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REVIEW

Improving the screening of risk factors in diabetic retinopathy

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ABSTRACT

Introduction: In 2002, Diabetic Retinopathy was reported as the leading cause of blindness in the working age group. The introduction of systematic screening programs in the UK has reduced visual loss and blindness due to diabetic retinopathy, but it does still occur with catastrophic consequences for the individual.

Areas covered: The author conducted an ongoing search for articles relating to diabetic retinopathy since 2000 utilizing Zetoc Alert with keywords and contents page lists from relevant journals. This review covers the risk factors for loss of vision due to diabetic retinopathy and discusses ways in which the awareness of these risk factors can be used to further reduce visual loss. Some risk factors such as glycemic and B/P control are well known from landmark trials. This review has included these factors but concentrated more on the evidence behind those risk factors that are not so clearly defined or so well known.

Expert opinion: The major risk factors are well known, but one continues to find that people with diabetes lose vision in situations in which a better awareness of the risks by both the individual with diabetes and the health workers involved may have prevented the visual loss.

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Diabetic retinopathy; diabetic macular edema; risk factors; screening; visual loss

1. Introduction

1.1. Importance of diabetic retinopathy

Kocur [1] reported in 2002 that, in people of working age in Europe, diabetic retinopathy was the most frequently reported causes of serious visual loss and blindness. Since that time strenuous efforts have been made to reduce the numbers who lose vision due to diabetic retinopathy and systematic screening programs have developed in the UK. In 2012, Sivaprasad [2] reported that minority ethnic communities with type 2 diabetes of African/Afro-Caribbean's and South Asian origin in the UK are more prone to visual impairment than white Europeans

In 2014, Liew [3] reported that diabetic retinopathy/maculopathy was no longer the leading cause of certifiable blindness among working age adults in England and there have been further reports [4,5] of reductions in blindness.

1.2. Methodology

The author has conducted an ongoing search for articles relating to diabetic retinopathy since March 2000. This involves a search technique for articles relating to diabetic retinopathy utilizing Zetoc Alert (http://zetoc.jisc.ac.uk/). This enables a search of the British Library's electronic table of contents on a daily basis using 22 different combinations of keywords (e.g. 'retinopathy' or 'surveillance' & 'diabet' & 'retinopathy' in title) on a daily basis. Page lists from 22 journals are also reviewed monthly. Articles of interest identified in his way are found from on-line electronic journal resources (e.g. Open Athens [6] or the Royal Society of Medicine [7]). This review identified all articles linked to the question 'What risk factors are there for diabetic retinopathy and progression to sight threatening diabetic retinopathy?'

2. Body of the article

2.1. Risk factors for progression of diabetic retinopathy

Many of the early studies which identified the main risk factors for progression of diabetic retinopathy (DR) to sight threatening diabetic retinopathy (STDR) were reported at a time when glycemic and blood pressure (B/P) control were poor and the prevalence of diabetic retinopathy and proliferative diabetic retinopathy was high. In 1980, baseline data from a population with diabetes in Wisconsin [8,9] reported a high prevalence of diabetic retinopathy (DR) and proliferative diabetic retinopathy (PDR). The 4-yr incidence figures reported in 1989 from the same population for any DR and PDR in those aged <30 yrs taking insulin were found to be 59% and 10.5%, in those ≥30 yrs taking insulin 47.4% and 7.4%, and in those aged ≥30 yrs not taking insulin 34.4% and 2.3%. A recent study [10] from Gloucestershire (92.5% Type 2, 7.2% Type 1, and 0.3% 'Other' Type of diabetes),)eported the 4 year incidence

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Article highlights

When trying to further reduce vision loss and blindness it will be important for clinicians to:

- Have an awareness of all the situations in which the risk of diabetic retinopathy progression is more likely
- Work collaboratively with other disciplines to try and reduce visual loss
- Assist with linkage of data so that the risk factor data can be used for the benefit of the person with diabetes

of any DR was 40.3 (95% CI: 39.1, 41.5) and PDR 1.2% (95% CI: 1.1, 1.4) with increased incidence of PDR in those with more severe retinopathy at baseline. In 2014, Broe reported [11] the 16-yr incidence of PDR in Type 1 diabetes was 31%. Wong [12], Klein [1313],nd Kiire [14] reported lower rates of progression from no DR to STDR and Visual Loss in later time periods, which is likely to be due to better control of risk factors that were identified in the early studies.

The following risk factors were identified:

2.1.1. The current level of retinopathy in an eye

The Early Treatment Diabetic Retinopathy Study [15] (ETDRS) described the progression of diabetic retinopathy in relation to the development of the specific lesions and later reported the ETDRS severity scale [16] which reported the risk of progression to PDR based on lesions in seven 30 degree stereo photographic fields taken in the study. However, Wong [12] reported that ETDRS levels were only reported in 4% of studies in his review. Wilkinson et al. developed a simplified International classification in which the highest risk of developing proliferative retinopathy was defined by the ETDRS '4:2:1 rule,' defining severe non-proliferative DR as:

a) Extensive intraretinal (blot) hemorrhages (>20) in 4 quadrants or

b) Definite venous beading in 2+ quadrants or

c) Prominent intraretinal microvascular abnormalities (IRMA) in 1+ quadrant and no signs of PDR

Aldington [17] first reported a relationship between the retinal microaneurysm count and progression of diabetic retinopathy, which was confirmed in further studies [18,19]. Scanlon reported [20] a lower rate of progression if diabetic retinopathy was only present in one eye than if it was present in both eyes.

2.1.2. Glycemic control

Landmark clinical trials such as the Diabetes Control and Complications Trial [21,22], the United Kingdom Prospective Diabetes Study [23,24] and the Wisconsin Epidemiological Study [25,26] have shown the importance of glycemic control. The only word of caution with respect to glycemic control was from the ACCORD (Action to Control Cardiovascular Risk in Diabetes) trial which was designed to examine the effects of intensive glycemic control on cardiovascular events in persons with type 2 diabetes who were at high risk for such events but this intervention was stopped early [27] because of the effects of this intervention on mortality.

2.1.3. The early worsening phenomenon [28]

In the Diabetes Control and Complications Trial, early worsening of retinopathy was seen in 13.1% of those in the intensive treatment group and only 7.6% of those in the conventional treatment group. However, in those with early worsening who had received intensive treatment, the long-term outcomes were similar to or better than those conventionally treated.

Patients who are prone to this phenomenon are those people with uncontrolled type 1 or 2 diabetes who are treated more intensively (e.g. Type 2 started on insulin [29] or Type 1 treated more intensively in pregnancy [30–32]), and after pancreas transplantation [33] or bariatric surgery [34]. A review [35] described early worsening as developing in 10–20% of patients within 3–6 months after abrupt improvement of glucose control, and in nearly two times that proportion in patients with advanced baseline diabetic retinopathy (DR).

2.1.4. Systemic hypertension [36,37]

In 1992, a study [36] of 600 patients with Type 1 diabetes in Norway, in a multiple logistic regression model, found mean arterial blood pressure to be significantly associated with retinopathy. The importance of control of systolic and diastolic B/P in reducing the development of STDR and Diabetic Macular Edema (DMO) was also found in Wisconsin Epidemiological Study [25,26] and in the UKPDS study [37,38]. More recently, the ACCORD [39] and the ADVANCE [40] trials did not show any benefits for retinopathy of more intensive blood pressure lowering.

2.1.5. Duration of diabetes

Yau [41] conducted a review of 35 studies (1980–2008) researching the global prevalence and major risk factors of diabetic retinopathy and concluded that longer diabetes duration was a major risk factor in people with diabetes.

Scanlon [42] worked with colleagues in the UK looking at the risk of diabetic retinopathy at first screen in UK screening programs in children at 12 and 13 years of age and found that the greatest risk of retinopathy was in those with longer diabetes duration, in particular those who developed diabetes under the age of 2 years.

2.1.6. Ethnicity

Ethnicity variations in the incidence if diabetic retinopathy were first reported in 2003 in the Barbados Eye Study [43] where, in Type 1 diabetes, the risk of any DR was increased in the Asian minority and the risk of sight threatening DR was increased in the Africans compared to white Caucasians. In type 2 diabetes, the risk of sight threatening DR was increased for all non-Caucasians.

In 2007, Simmons reported [44] from New Zealand that that moderate or more severe retinopathy is more common in Polynesians than Europeans but concluded that the reasons for this are unclear but may be related to long-standing hyperglycemia.

In 2009, Raymond [45] reported that compared to the ethnic minority group of Southern Asians with Type 2 diabetes

had a higher prevalence of diabetic retinopathy. This was also associated with higher systolic and diastolic blood pressures, HbA1c and total cholesterol, and younger age when diagnosed with diabetes. Their life expectancy was also less.

In 2012, Sivaprasad [2] reported the results of a cross-sectional study (DRIVE UK) from West Yorkshire and South East London. Compared to 'White Europeans,' 'Blacks' and 'South Asians' had a higher prevalence of any DR, sight threatening DR and visual impairment. In type 2 diabetes, sight threatening DR was prevalent in 11.5% (95% CI 10.7 − 12.3%) of Afro-Caribbeans, 10.3% (95% CI 9.0–11.5%) of South Asians compared to 5.5% (95% CI 5.3% to 5.8%) of white Europeans.

In 2013, Thomas [46] reported that Asian Indians with Type 1 diabetes had a higher incidence of any DR and Africans with type 1 diabetes had a higher incidence of referable DR than Caucasians, whereas with Type 2 diabetes all non-Caucasians had a higher incidence of referable DR. It was difficult to separate ethnic risk factors from duration of diabetes and poor glycemic control.

2.1.7. Blood lipids

In 1996, Chew reported [47] from the ETDRS study that patients with elevated cholesterol levels at commencement of the study were twice as likely to have hard exudates in the retinal photographs.

In 2016, a report [48] of the association between lipids and diabetic retinopathy concluded that, in the studies that they had reviewed, there was a modest association between serum triglycerides or cholesterol and DR severity. A further report [49] concluded that stronger associations between specific lipoprotein species DR severity could be found.

2.1.8. Smoking

In type 1 diabetes Muhlhauser [50] and Karamanos [51] reported smoking to be a risk factor for progression. Muhlhauser commented that, 'while significant associations between smoking, and retinopathy and nephropathy respectively, were found, the relations were variable depending on the statistical model used.' However, more recently, in a Danish population [52] with Type 1 diabetes, neither a beneficial nor a harmful effect of smoking on long-term incidence of proliferative DR was found. Selective mortality among smokers and patients with PDR at baseline might provide at least part of the explanation for this.

In Type 2 diabetes, the evidence is controversial with the UKPDS reporting [53] that retinopathy is more likely to progress in nonsmokers which may also be partially explained by selective mortality among smokers.

2.1.9. Age

In Type 1 diabetes, the effect of age of onset of and the risk of progression of diabetic retinopathy is controversial. Hietala [54] reported from 1117 patients in the Finn Diane study that the highest risk of proliferative diabetic retinopathy is in age-at-onset group 5–14 years, whereas the lowest risk is in age-at-onset group 15–40 years. However, Scanlon [42] has reported data from screening programs in England, Scotland, Wales, and Northern Ireland on retinopathy levels for those children having their first screen at the age of 12 years. In those diagnosed at the age of 2 years or less, 20% had retinopathy in one eye and 11% in two eyes. If a child was diagnosed over the age of 2 years, 8% had retinopathy in one eye and 2% in two eyes. The highest risk group for progression to referable retinopathy in their teenage years were those diagnosed at the age of 4 years or less.

The Wisconsin Epidemiological Study [8,9,55] reported that, in those aged <30 yrs taking insulin and who had diabetes of 10 years duration or less, the severity of retinopathy was related to older age at examination, whereas when the age at diagnosis was ≥30 yrs and taking insulin, the severity of retinopathy was related to younger age at diagnosis.

In Type 2 diabetes in the UKPDS [53], in those who already had retinopathy, progression was associated with older age.

2.1.10. Genetic predisposition

Kuo [56] wrote about the challenges in elucidating the genetics of diabetic retinopathy describing the greatest obstacles as a lack of power because of small sample size of available studies and a lack of phenotype standardization.

Hietala [57] found an increased risk of proliferative retinopathy in siblings with Type 1 diabetes, suggesting a genetic component. Other studies [58–64] have suggested a genetic component in the development of diabetic retinopathy in different populations.

2.1.11. Pregnancy

Pregnancy has, in its own right, been shown to be an independent risk factor for progression of DR in two studies [30,65]. Pregnancy has also been shown to be a risk factor for progression of DR when linked to other known risk factors such as baseline severity of retinopathy [31,32,66], poor metabolic control at conception [31], rapid improvement of glycemic control [30–32,66] (the early worsening phenomenon, poor metabolic control during pregnancy or the early postpartum period [30,65–67]), duration of diabetes [66,68,69], and chronic hypertension and pregnancy-induced hypertension [66] .

2.1.12. Renal Function

There are some studies that report [70] that there are many patients with Type 2 diabetes and renal abnormalities (proteinuria and/or renal insufficiency) that show no signs of diabetic retinopathy or that, in Type 1 diabetes, many patients with normal renal function had retinopathy [71] in particular, the earlier stages of mild non-proliferative retinopathy. However, the majority of studies report a strong association between greater severity of retinopathy and decrease in renal function.

In 2001 Colhoun [72] reported from the WHO Multinational Study of Vascular Disease in Diabetes that, in both Type I and Type II diabetes, diabetic retinopathy, and proteinuria were strongly associated with renal failure.

In 2012, Grunwald [73] reported results from the Chronic Renal Insufficiency Cohort (CRIC) study, which was an observational, cross-sectional study of 2605 patients with chronic kidney disease. In this study, there was a strong association found between the severity of diabetic retinopathy and reduced glomerular filtration rate, which could not be

accounted for by other known risk factors. However, a further report from the same study [74] in 2019 concluded that progression of diabetic retinopathy was linked to progression of chronic renal insufficiency on univariable analysis but not on multivariable analysis. This suggested that similar risk factors may be causing progression of diabetic retinopathy and renal disease.

In 2013, He [75] reported a meta-analysis on diabetic retinopathy and renal disease. The pooled sensitivity from the 26 papers of diabetic retinopathy to predict diabetic nephropathy was 0.65 (95% CI 0.62, 0.68) with a specificity of 0.75 (95% CI 0.73, 0.78). However, when it came to the pooled sensitivity for proliferative DR to predict diabetic nephropathy, the pooled sensitivity from the 26 papers was only 0.25 (95% CI 0.16, 0.35) but the specificity was very high at 0.98 (95% CI 0.92, 1.00).

In 2013, Moriya [76] examined the interactive relationship between diabetic retinopathy (DR) and diabetic nephropathy (DN) patients in Japan with type 2 diabetes. The study reported that patients with microalbuminuria and DR showed the fastest estimated glomerular filtration rate decline and concluded that the combination of albuminuria and DR should be considered as risk factors of renal prognosis in type 2 diabetic patients.

In 2019, Kaewput [77] reported results from a multicentre nationwide cross-sectional study designed to assess the association between estimated glomerular filtration rate (GFR) and DR, severe DR, and severe visual impairment among 13,192 T2DM patients from 831 public hospitals in Thailand in the year 2013. Decreased GFR was independently associated with increased DR, severe DR, and severe visual impairment. The study concluded that the estimated GFR should be monitored in diabetic patients for DR awareness and prevention.

In 2019, Zhuang [78] reported results from a single-center retrospective observational study of 413 southern Chinese patients with type 2 diabetes mellitus conducted from December 2017 to November 2018. Stages of DR and DME were positively correlated with renal function, while stage of urine albumin-to-creatinine ratio performed a better relevance than stage of estimated glomerular filtration rate.

2.1.13. Combination of retinopathy and macroalbuminuria as a risk factor for cardiovascular events

In 2007, Tong [79] reported that patients with the combination of diabetic retinopathy and macroalbuminuria had a higher incidence of cardiovascular and renal events and a higher mortality compared to those without these complications.

In 2012, Pugliese [80] reported a high prevalence of advanced DR in subjects with type 2 diabetes from the Renal Insufficiency and Cardiovascular Events (RIACE) in the Italian Multicentre Study cohort.

2.1.14. Retinal vascular geometry, diabetic retinopathy, and renal function

In 2004, Wong reported [81] that a large diameter of retinal veins was associated with the development of proteinuria and renal insufficiency. In 2011, Benitez-Aguirre [82] reported that retinal vascular geometry predicts incident retinopathy in young people with type 1 diabetes. In 2012, Benitez-Aguirre [83] reported that retinal vascular geometry independently predicted incident renal dysfunction in young people with type 1 diabetes. Retinal vascular geometry (including length-to-diameter ratio [LDR] and simple tortuosity [ST]) was quantified from baseline retinal photographs.

2.1.15. Non-attendance at screening and clinic appointments

In 2005, Zoega [84] reported that patients who were registered blind on the Icelndic National Registry had a long history of nonattendance in the Diabetic Retinopathy Screening Programme in Iceland compared with those with better visual outcomes. In 2009, Gray [85] reported on a study that suggested that clinic nonattendance is likely to be a risk factor for sight threatening retinopathy. This was confirmed in 2013 when Forster [86] reported from a cohort study of 6,556 residents with diabetes in inner London that patients who do not attend diabetic eye screening are at increased risk of developing STDR. In those with mild non-proliferative DR at first screen who subsequently missed two screens, the adjusted relative odds of developing proliferative or moderate-to-severe non-proliferative retinopathy compared to those who attended for screening were 5.72 (95% CI 7.43, 22.83; $p = 0.013$). It was also confirmed by Scanlon [87] in 2014 who reported that, of those screened within 6 months of diagnosis, 2.3% had referable retinopathy and, 3 years or more after diagnosis, 4.2% had referable retinopathy. In 2012, Sachdeva [88] reported results from a telephone survey of people with diabetes who had not attended for DR screening. The study reported that attendance was poorest in younger individuals with poor HbA1c values and high blood pressure readings (systolic and diastolic). Fifty percent of those at highest risk of DR did not attend. In 2016, Scanlon [89] reported that those in the 18–34 year age group are least likely to attend promptly for screening after registration with a higher risk of referable diabetic retinopathy being present at the time of first screen. In 2018, Kashim [90] reported a systematic review on patients' nonattendance for diabetic retinopathy screening in Diabetic Eye Screening programs.

The review 16 studies between 2003 and 2017 concluded that nonattendance as linked to socio-economic deprivations and to the development of sight threatening DR.

In 2021, Kelly [91] reported reasons for nonattendance in the Irish National DR Screening Programme which included age (OR: 1.23 per decade away from 70; 95% CI: [1.22–1.24]), type 2 diabetes (OR: 1.10; 95% CI: [1.06–1.14]) and socio-economic deprivation (OR: 1.12; 95% CI: [1.09–1.16]). Additionally, this study reported that adverse weather conditions (freezing or below-zero) were also associated with non-attendance with an odds ratio of 1.57 (95% CI .45–1.7 and $p < 0.001$).

2.1.16. Sleep apnea

In 2010, West [92] reported that, in men with Type 2 diabetes, there is a strong association between diabetic retinopathy and maculopathy severity and obstructive sleep apnea, independent of conventional retinopathy risk factors.

In 2013, Banerjee [93] reported that, in Type 2 diabetes, the apnea-hypopnea index (AHI) of >/ = 15 events/hour was not associated with DR but minimum oxygen saturations during sleep may be associated and, in 2015 Zhang [94] reported a similar association between Type 2 diabetes, obstructive sleep apnea, and low oxygen saturations, of which the lowest oxygen saturations were associated with PDR.

Storgaard [95] In 2014, reported an association between people with Type 2 diabetes and sleep apnea and, in 2015, Manin [96] reported an association between people with Type 1 diabetes and sleep apnea. Manin also reported that obstructive sleep apnea was associated with DR severity.

In 2017, a meta-analysis by Zhu [97] of available studies concluded that obstructive sleep apnea is related to increased risk of DR in both Type 1 and Type 2 diabetes mellitus.

In 2019, Feher [98] reported, using the Royal College of General Practitioners Research and Surveillance Center database, that obstructive sleep apnea was prevalent in people with both type 1 and Type 2 diabetes across the range of overweight categories and not simply in the highest obesity class.

2.1.17. Anemia

Although anemia can cause retinopathy in its own right, it can also increase the progression of diabetic retinopathy without renal disease. It can lead to the progression of diabetic retinopathy [99–101] with an increased severity of diabetic retinopathy [102] and progression of proliferative diabetic retinopathy after laser photocoagulation [103] probably caused by an increase in retinal ischemia.

3. How could one improve the screening of these risk factors for the benefit of reduced sight loss for our patients with diabetes?

In recent years, progression of diabetic retinopathy has slowed in countries with higher socioeconomic levels due to better glycemic, blood pressure, and control of lipids. There is a concentration on these known risk factors in clinics overseen by diabetes physicians and primary care physicians.

It is also important to be aware of situations in which progression of diabetic retinopathy is more likely. In these circumstances, regular monitoring of retinopathy levels should take place. For example:

a) a patient whose glycemic control improves over a short period of time due to commencing insulin or the individual becoming more interested in improving their control;

b) a patient whose renal function is declining and who has not attended for eye screening;

c) a patient with sleep apnea.

There are some situations in which it is important to monitor the diabetic retinopathy more closely such as in pregnancy or in the first 6 months postpartum.

From the point of view of an eye screening program, an HTA report [104] gave the results of Cox proportional hazards model for time to referable diabetic retinopathy for preproliferative DR (R2), proliferative DR (R3), and maculopathy (M1) to be:

Mild NPDR in both eyes at screening visit 7.13 (95% CI: 5.84 to 8.70)

Mild NPDR in one eye at screening visit 2.56 (95% CI: 2.05 to 3.20)

HbA1c (per 10 mmol/mol increase) 1.28 (95% CI: 1.23 to 1.34)

Duration of diabetes (per 5 year increase) 1.20 (95% CI: 1.16 to 1.24)

Total serum cholesterol (per 1 mmol/L) 1.12 (95% CI: 1.05 to 1.19)

Serum creatinine (per 10 µmol/L) 1.04 (95% CI: 1.01 to 1.07)

The population under study had well-controlled B/P but, in a population that is not well controlled, this will be an important additional risk factor.

The HTA study developed a risk score that was related to the level of DR found in the eye and associated risk factors:

Mild non-proliferative DR in both eyes = 1.96 + Y

Mild non-proliferative DR in one eye = 0.94 + Y

No DR = 0 + Y

Y = (0:25 × (HbA1c/10)) + (0:18 × duration of diabetes/5) + (0:11 × total cholesterol) + (0:04 serum creatinine/10)

These risk scores led to five groups that had a risk of 10–60% of developing referable diabetic retinopathy within 5 years.

Other risk factors were not included because they either did not reach statistical significance in the population or were recorded in too few numbers (e.g. renal function) or occurred infrequently (e.g. sleep apnea). This does not mean that they are not important in an individual with these conditions.

The problem for all diabetic retinopathy screening programs is having access to additional data items as well as the retinopathy screening results. The previous eye screening results are by far and away the biggest hazard ratio and it is very difficult in England to join up all the other risk factor items such as HbA1c and have them in the eye screening database. Hence, the UK National Screening Committee has advised an extension of the screening interval to 2 years for those people with diabetes who have been found to have no retinopathy on their previous two screening episodes [105]. The English NHS Diabetic Eye Screening Programme has tried for many years to link up risk factor data to eye screening data, but this has proved very difficult due mainly to commercial factors and data protection issues. However, this has been achieved in Scotland showing that it is possible. When the IT infrastructure in the NHS improves to be able to link other risk factor data together in a high percentage of patients, other risk factor data may be included in the screening algorithm for extension of screening intervals.

Other algorithms [106–108] have been developed that do include the extra risk factor data that can be used when this is readily available, and they have been tested in populations in Ireland [109] and Holland [110].

In any screening program, it is important to focus on non-attenders as these are the people who are most at risk of progression of DR and loss of vision. The NHS Diabetic Eye Screening Programme in England has introduced a standard [111] that is a Key Performance Indicator that all of the regional programs are judged against which has brought a key

measurement for each program of proportion of eligible people with diabetes who have not attended for routine digital screening in the previous 3 years. This has inevitably meant that much more attention is being paid to try to get regular non-attenders to attend for screening, which will have long-term beneficial visual results for those that do attend.

It is also important to try and focus on ad-hoc methods of detection of retinopathy in general medical clinics if a regular non-attender does attend. Is there some method available to the diabetologist for examining the retina and do they have the expertise to do so?

4. Conclusion

This article has highlighted the important risk factors for progression of diabetic retinopathy and discussed how these risk factors might be better utilized to prevent sight loss in different healthcare settings linked to the management of diabetes. In order to reduce the risk of progression of DR, one needs to control risk factors that are modifiable for that individual, e.g. glycemic control, blood pressure, lipids, renal function, and anemia.

5. Expert opinion

In modern medicine, many clinicians work in specialist areas that do not look at an individual as a whole. For example, there are primary care physicians, nurses in primary and secondary care, diabetologists, nephrologists, vascular surgeons, neurologists, gastroenterologists, podiatrists, and ophthalmologists looking after the care of these patients. Communication between primary and secondary care needs to be improved and there needs to be better communication between subspecialties. For example, it is tragic when a patient who is attending for renal dialysis three times a week suddenly loses vision and is found to have very advanced diabetic retinopathy and has not been attending for eye screening. Access to the data is not joined up. It should not be so difficult across the NHS to join up risk factor data to eye screening data for the benefit of patients, but it has been.

Data also need to improve in accuracy. For example, the date of diagnosis of Type 1 diabetes is often well remembered by the individual with diabetes but may be recorded in primary care as when the person joined that practice. Data protection is often used as a reason for making this linkage more difficult but, if this is in the patient's best interest, it should be made easier.

Research to improve uptake for screening in the vulnerable 18–45 year age groups will be important to reduce loss of vision in this working age group, who are historically poor attenders compared to people in the older age group with diabetes. I am hopeful that new cameras which do not require pupil dilation may encourage more of them to attend.

There may also be benefits in the automated reading of images so that a clinician who is not confident at any form of retinal examination can use a camera, which has some automated method of reading the images for patients who are regular non-attenders who present in an ad-hoc way. Automated reading may also help systematic eye screening programs once they have been proven to have high enough sensitivities and specificities for the detection of any DR or sight threatening DR. In Scotland [112], they currently use an algorithm to detect any DR that has reduced the workload for their graders by taking images away from the grading queue that the automated method reads as no diabetic retinopathy.

What I would like to see in the next 10 years (and should be possible) is:

(a) Use of new camera technology that does not require dilation of the pupil in 90% of people with diabetes. A small percentage will always need dilation, but I believe that this should be less than 10%.
(b) Use of artificial intelligence software to take out images that show no retinopathy to a high level of specificity.
(c) Linkage of data so that screening services, those looking after people with diabetes, and the individuals themselves have easy access to joined up data that includes screening grading results and relevant risk factor data.

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