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Prevalence Rates of Diabetic Retinopathy and Undiagnosed Diabetes Among Delaware Nursing Home and Assisted Living Facility Residents

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Abstract

Objectives: To determine the prevalence of diabetic retinopathy and undiagnosed diabetes among Delaware nursing home and assisted care facility residents. **Methods:** This cross-sectional study involved the statistical analysis of comprehensive eye examination records of 2,063 nursing home residents residing in 18 facilities and 4 assisted living facilities in Delaware from 2005 to 2009. Descriptive statistical analyses were conducted to identify the rates of retinal dot and blot hemorrhages and existing systemic diabetes diagnoses. **Results:** The mean age of nursing home and assisted care facility residents was 77 years (range 9–104), and 64.4% were over the age of 80. Most residents were female (61.1%) and white (72.5%). 3.6% of the 2,063 nursing home residents had blot or dot hemorrhages in one or both eyes. 32.8% had a type 1 or type 2 diabetes diagnosis. Of the ones with a positive dot and blot hemorrhage finding, 56.8% had a diagnosis of diabetes, and 43.2% did not. **Discussion:** There was a high prevalence of dot and blot hemorrhages without a systemic diagnosis of diabetes, indicating a need for regular eye care among residents.

Keywords

diabetic retinopathy, undiagnosed diabetes, nursing home, assisted living facility, coordinated interprofessional healthcare

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Introduction

Eye Care Services in Post-Acute and Long-Term Care Facilities

Post-acute and long-term care services in the US serve a population of 9.5 million in different types of settings, including community (e.g., adult day services centers), home (e.g., home health agencies), institutions (e.g., nursing homes), and other residential settings (e.g., assisted living) (Sengupta et al., 2022). Provided services vary greatly based on the care organization type. Assisted living residents can reside independently. However, shared spaces offer general living-related possibilities and services. In contrast, nursing homes provide 24-hour care. Roughly 9 of 10 nursing home residents need help with daily activities, such as eating and toileting. Nursing homes offer various healthcare services besides skilled nursing and therapeutic services, such as dementia services, podiatry services, and dental services. Some specialty healthcare services, such as eye care, are not mandated. (Harris-Kojetin et al., 2016; Sengupta et al., 2022.)

However, the US Centers for Disease Control and Prevention recognizes the importance of regular eye examinations, which can lead to earlier detection and treatment of vision-threatening eye diseases among at-risk patients. Known risk groups for vision impairment include the elderly population, diabetic patients, and patients with existing eye conditions. Improved access

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to general medical services is proposed as a good opportunity for earlier recognition of eye diseases, and this offers a vehicle for referral to eye care providers. Ocular screening of diabetic patients is proposed to decrease the rates of vision and other chronic disease-related disabilities linked with diabetes. As an example, timely treatment of sight-threatening diabetic retinopathy has been found to decrease vision loss more than tenfold. (Centers for Disease Control and Prevention, 2010.)

Undiagnosed Diabetes and Diabetic Retinopathy (DR)

In 2019, the US population aged 65 years or older was 54.1 million, and it is estimated to reach 80.8 million in 2040. The growing life expectancy creates a challenge for healthy aging. Aging is one of the major risk factors for chronic diseases, including diabetes. (Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 2022.) Two-thirds of the US population aged 65 years or older have more than one chronic disease, diabetes being one of them. Diabetes is the sixth leading contributor to all deaths in the United States among the population aged 65 years or older. Two-thirds of the national healthcare budget is directed toward caring for these conditions. (Centers for Disease Control and Prevention, 2013.) The prevalence of diagnosed and undiagnosed diabetes in the US in 2019 was estimated to be 11.3%. The undiagnosed portion represented approximately one-fourth of the total percentage. The projections indicate an increasing prevalence of total, diagnosed, and undiagnosed diabetes in the United States (Centers for Disease Control and Prevention, Data and Statistics, 2022).

Diabetes can cause life-debilitating complications, including diabetic eye disease, considered one of the primary vision-threatening eye diseases (NORC, National Center for Chronic Disease Prevention and Health Promotion, 2018; Zhang et al., 2010). Seventeen major population-based studies estimated the prevalence of DR in the US among different subgroups of populations. Four of these studies were designed to evaluate the prevalence of systemic diabetes without restrictions to persons diagnosed with it (NORC, National Center for Chronic Disease Prevention and Health Promotion, 2018). The most recent study was conducted by Zhang et al. (2010), which analyzed data from the National Health and Nutrition Examination Survey from 2005 to 2008. They used fundus photography to assess the retina for retinal dot and blot hemorrhages as a clinical hallmark finding to diagnose DR. A previous diagnosis of diabetes or elevated hemoglobin A1C measurements were used to determine diagnosed and undiagnosed diabetes. The estimated overall prevalence rate of DR among the US population was predicted to be 3.8%. However, among diabetic patients, the prevalence of DR was found to be 32.9%, of which 4.4% was found to be sight threatening. Males had higher prevalence rates than women, and race-related risk factors included non-Hispanic black and Mexican American races. Longer duration of diabetes was also found to predict higher prevalence rates for DR, making older age a risk factor (Zhang et al., 2010).

Data indicates that vision loss and ocular diseases form one of the leading healthcare-related economic costs in the United States, and expenses are projected to grow due to the aging population. Evaluation of medical expenses per person reveals diagnosed blindness as the most expensive condition, followed by retinal disorders such as DR (Rein et al., 2022).

Pathophysiology of Microvascular Diabetic Disease

Increased blood sugar levels in diabetic patients can lead to highly destructive consequences, causing cardiovascular disease (macrovascular) and neuropathy, nephropathy, and retinopathy (microvascular). As a result, these can end in life-debilitating complications such as myocardial infarction, stroke, foot amputation, kidney failure, and blindness. Vision loss occurs concurrently with the development of nephropathy, peripheral neuropathy, and cardiovascular events. (Cole & Florez, 2020.)

Molecular mechanisms: The pathobiology of diabetic complications shows features of hyperglycemia-induced tissue modification, and the mechanism of microvascular diabetic disease is summarized in Figure 1.

Inflammation: Proinflammatory changes in diabetic microvascular retinopathy are consistent with the innate immune system pathway. The activation of nuclear factor-kappa beta translocation of p50-p65 heterodimers into the nucleus, where there will be transcription of a variety of pro-inflammatory proteins subsequently induced. Nuclear factor-kappa beta appears to play an early role in the pathogenesis of the early stages of DR. Angiotensin 2 (Ang II) is a major effector of the renin-angiotensin-aldosterone system. It is now thought of as a pro-inflammatory mediator that causes transcription of pro-inflammatory genes via nuclear factor-kappa beta. Multiple systemic inflammatory factors are involved in the etiology and progression of DR. Vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF), angiopoietins (Ang-2), stomal derived factor-1 (SDF-1), basic fibroblast growth factor-2 (bFGF), hepatocyte growth factor (HGF), tumor necrosis factor (TNF) and interleukin-6 are all expressed. As established through clinical studies, retinal inflammation plays an important role in the formation of DR. Inflammation eventually leads to the hallmark of DR, known as the breakdown of the inner blood-retinal barrier. The systemic biomarkers of C-reactive protein (CRP) and overexpression of endothelial vascular adhesion molecules such as ICAM1,

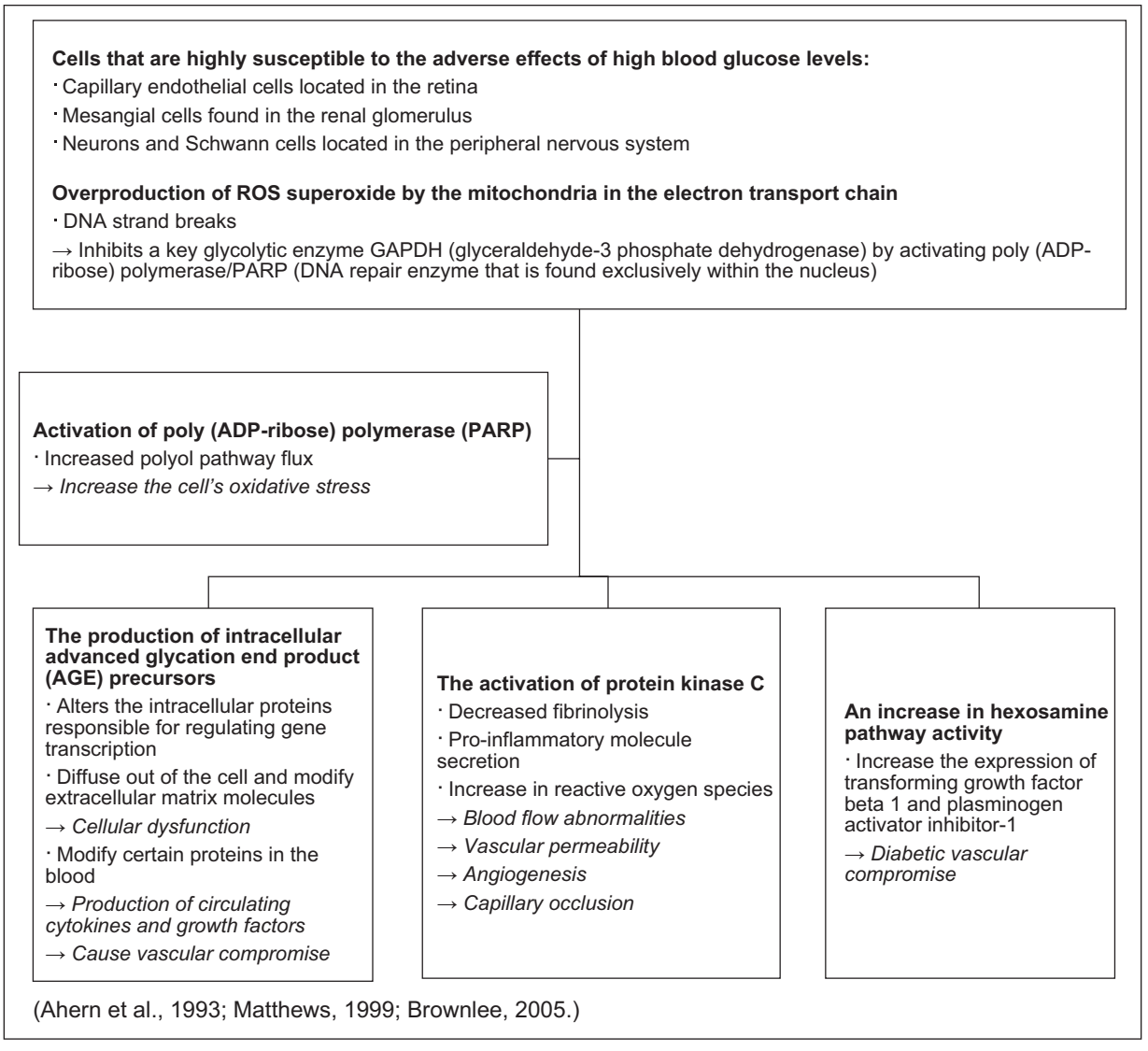


Figure 1. Mechanisms of hyperglycemia-induced tissue modifications in microvascular diabetic disease.
Source. Ahern et al. (1993); Brownlee (2005); Matthews(1999).

VCAM1, PECAM-1, and P-selectin and its leukocyte counter-receptor CD18 promote diabetic microvascular complications. Elevated neutrophil count, IL-1 beta, TNF-alpha, and VEGF all correlate with the presence and severity of DR. Certain studies have proven the link between DR and monocyte chemoattractant protein (MCP-1)/CCl2 gene polymorphism and its role in the disease process. The Rho/Rho kinase (ROCK pathway) has been identified in diabetic microvascular disease because of its inflammatory mechanisms. MCP-1, IL-1 beta, IL-8, Tumor Necrosis Factor-alpha (TNF-alpha), and VEGF are all elevated in proliferative diabetic retinopathy (PDR) (Rangasamy et al., 2012; Tang & Kern, 2011) (Figure 2).

Understanding retinal structure: The retinal structure is unique and may cause physiologic constraints compared to other nervous system tissues because it has to remain transparent. Unmyelinated nerves, due to the absence of a myelin sheath, experience a greater demand for energy in order to maintain their membrane potentials. The inner retina, because of the density of blood vessels, has an oxygen tension that is relatively hypoxic. The inner retina has relatively few mitochondria that contain light-absorbing heme-base cytochrome proteins of the electron transport chain. Therefore, the inner retina relies heavily on glycolysis, a less efficient means of generating ATP than oxidative phosphorylation. The combination of high metabolic demand limits the inner retina to adapt to the metabolic stress of hyperglycemia. The outer retina receives its oxygen and nutrient supply from the choroid and thus is relatively spared from early diabetes. The proper functioning of neurons greatly depends on the vital role played by glial cells because they supply circulating glucose into the retina for ATP production. This specialized structure and physiology of the retina may predispose it to hyperglycemia-inducing

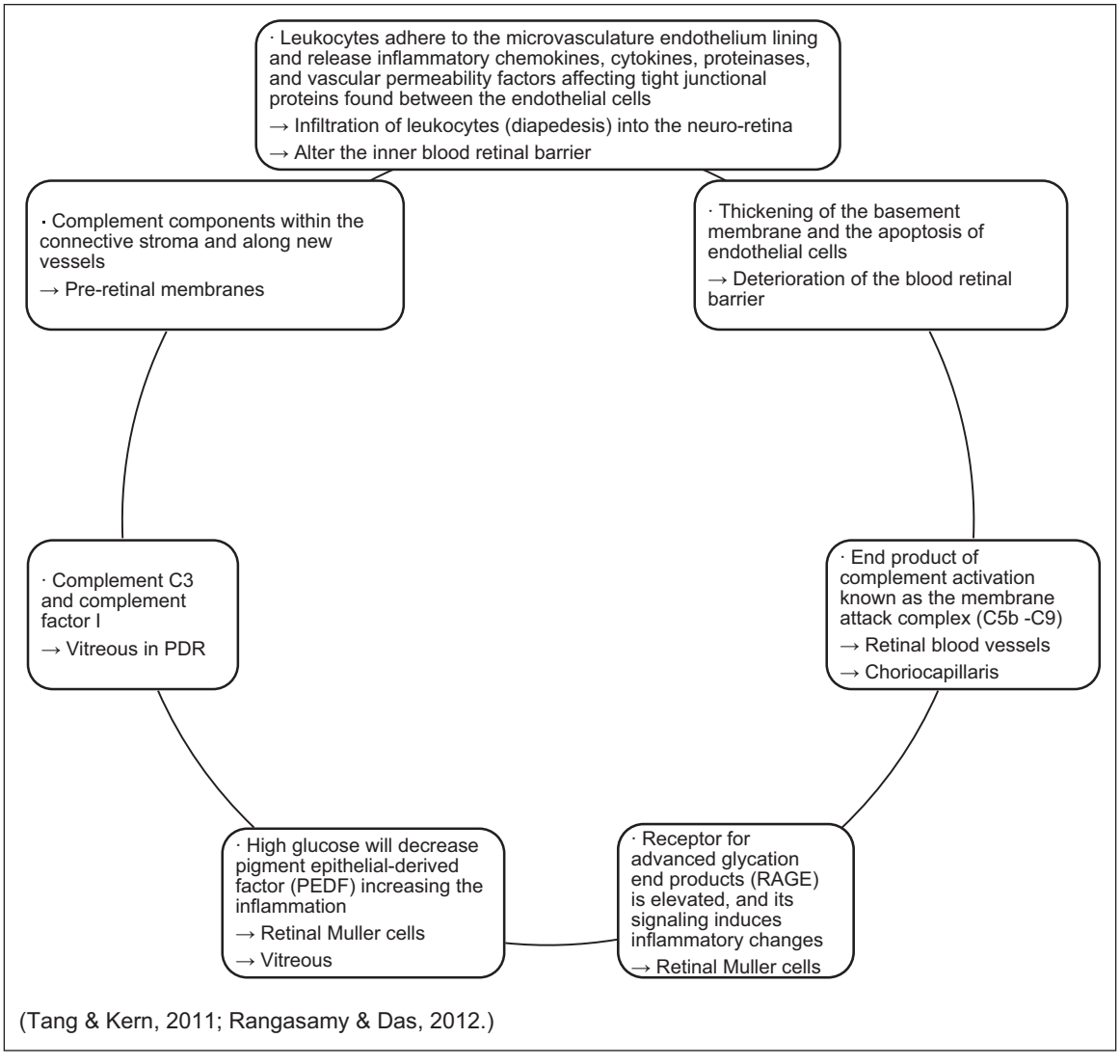


Figure 2. Inflammation processes and affected ocular structures in diabetic retinopathy.
Source. Rangasamy et al. (2012); Tang & Kern (2011).

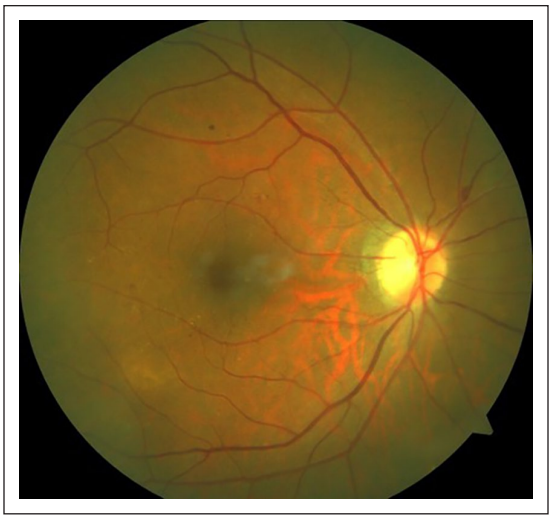
retinopathy. Neuro-retinal function is compromised before the onset of vascular lesions in humans. All retinal cells are eventually affected in both function and structure. Animal studies have shown an acceleration of apoptosis of retinal neurons, glial activation, impaired glial cell metabolism, and microglial cell activation. Neural retinal defects are among the earliest modifications in diabetes (Ansari et al., 2022).

As the disease advances, retinal ischemia causes an increase in the expression of vascular endothelial growth factor (VEGF) by activating hypoxia-inducible factor 1 (HIF-1). VEGF is known to cause proliferation of endothelial cells through the activation of mitogen-activated protein (MAP). The expression of VEGF has been detected in the vitreous of patients with center-involved diabetic macular edema and PDR. Other angiogenic factors, such as angiopoietins (Ang-1, Ang-2), are also known to have a role in regulating vascular permeability by interplaying with endothelial receptor tyrosine kinase Tie2 (Ansari et al., 2022). In summary, functional changes in DR include vascular permeability, leukostasis, and reduction in vision.

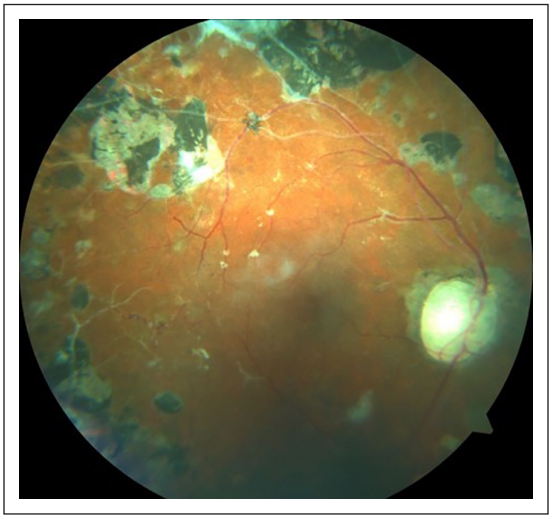
Clinical Assessment and Management of Diabetic Retinopathy (DR)

DR is classified either as non-proliferative or proliferative. Findings of the non-proliferative form can include retinal microaneurysms (dot hemorrhages), retinal hemorrhages (blot hemorrhages), exudates, cotton wool spots, intraretinal microvascular anomalies (IRMA), or venous beadings (Yang et al., 2022) (Picture 1).

The proliferative form is more severe and brittle; pathological new vessels develop, leading to leakage, vitreous hemorrhage, and eventually fibrotic strands from the retina into the vitreous. Fibrotic strands can lead to tractional retinal detachment (Zetterberg, 2016) (Picture 2).



Picture 1. Non-proliferative diabetic retinopathy (dot and blot hemorrhages and hard exudates).
Source. Robert Andersson (2023). Robert Andersson, Salus University



Picture 2. Advanced-stage diabetic eye disease (PDR with PRP).
Source. Robert Andersson (2023).

Center-involved diabetic macular edema is a prevalent condition that leads to the most notable visual impairment in individuals with DR and can occur at any stage of the disease process (Tatsumi, 2023). Diabetic retinal changes can be observed during a comprehensive eye examination or using different types of imaging studies (Table 1).

Early Treatment Diabetic Retinopathy Study (ETDRS) is the widely accepted standard for the classification (Bowling, 2015; Solomon & Goldberg, 2019). Management of non-proliferative DR includes careful assessment of the ocular findings and communicating with the primary care doctor to achieve control of the blood sugar levels (Arabi et al., 2022). Hypertension is another well-recognized risk factor for vision impairment in diabetic patients. Adequate control of blood pressure has a significant benefit in preventing DR-related vision impairment by reducing the dysfunction of endothelial cells (Arabi et al., 2022; Lee et al., 2015; Raum et al., 2015).

Panretinal laser photocoagulation (PRP) treatment is the gold standard therapy in proliferative DR, and intravitreal anti-vascular endothelial growth factor (anti-VEGF) injections are the first choice to treat center-involved diabetic macular edema. Anti-VEGF injections are also combined with PRP to treat proliferative DR (Tatsumi, 2023). Advanced diabetic eye disease, including tractional retinal detachment and persistent blood leakage into the vitreous cavity, is managed using a surgical vitrectomy (Tan & Wong, 2022).

Methodology

The Delaware Nursing Home Eye Study (DNHES) by Andersson et al. (2020) is the largest population-based eye care study on long-term care patients describing vision loss in Delaware nursing homes. A second study by Monaco et al. (2021) extended the results by quantifying the associations between vision loss and primary age-related eye diseases.

Our study analyzes the prevalence rates of diabetic retinopathy and undiagnosed diabetes among Delaware skilled care and assisted living residents. Unlike our earlier reports, age was not used as an exclusion criteria in this study.

All patient data were initially de-identified. The institutional review board at Salus University in Philadelphia approved the study for the exemption of a project involving human subjects, and the study followed the tenets of the Declaration of Helsinki.

Setting: This cross-sectional study involved the statistical analysis of comprehensive eye examination records of 2,063 nursing residents residing in 18 nursing homes and 4 assisted care facilities in Delaware from 2005 to 2009.

Data collection: All data were collected by a single optometrist who provided the clinical patient records for the research purposes of this study. Delaware had 46 nursing homes and 27 assisted living facilities in 2005 (Bureau of Health Planning & Resources Management, 2008a, 2008b). The optometrist contacted all facilities and offered onsite comprehensive eye examination services; 22 elected to participate. All assisted living facilities in this study were private, and nursing homes were for-profit-, non-profit- or faith-based (Catholic) institutions. The number of residents per facility varied from approximately 50 to 300, with a median of approximately 100. Eye care was offered to all residents. A request of the resident or family or referral by the attending physician or medical director of the facility was required before the exam could be performed.

The following inclusion and exclusion criteria were established for this study:

Inclusion criteria: Initial patient visits from 2005 to 2009.

Table 1. Imaging Studies for Assessing Diabetic Patients.

Fundus assessment modality	Specifications	Features
Fundus photography	Structural two-dimensional assessment of 45° retina	Non-invasive Covers 30% of the central retina
Ultra-widefield fundus photography	Structural two-dimensional assessment of 110 to 200° retina	Non-invasive Covers up to 80% of the retina: About half of the diabetic retinopathy-related findings are located more peripherally
Optical coherence tomography	Structural three-dimensional assessment of 45° retina	Non-invasive Assessment of blood flow patterns, the extent of blood leakages, and pathological retinal neovascularization
Fluorescein angiography	Functional assessment of choroidal and retinal vasculature	Invasive Thickness of different retinal layers: Macular edema Diabetic retinal neurodegeneration or neural dysfunction is seen in the form of a decrease in the thickness of the retinal neurofiber layer and ganglion cell-inner plexiform layer Microglial activation and migration can be observed as intraretinal hyper-reflective foci Pathological changes in the external limiting ellipsoid zone are directly linked with decreased visual acuity
Optical coherence tomography angiography	Functional assessment of choroidal and retinal vasculature	Non-invasive Assessment of changes in retinal capillary plexuses early on, including non-perfusion and microaneurysms Intraretinal microvascular abnormalities (IRMA) and retinal neovascularization

Note. Yang et al. (2022); Yu et al. (2021).

Exclusion criteria: Patient records with missing data on the evaluated parameters.

Clinical measurements: Medicare-mandated guidelines for accessing eye care were used to offer comprehensive eye examinations to all residents. Comprehensive optometric eye examinations were performed onsite and by means of an electronic exam record. Medical history was obtained from medical records, patient interviews, and nursing staff interviews. All eye exams were performed in an assigned exam room with the patient seated in a wheelchair, jerry, or conventional chair or at the bedside in the resident's room. Presenting distance visual acuity was measured with current eyeglasses or without if they were not available (permitting best initial visual acuity). Presenting near visual acuity was measured without the eyeglasses and/or with the current eyeglasses. Ocular motility and integrity of the extraocular muscles were assessed with the cover and motility tests with a penlight. Pupil functions were evaluated with a penlight. Gross visual field defects were assessed with confrontation visual field testing (finger perimetry). Visual field loss was reported as central, peripheral, or quadrantanopia. Refraction was performed using the Welch Allyn Sure Sight Autorefractor in conjunction with the trial frame and lenses. Intraocular pressures were measured with the Reichert TONOPEN. Anterior segment assessment was performed with a portable slit-lamp biomicroscope, and dilated posterior segment assessment was performed with a direct ophthalmoscope and binocular indirect ophthalmoscope using a 20-diopter condensing lens. Supplemental tests included the Amsler grid, Ishihara color vision plates, Titmus Stereo test, and fundus photography. Based on indication, patients were provided optometric management and follow-up and/or received medical management in the facility and/or were referred (Table 2).

Study variables and initial data extraction from electronic exam records: Ocular diabetic retinopathy findings and diagnosed diabetes were recorded using a checkbox function on the electronic exam records. The initial data extraction from the electronic exam records included retinal dot and/or blot hemorrhages (either one or both eyes) as ocular variables to identify diabetic retinopathy and positive patient history of diabetes as a variable to identify diagnosed diabetes.

Statistical analyses and outcome measures: All statistical analyses were performed using the SPSS program. Descriptive statistics were used to examine demographics, rates of retinal dot and blot hemorrhages, and diagnosed diabetes to quantify the prevalence of diabetes-related retinopathy and undiagnosed diabetes suspects.

Table 2. Clinical Assessment.

Medical history	Obtained from medical records, patient interviews, and nursing staff interviews
Comprehensive eye examination	Presenting distance and near visual acuity Ocular motility Pupil functions Confrontation visual fields Refraction (Welch Allyn Sure Sight Autorefractor and trial frame and lenses) Intraocular pressure (Reichert TONOPEN) Anterior segment assessment (portable slit-lamp biomicroscope) Dilated posterior segment assessment (direct ophthalmoscope and binocular indirect ophthalmoscope)

Table 3. % Distribution of Delaware Nursing Home and Assisted Living Facility Residents by Age, Gender, and Race.

Age	
<55	9.5%
55–64	10.1%
65–69	6.0%
70–74	8.8%
75–79	12.2%
80–84	18.9%
85–89	18.4%
>89	16.1%
Gender	
Female	61.1%
Male	38.9%
Race	
White	72.5%
Black	25.3%
Hispanic	1.5%
Asian	0.7%

Results

Initial patient visits of 2,093 residents met the inclusion criteria of the study. Of these, 30 residents were eliminated because of the lack of demographic data. The resultant study sample was 2,063 residents.

Demographics: The mean age of nursing home residents was 76.7 years (range 9–104), and 64.4% were over the age of 80 years: <55 years 9.5%; 55 to 64 years 10.1%; 65 to 69 years 6.0%; 70 to 74 years 8.8%; 75 to 79 years 12.2%; 80 to 84 years 18.9%; 85 to 89 years 18.4%, and >89 years 16.1%. Most nursing home residents were female (61.1%) and white (72.5%) (Table 3).

Dot and blot hemorrhages and diabetes: 74 (3.6%) of the 2,063 nursing home residents had blot and/or dot hemorrhage in one or both eyes. 54 (2.6% of 2,063 nursing home residents) were diagnosed with type 1 diabetes. 622 (30.2% of 2,063 nursing home residents) were diagnosed with type 2 diabetes. 676 (32.8% of 2,063 nursing home residents) were diagnosed with type 1 or type 2 diabetes. Of the 74 with a positive ocular finding, 42 (56.8%) had a diagnosis of diabetes, and 32 (43.2%) did not (Table 4).

Table 4. Dot and/or Blot Hemorrhages and Diabetes Cross-Tabulation.

Dot and blot hemorrhages	With diagnosed type 1 or 2 diabetes	Without diagnosed type 1 or 2 diabetes
3.6%	56.8%	43.2%

Discussion

Diabetes is a growing, life-debilitating disease that may be considered an epidemic (Forbes & Cooper, 2013; Yu et al., 2021). Unrecognized diabetes forms a significant part of the total prevalence and remains a public health challenge (Centers for Disease Control and Prevention, Data and Statistics, 2022). A significant number of diabetic patients will develop vision-threatening DR (Zetterberg, 2016). Vision is essential for maintaining sufficient physical and social activity levels that allow improved quality of life and promote healthier aging (Andersson et al., 2020). Early treatment warrants significantly better outcomes and is cost-effective (Centers for Disease Control and Prevention, 2010; Rein et al., 2022).

Vascular diseases with ocular manifestations, such as diabetes, cerebrovascular disease, and heart disease related to hypertension, co-occur with vision impairment and are among the 10 leading causes of death (Centers for Disease Control and Prevention, 2013). Ocular posterior segment assessment provides a unique window to observe the retina, an extension of the brain. The retina also has a very rich vascular supply from retinal blood vessels and a layer behind the retina, choroid. The retina is the only body part where cardiovascular functions can be observed, directly reflecting what is happening in different-sized blood vessels throughout the body, providing an opportunity to detect diabetic changes (American Optometric Association, 2019).

Regular eye assessments are recommended for patients with previously diagnosed eye conditions needing follow-up, geriatric patients, and diabetic patients. Institutionalized patients receive health care, offering primary care providers an excellent opportunity to recognize the need for eye care (Centers for Disease Control and Prevention, 2010).

Geriatric eye care providers must be equipped to assess and manage challenging patients, usually suffering from multiple chronic diseases, which can be non-ambulatory (U.S. Department of Health and Human Services, 2010). This can mean providing care in

domiciliary or institutional settings instead of typical clinical practice. Competency to deal with complex cases using an evidence-based and interdisciplinarity approach is an essential skill. The interdisciplinary approach requires good communication with all stakeholders, keeping the patient and caregivers at the center of the process.

Although the demographics in this dataset closely resemble nationwide nursing home data, this study did not include sufficient information on Hispanic and Asian races. Therefore, study results reflect and are limited to white and black populations.

The second limitation of this study was that it included all patients with blot hemorrhages. However, blot hemorrhages are present in hypertensive retinopathy in more severe staging, and the other conditions contained in the differential diagnosis have a low prevalence (Bowling, 2015).

Conclusion

The high prevalence of dot and blot hemorrhages without a systemic diagnosis of diabetes indicates that undiagnosed diabetes is a public health challenge in nursing homes and assisted living facilities that should be addressed proactively.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical Approval Statement

The institutional review board at Salus University in Philadelphia approved the study for the exemption of a project involving human subjects, and the study followed the tenets of the Declaration of Helsinki.

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