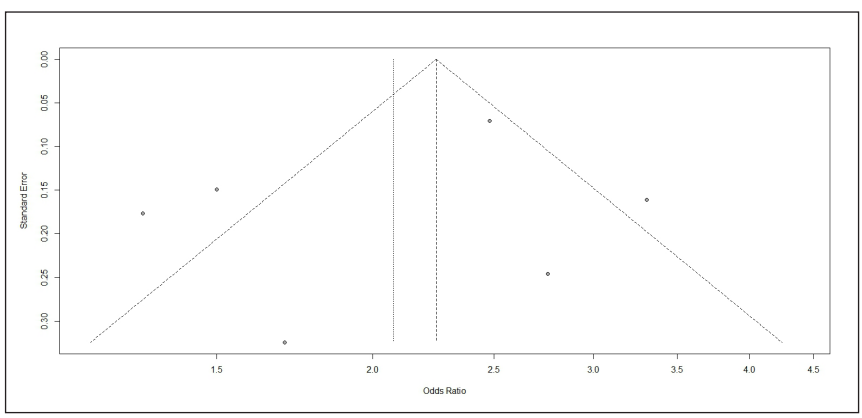

Figure 3. The funnel plot shows its symmetric appearance which is suggestive of low publication bias.

in 61.8% of patients with DR and 50% of those without DR. Their analysis revealed a significant association between DR and age and gender (male). Moreover, the presence of DN was found to increase the risk of DR. The study suggests that DPN is frequently observed in patients with type 2 diabetes mellitus and augments the risk of diabetic retinopathy.[27] Al-Maskari *et al*.[15] conducted a cross-sectional study involving 513 diabetic patients with a mean age of 53. The study revealed that retinopathy was present in 19% of the study population and was more prevalent among males. Additionally, the incidence of retinopathy increased with age and disease duration. Type I DM was identified as a significant contributing risk factor, with 38.3% prevalence among type 1 diabetes patients compared to 16.4% among type 2 diabetes patients. Furthermore, the study found higher rates of retinopathy among patients with comorbid conditions such as hypertension, microalbuminuria, peripheral vascular disease, coronary artery disease, and neuropathy.[15] In the cross-sectional study by Al-Rubeaan *et al*.[14], a cohort of 50,464 type 2 diabetic patients was examined. The study found that the prevalence of DR was 19.7% overall, with 9.1% having non-proliferative diabetic retinopathy (NPDR) (what is that?), 10.6% having proliferative diabetic retinopathy (PDR) (what is that?), and 5.7% having macular edema (ME). The research identified the duration of diabetes and age as the most significant risk factors for diabetic retinopathy. Additionally, nephropathy, neuropathy, insulin use, poor glycemic control, hypertension, and male gender were associated with an increased risk of DR, while smoking, hyperlipidemia, and obesity were found to reduce the risk among the type 2 Saudi diabetic cohort.[14] The study conducted by Klein *et al*.[13] revealed a significant association between sensory neuropathy, heart rate variability, PDR, and ME in individuals with long-term type 1 diabetes (T1D). The findings indicated that PDR and ME were notably linked to incident sensory neuropathy, and conversely, sensory neuropathy showed a significant association with incident PDR.[13] Thus, recent studies have established a correlation between diabetic retinopathy and diabetic neuropathy. Our results of this meta-analysis indicate a two-fold increase in the risk of diabetic retinopathy associated with diabetic neuropathy.

This study is subject to certain limitations, notably that the findings stem from a relatively small number of studies with diverse designs. This has restricted the range of interventions that can be endorsed. Additionally, the research was conducted in specific geographical locations such as America, India, and Arab countries, indicating that the conclusions may have limited generalizability across different racial groups.

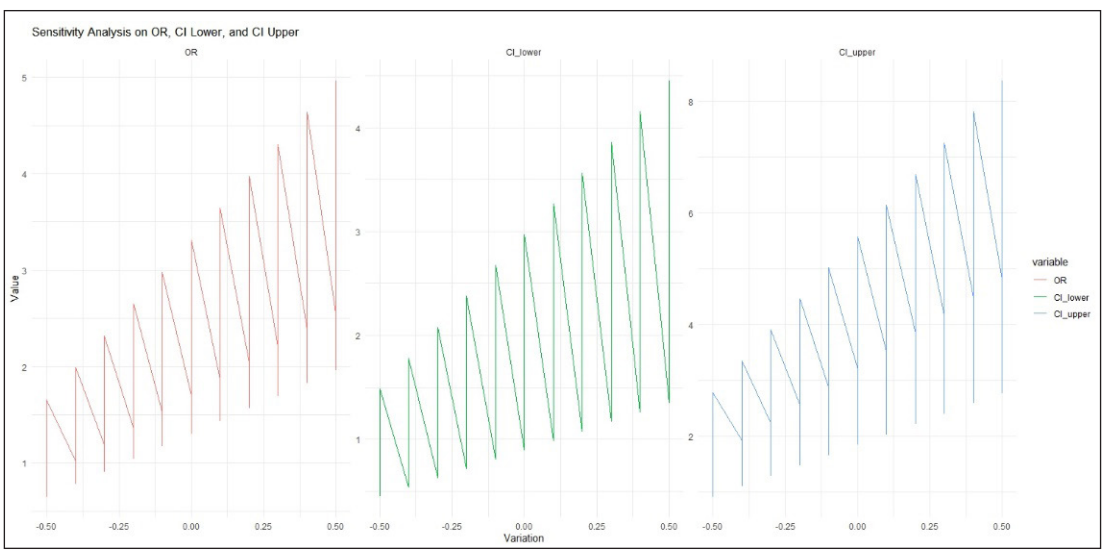

Figure 4. Sensitivity analysis plot (The range is between 2 to 8).
The OR plot (Red plot) shows the changes of OR to the variations, which are between 1 and 5.
The CI lower plot (Green plot) reveals that the lower limit of the confidence interval increases as the variations increase. The range is between 1 and 8.
CI upper plot (Blue plot) shows the changes of upper limits to variations. It also confirms the pattern like the CI lower plot.

In conclusion, this study highlights the significant relationship between DR and DN, two of the most common complications of diabetes. As the duration of diabetes increases, DN becomes more prevalent than DR. Various mechanisms, including microvascular changes and metabolic processes triggered by prolonged hyperglycemia, contribute to both conditions. The findings emphasize the importance of managing blood sugar, lipids, and blood pressure to mitigate these complications, and suggest that targeting multiple metabolic pathways may be a more effective treatment strategy. Additionally, studies show that factors such as disease duration, age, and comorbidities like hypertension and nephropathy significantly increase the risk of both DR and DN. Overall, this meta-analysis suggests a strong, bidirectional correlation between diabetic neuropathy and retinopathy.

DISCLOSURE

Data availability: Data is available upon request from the corresponding author.

Financial support: None

Conflict of interest: None

REFERENCES

1. Jameson JL, Kasper DL, Fauci AS, Hauser SL, Longo DL, Loscalzo J. Harrison's principles of internal medicine: McGraw-hill education; 2018.
2. Kasper D, Fauci A, Hauser S, Longo D, Jameson J, Loscalzo J. Harrison's principles of internal medicine, 19e: Mcgraw-hill New York, NY, USA:; 2015.
3. Saini DC, Kochar A, Poonia R. Clinical correlation of diabetic retinopathy with nephropathy and neuropathy. *Indian J Ophthalmol* 2021;69(11):3364-8. https://doi.org/10.4103/ijo.IJO_1237_21
4. Abbate M, Cravedi P, Iliev I, Remuzzi G, Ruggenenti P. Prevention and treatment of diabetic retinopathy: evidence from clinical trials and perspectives. *Curr Diabetes Rev* 2011;7(3):190-200.https://doi.org/10.2174/157339911795843168
5. Boulton AJ, Malik RA. Diabetic neuropathy. *Med Clin North Am* 1998;82(4):909-29. https://doi.org/10.1016/S0025-7125(05)70029-8
6. Gardner TW, Antonetti DA, Barber AJ, LaNoue KF, Levison SW. Diabetic retinopathy: more than meets the eye. *Surv Ophthalmol* 2002;47:S253-S62. https://doi.org/10.1016/S0039-6257(02)00387-9
7. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care* 2004;27(5):1047-53. https://doi.org/10.2337/diacare.27.5.1047
8. Ryan MK, Hendrickson AE. Interplexiform cells in macaque monkey retina. *Exp Eye Res* 1987;45(1):57-66. https://doi.org/10.1016/S0014-4835(87)80078-7
9. Al-Bdour MD, Al-Till MI, Abu Samra KM. Risk factors for diabetic retinopathy among Jordanian diabetics. *Middle East Afr J Ophthalmol* 2008;15(2):77-80. https://doi.org/10.4103/0974-9233.51997
10. Boulton AJ, Vinik AI, Arezzo JC, *et al*. Diabetic neuropathies: a statement by the American Diabetes Association. *Diabetes Care* 2005;28(4):956-62. https://doi.org/10.2337/diacare.28.4.956
11. Pirart J. Diabetes mellitus and its degenerative complications: A prospective study of 4,400 patients observed between 1947 and 1973. Retrieved 27 February 2019. 1978. https://doi.org/10.2337/diacare.1.4.252
12. Pradeepa R, Anjana RM, Unnikrishnan R, Ganesan A, Mohan V, Rema M. Risk factors for microvascular complications of diabetes among South Indian subjects with type 2 diabetes—the Chennai Urban Rural Epidemiology Study (CURES) Eye Study-5. *Diabetes Technol Ther* 2010;12(10):755-61. https://doi.org/10.1089/dia.2010.0069
13. Klein BE, Horak KL, Lee KE, *et al*. Neural dysfunction and retinopathy in persons with type 1 diabetes. *Ophthalmic Epidemiol* 2018;25(5-6):373-8. https://doi.org/10.1080/09286586.2018.1489971
14. Al-Rubeaan K, Abu El-Asrar AM, Youssef AM, *et al*. Diabetic retinopathy and its risk factors in a society with a type 2 diabetes epidemic: a Saudi National Diabetes Registry-based study. *Acta Ophthalmol* 2015;93(2):e140-e7. https://doi.org/10.1111/aos.12532
15. Al-Maskari F, El-Sadig M. Prevalence of diabetic retinopathy in the United Arab Emirates: a cross-sectional survey. *BMC Ophthalmol* 2007;7:1-8. https://doi.org/10.1186/1471-2415-7-11
16. Lee WJ, Sobrin L, Lee MJ, Kang MH, Seong M, Cho H. The relationship between diabetic retinopathy and diabetic nephropathy in a population-based study in Korea (KNHANES V-2, 3). *Invest Ophthalmol Vis Sci* 2014;55(10):6547-53. https://doi.org/10.1167/iovs.14-15001
17. Dyck PJ, Davies JL, Wilson DM, Melton III LJ, O'Brien PC. Risk factors for severity of diabetic polyneuropathy. *Diabetes Care* 1999;22(9):1479-86. https://doi.org/10.2337/diacare.22.9.1479
18. Lin IC, Wang YH, Lin CL, Chang YJ, Lee SH, Wang IJ. Diabetic polyneuropathy and the risk of developing diabetic retinopathy: a nationwide, population-based study. *Acta Ophthalmol* 2015;93(8):713-8. https://doi.org/10.1111/aos.12746
19. Bell DS, Ketchum CH, Robinson CA, Wagenknecht LE, Williams BT. Microalbuminuria associated with diabetic neuropathy. *Diabetes Care* 1992;15(4):528-31. https://doi.org/10.2337/diacare.15.4.528
20. Li J, Cao Y, Liu W, Wang Q, Qian Y, Lu P. Correlations among diabetic microvascular complications: A systematic review and meta-analysis. *Sci Rep* 2019;9(1):3137. https://doi.org/10.1038/s41598-019-40049-z
21. Jeng CJ, Hsieh YT, Yang CM, Yang CH, Lin CL, Wang IJ. Diabetic retinopathy in patients with diabetic nephropathy: development and progression. *PLoS One* 2016;11(8):e0161897. https://doi.org/10.1371/journal.pone.0161897

22. Rasheed R, Pillai GS, Kumar H, Shajan AT, Radhakrishnan N, Ravindran GC. Relationship between diabetic retinopathy and diabetic peripheral neuropathy - Neurodegenerative and microvascular changes. *Indian J Ophthalmol* 2021;69(11):3370-5. https://doi.org/10.4103/ijo.IJO_1279_21
23. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Int Med* 2009;151(4):264-9. https://doi.org/10.1136/bmj.b2535
24. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med* 2002;21(11):1539-58. https://doi.org/10.1002/sim.1186
25. DerSimonian R, Kacker R. Random-effects model for meta-analysis of clinical trials: an update. *Contemp Clin Trials* 2007;28(2):105-14. https://doi.org/10.1016/j.cct.2006.04.004
26. Sterne JA, Harbord RM. Funnel plots in meta-analysis. *Stata J* 2004;4(2):127-41. https://doi.org/10.1177/1536867X0400400204
27. Wei WW, Yang XF, Gu H, Liu NP. [Association of diabetic retinopathy with diabetic peripheral neuropathy in type 2 diabetic patients: the Beijing Desheng Diabetic Eye Disease Study]. *Zhonghua Yan Ke Za Zhi* 2017;53(7):509-13. https://doi.org/10.3390/ijms19061816
28. Rasheed R, Pillai GS, Kumar H, Shajan AT, Radhakrishnan N, Ravindran GC. Relationship between diabetic retinopathy and diabetic peripheral neuropathy-neurodegenerative and microvascular changes. *Indian J Ophthalmol* 2021;69(11):3370-5. https://doi.org/10.3760/cma.j.issn.0412-4081.2017.07.007
29. Wang W, Lo AC. Diabetic retinopathy: pathophysiology and treatments. *Int J Mol Sci* 2018;19(6):1816. https://doi.org/10.3390/ijms19061816
30. Ejaz S, Chekarova I, Ejaz A, Sohail A, Lim CW. Importance of pericytes and mechanisms of pericyte loss during diabetic retinopathy. *Diabetes Obes Metab* 2008;10(1):53-63. https://doi.org/10.1111/j.1463-1326.2007.00795.x
31. Beltramo E, Porta M. Pericyte loss in diabetic retinopathy: mechanisms and consequences. *Curr Med Chem* 2013;20(26):3218-25. https://doi.org/10.2174/09298673113209990022
32. Yagihashi S, Mizukami H, Sugimoto K. Mechanism of diabetic neuropathy: Where are we now and where to go? *J Diabetes Investig* 2011;2(1):18-32. https://doi.org/10.1111/j.2040-1124.2010.00070.x
33. Yagihashi S, Yamagishi SI, Wada R. Pathology and pathogenetic mechanisms of diabetic neuropathy: correlation with clinical signs and symptoms. *Diabetes Res Clin Pract* 2007;77(3):S184-S9. https://doi.org/10.1016/j.diabres.2007.01.054
34. Kulkarni A, Thool AR, Daigavane S. Understanding the clinical relationship between diabetic retinopathy, nephropathy, and neuropathy: A comprehensive review. *Cureus* 2024;16(3):e56674.https://doi.org/10.7759/cureus.56674
35. At a glance: Diabetic Retinopathy2024. Available from: https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/diabetic-retinopathy.
36. Zhang J, Zhang J, Zhang C, *et al*. Diabetic macular edema: Current understanding, molecular mechanisms and therapeutic implications. *Cells* 2022;11(21):3362. https://doi.org/10.3390/cells11213362
37. Ayad F, Belhadj M, Pariés J, Attali JR, Valensi P. Association between cardiac autonomic neuropathy and hypertension and its potential influence on diabetic complications. *Diabet Med* 2010;27(7):804-11. https://doi.org/10.1111/j.1464-5491.2010.03027.x