Journal of Infrastructure, Policy and Development 2024, 8(10), 6668.
https://doi.org/10.24294/jipd.v8i10.6668

Review

Comprehensive guidelines and best practices for implementing effective Diabetic Retinopathy Screening Programs to mitigate global vision loss

Xiaoting Pei[1,2,3,4,5], Zhijie Li[1,2,3,4,5,*]

[1] Henan Eye Institute, Zhengzhou 450003, China
[2] Henan Eye Hospital, Zhengzhou 450003, China
[3] Henan Provincial People's Hospital, Zhengzhou 450003, China
[4] People's Hospital of Henan University, Zhengzhou 450003, China
[5] People's Hospital of Zhengzhou University, Zhengzhou 450003, China
*** Corresponding author:** Zhijie Li, tzhijieli@jnu.edu.cn

CITATION

Pei X, Li Z. (2024). Comprehensive guidelines and best practices for implementing effective Diabetic Retinopathy Screening Programs to mitigate global vision loss. Journal of Infrastructure, Policy and Development. 8(10): 6668. https://doi.org/10.24294/jipd.v8i10.6668

ARTICLE INFO

Received: 27 May 2024
Accepted: 26 June 2024
Available online: 30 September 2024

COPYRIGHT

Copyright © 2024 by author(s). *Journal of Infrastructure, Policy and Development* is published by EnPress Publisher, LLC. This work is licensed under the Creative Commons Attribution (CC BY) license. https://creativecommons.org/licenses/by/4.0/

Abstract: Diabetic retinopathy (DR) is a major cause of blindness globally. Effective screening programs are essential to mitigate this burden. This review outlines key principles and practices in implementing DR screening programs, emphasizing the roles of technology, patient education, and healthcare system integration. Our analysis highlights key principles for establishing successful screening initiatives, including the importance of regular screenings, optimal intervals, recommended technologies, and necessary infrastructure. We emphasize the roles of healthcare providers, patients, and policymakers in ensuring the effectiveness of these programs. Our recommendations aim to support the creation of robust policies that mitigate the impact of DR, ultimately improving public health outcomes and reducing the incidence of blindness due to diabetic retinopathy.

Keywords: diabetic retinopathy screening; preventable blindness; public health intervention; healthcare innovation; diabetes management

1. Introduction

Diabetic retinopathy (DR), a severe complication of diabetes, is a leading cause of blindness among working-age adults globally. Early detection and treatment can prevent up to 95% of vision loss, highlighting the critical role of screening programs in diabetes care. As the number of people with diabetes continues to rise worldwide, timely and effective DR screening is becoming increasingly important (Pedrosa et al., 2018). Many countries have implemented structured, efficient, and sustainable Diabetic Retinopathy Screening Programs (DRSPs), which are organized health care plans aimed at early detection and management of DR (Pandey et al., 2022). The primary goal of these programs is to implement early intervention and treatment by detecting asymptomatic stages of retinal lesions in a timely manner to prevent or slow disease progression, thereby reducing the incidence of blindness (Rodriguez-Acuña et al., 2020).

DRSP systematically invites all diagnosed diabetics in target populations for regular retinal examinations. These screenings typically involve taking digital images of the retina using fundus photography, which are then evaluated by trained professionals for signs of DR (Egunsola et al., 2021). If DR or other eye diseases are detected, patients are referred to ophthalmologists for further evaluation (Fenneret al., 2018). The successful implementation of DRSPs relies not only on advanced screening technologies and methods, but also on close collaboration among multidisciplinary

teams, including ophthalmologists, screening personnel, data scientists, and program managers (Islam et al., 2018). In addition, the design and management of screening programs must adhere to a set of principles and standards to ensure their effectiveness, reliability, and fairness. These principles include, but are not limited to, determining screening targets, setting screening frequencies, selecting screening modes/models, and establishing screening pathways and standards (Bellemo et al., 2019).

The aim of this review is to describe the main principles and components of DRSPs, to analyze the advantages and challenges of different screening modalities, to discuss the role of interdisciplinary team collaboration in screening programs, and to explore current challenges and future development directions. By reviewing the latest research and practical experience, this paper aims to provide valuable insights and recommendations for further optimization and promotion of DR screening programs.

2. The implementation status of DRSPs in different countries

Many countries have implemented DR screening programs for early detection and treatment of DR. The implementation of these screening programs varies among countries, mainly in terms of screening technology, frequency, funding sources, participation rates, and follow-up management. The following is a detailed analysis of DR screening programs based on the level of national development.

In developed countries, DR screening programs are typically supported by comprehensive national health systems that ensure high screening coverage and frequency. The United Kingdom's National Health Service (NHS), for example, offers a free retinal screening service that provides annual screenings using digital fundus photography for all diabetic patients aged 12 years and older, demonstrating a strong commitment to public health (Kashim et al., 2018). In contrast, screening programs in the United States rely on individual health insurance systems, with the American Diabetes Association's recommended standards providing professional guidance for screening (Egunsola et al., 2021). Screening strategies in Australia and Canada emphasize the use of telemedicine technology and the importance of interdisciplinary collaboration to improve access to services for patients in remote areas (Valpuesta Martin et al., 2020). The example of Sweden also demonstrates the benefits of universal free screening programs in increasing participation rates and data management efficiency (Huemer et al., 2020). The implementation of Diabetic Retinopathy Screening Programs across different countries are shown in **Figure 1**.

In contrast, many developing countries face the dual challenges of resources and technology in implementing DR screening programs. International organizations and non-governmental organizations play a critical role in these countries' screening programs, providing the necessary funding and technical support, as well as engaging in public education and training of health care workers (Piyasena et al., 2019). Despite the challenges, some projects have made initial progress in raising public awareness and establishing screening networks. However, there is still significant room for improvement in screening frequency, technology application, and patient participation compared to developed countries (Islam et al., 2018). Screening programs in developing countries urgently need innovative solutions, such as the use of artificial intelligence for fundus screening, and increased international cooperation and funding

to overcome resource limitations and improve coverage and efficiency (Bellemo et al., 2019).

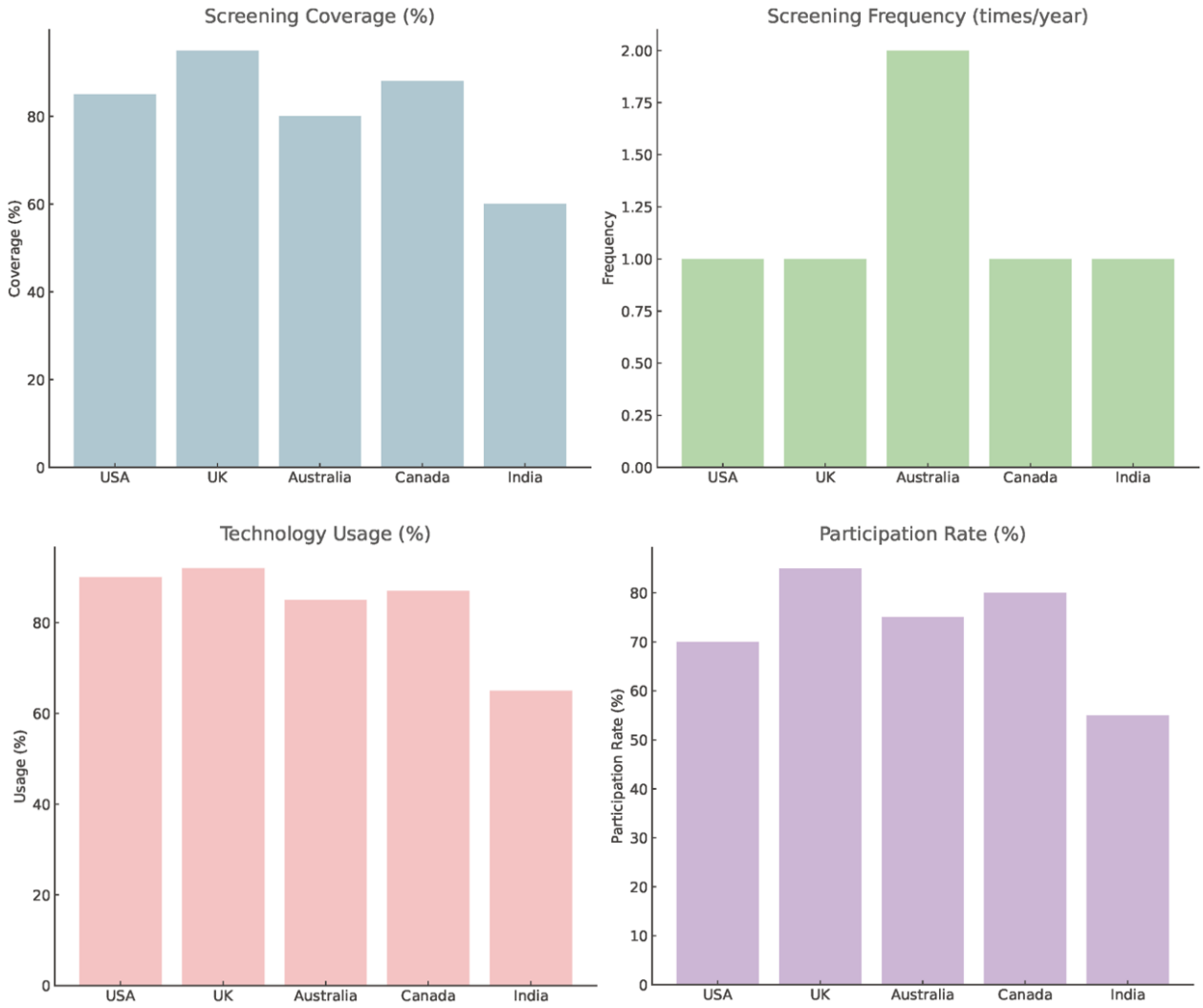

Figure 1. The implementation of Diabetic Retinopathy Screening Programs across different countries.

Overall, the status of implementation of DR screening programs worldwide reveals inequalities in the allocation of public health resources and different emphases in the application of medical technologies. The successes in developed countries and the challenges in developing countries highlight the importance of global cooperation in promoting early detection and treatment of DR.

3. Principles for the implementation of DRSPs

DRSPs are a critical public health intervention aimed at preventing vision loss and blindness in people with diabetes through early detection and treatment of DR. To achieve this goal, DRSPs must be designed and implemented based on a set of core principles, including universality and accessibility, standardized screening protocols, quality control and assurance, data management and follow-up systems, patient education and engagement, adherence to ethical principles, and interdisciplinary collaboration (**Table 1**, **Figure 2**).

Universality and accessibility ensure that all people with diabetes, regardless of geographic location, have access to screening services (Lanzetta et al., 2020). To ensure consistency and high quality in the screening process, standardized screening protocols are developed and followed, including establishing screening intervals, using standardized image acquisition and interpretation procedures, and establishing clear referral criteria (Egunsola et al., 2021). Quality control and assurance mechanisms are achieved through regular calibration of screening equipment, training and evaluation of screening personnel, and regular review of screening results to ensure the accuracy and reliability of screening (Kashim et al., 2018).

Effective data management and follow-up systems are critical for tracking screening results and managing follow-up and referrals. This includes not only the use of electronic health records, but also specialized screening databases to increase the efficiency and accuracy of data processing (Pedrosa et al., 2018). Patient education and engagement are key to increasing screening participation rates. By raising awareness of DR and the importance of screening, patients can be encouraged to actively participate in screening and follow-up (Riordan et al., 2020b).

The implementation of all these measures must be ethically sound, respecting patients' autonomy and privacy, ensuring that patients' consent to participate is given with full understanding, and that the handling of patient data meets privacy standards (Lanzetta et al., 2020). In addition, successful implementation of DRSPs relies on interdisciplinary collaboration involving ophthalmologists, diabetes specialists, primary care physicians, nurses, and other professionals from various disciplines (Valpuesta Martin et al., 2020).

By adhering to these core principles, DRSPs can effectively improve the quality of life for people with diabetes, reduce the risk of vision loss and blindness, and provide comprehensive, effective, and equitable health care for people with diabetes. Implementation of these principles reflects a deep understanding of and commitment to public health and is essential to reducing vision loss from DR worldwide.

Table 1. Core principles of DRSPs.

Core Principles	Description
Universality and Accessibility	Ensure that all diabetic patients, regardless of geographical location, have access to screening services.
Standardized Screening Protocols	Guarantee consistency and quality in the screening process through uniform intervals, image acquisition and evaluation processes, and clear referral criteria.
Quality Control and Assurance	Ensure accuracy and reliability of screening through calibration of equipment, staff training, and result review.
Data Management and Follow-up Systems	Utilize electronic health records and dedicated databases to track screening results, manage follow-ups, and referrals, and improve data processing efficiency.
Patient Education and Engagement	Raise awareness about DR and the importance of screening to encourage active participation in screening and subsequent treatments.
Adherence to Ethical Principles	Respect patient autonomy and privacy, ensure informed consent, and handle patient data in compliance with privacy standards.
Interdisciplinary Collaboration	Foster joint efforts among professionals from various fields including ophthalmologists, diabetes specialists, general practitioners, and nurses.

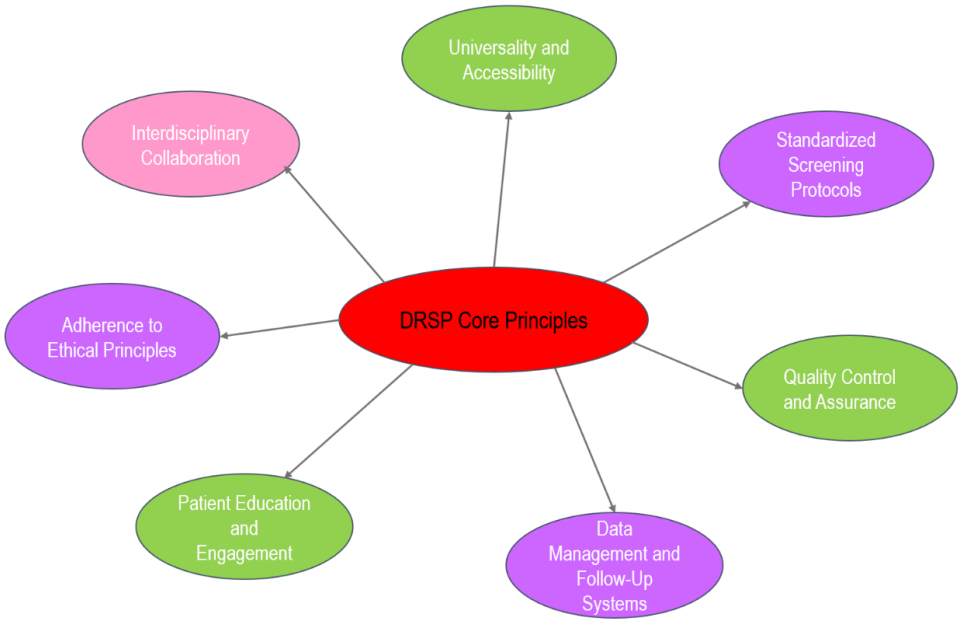

Figure 2. The key principles guiding the implementation of Diabetic Retinopathy Screening Programs.

4. Factors affecting the implementation of DRSPs

The implementation and effectiveness of DRSPs are influenced by several factors. These include (1) Availability of resources: The availability of funds, medical equipment, and human resources is critical to the successful implementation of DRSPs. Regions with abundant resources can provide more comprehensive and higher quality screening services (Broadbent, Wang, et al., 2021). (2) Patient participation: Increasing patient awareness and understanding of the risks of DR is key to improving screening participation. Effective patient education and communication strategies can significantly increase patient willingness to participate in screening (Islam et al., 2018). (3) Socioeconomic and Cultural Differences: Socioeconomic status, cultural beliefs, and health beliefs have a significant impact on patient attitudes toward screening. Understanding and respecting these differences and adopting strategies to overcome cultural and language barriers are key to achieving widespread coverage of screening programs (Lawrenson et al., 2018).

In summary, the implementation of DRSPs around the world demonstrates the diverse practices and challenges of diabetic retinopathy screening across socioeconomic backgrounds. Successful screening programs must comprehensively address resource availability, patient participation, and socioeconomic and cultural factors, using innovative and adaptive strategies to ensure the effectiveness and equity of screening services.

5. Aims of the screening program

The fundamental goal of the DR Screening Program is to significantly reduce the vision loss caused by DR and its impact on the quality of life of people with diabetes through early detection and effective treatment of retinal lesions. This goal is based on several key principles and concepts, which are described in detail below:

5.1. Early detection

Early detection is critical in the management of DR because DR typically has no obvious symptoms in its early stages. Many diabetics do not notice vision loss until the disease has progressed to a more severe stage requiring more complex treatment. Therefore, regular screening is an effective way to detect early signs of DR before it causes irreversible vision loss (Dai et al., 2021). Screening typically uses professional fundus photography technology to regularly examine the retinas of diabetic patients for early indicators such as microvascular abnormalities, hemorrhages, or leaks (Zago et al., 2020). Identifying these early signs allows doctors to intervene promptly and manage the condition through lifestyle adjustments and necessary medical interventions (Safi et al., 2018).

In some cases, early DR treatment may be limited to regular monitoring and improved glycemic control, while more advanced lesions may require drug therapy or laser photocoagulation and other more aggressive interventions (Tymchenko et al., 2020). The importance of regular screening has been confirmed by numerous studies showing that early detection and treatment of DR can significantly reduce the risk of vision loss in people with diabetes, effectively preventing further progression of the disease, protecting vision, and improving quality of life (Elsharkawy et al., 2022). This comprehensive screening and intervention strategy not only helps maintain the visual health of people with diabetes, but also lays the foundation for preventing other health complications caused by DR.

5.2. Effective treatment

In the treatment of DR, timely and effective therapeutic measures are crucial to preventing disease progression and vision loss. Currently, the medical community has developed various treatment methods to address DR, which, when applied based on early diagnosis, can significantly enhance the chances of patient recovery. The main treatment methods include laser therapy, intravitreal injections (anti-VEGF therapy), and eye surgeries for severe cases, such as vitrectomy. Laser therapy helps prevent further vision deterioration by reducing the growth and leakage of abnormal blood vessels (Tomita et al., 2021). Anti-VEGF drug injections directly target the biological factors causing abnormal blood vessel growth, effectively controlling the progression of DR (Wang and Lo, 2018). When DR progresses to advanced stages, especially with proliferative DR, eye surgery may be required to remove vitreous hemorrhage or repair retinal detachment to preserve vision (Mansour et al., 2020).

Timely treatment can not only effectively slow disease progression but also partially restore damaged vision in some patients, greatly improving their quality of life. This is particularly important for diabetic patients, as DR is a leading cause of vision loss among diabetics worldwide (Chalke and Kale, 2021). Combining early screening with timely treatment can significantly reduce the risk of vision loss due to DR, which is undoubtedly great news for patients. Additionally, this helps reduce the socioeconomic burden and medical pressure caused by vision loss, representing an effective saving of public health resources from a societal perspective (Simó and Hernández, 2022).

Overall, effective treatment of DR requires early identification, combined with

various existing treatment methods, to provide personalized treatment plans for diabetic patients. With continuous advances in medical technology, more efficient and safe treatments are expected to be developed in the future, bringing more hope to diabetic patients (Arrigo et al., 2022).

5.3. Improving quality of life

As one of the most important human senses, vision has a significant impact on daily life, work ability, and social interactions. DR, a common complication of diabetes, can cause vision loss that severely affects patients' quality of life and can even lead to complete blindness. Preventing vision loss from DR through screening and timely treatment is therefore not only important from a medical health perspective, but also has a profound social and psychological impact on patients.

DRSPs can significantly reduce the risk of vision loss by detecting early signs of the disease and providing effective treatment. This can help patients maintain their vision and avoid the occupational limitations and daily inconveniences of vision loss, as well as reduce the psychological burden of anxiety, depression, and decreased self-esteem caused by the disease (Granado-Casas et al., 2019). By maintaining good vision, patients can more confidently participate in social activities and maintain a normal work and life routine, which is critical to improving their quality of life (Deswal et al., 2020). In addition, maintaining vision helps patients better manage other diabetes-related health issues, as those with good vision can more easily read medical information, take medications, and perform daily self-monitoring. This improvement in self-management skills is critical to long-term diabetes control (Pan et al., 2018).

6. Key components of the screening program

The key elements of the screening program include program management, clinical management, screening tests, image grading, monitoring pathways, ophthalmic referral, fail-safe measures, and internal quality assurance (**Figure 3**). The effective implementation of DR screening programs relies on the coordinated efforts of multiple key components. The following is a detailed description of these components:

Figure 3. The key components of a diabetic retinopathy screening program.

6.1. Program management

The successful implementation of DR screening programs depends on effective program management, which includes several key aspects to ensure efficient execution and achievement of objectives. The comprehensive process of establishing and operating a diabetic retinopathy screening program are shown in **Figure 4**. It mainly includes the following key issues:

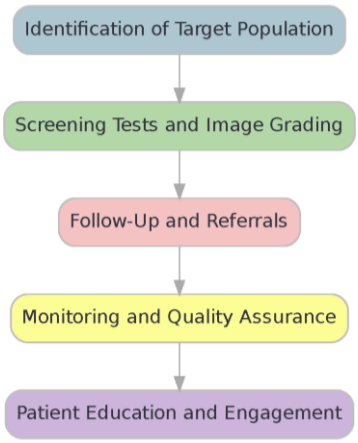

Figure 4. The comprehensive process of establishing and operating a diabetic retinopathy screening program.

Identifying the target population: The screening program must define the diabetic patient population it serves, whether type 1 or type 2 diabetes patients. By analyzing databases and medical records, and collaborating with healthcare providers, program management can identify and invite all eligible patients to participate in the screening (Egunsola et al., 2021).

Developing the screening plan: This involves detailing the specific implementation scheme, including screening frequency, site selection, specifying technologies and equipment used, and the follow-up procedures after patients complete the screening. The development of this plan is based on the latest medical research, technological advancements, and resource availability, aiming to provide the most effective screening services (Lin et al., 2019).

Resource and personnel allocation: Program management ensures that the screening program has adequate financial support and a professional team. Proper resource allocation involves the purchase and maintenance of screening equipment, salaries for professionals such as doctors, nurses, and technicians, and coverage of other operational costs. Building and training a professional team is fundamental to ensuring high-quality screening services (Pedrosa et al., 2018).

Ensuring smooth flow: The goal is to ensure the smooth flow of the screening process, from patients receiving screening invitations to completing the screening, obtaining results, and undergoing necessary follow-up treatment, with each step being efficient and orderly (Islam et al., 2018).

Continuous monitoring and evaluation: Continuous monitoring and evaluation of the entire screening program are indispensable components that ensure the screening services meet the set objectives and allow for timely adjustments and improvements

to address any issues that arise during the process. Through meticulous management and evaluation, DRSPs can effectively reduce the risk of vision loss due to DR and significantly improve patients' quality of life (Nørgaard and Grauslund, 2018).

6.2. Clinical management

In DR screening programs, clinical management plays a critical role in ensuring that the entire screening process strictly adheres to medical guidelines and standards, thereby ensuring the medical quality and effectiveness of the screening. Clinical management covers a wide range of areas, including but not limited to clinical evaluation of patients, quality control of the screening and treatment process, and continuous follow-up management of patients. It mainly involves the following three aspects:

Clinical evaluation: This involves a comprehensive health assessment of patients participating in screening to ensure that the screening program can accurately identify diabetic patients at risk for retinal lesions. This assessment is based not only on the patient's medical history and current health status, but also on a comprehensive consideration of genetic information, lifestyle habits, and other relevant health indicators (Egunsola et al., 2021).

Ensuring the quality of screening and treatment: This requires the screening program to use the most advanced medical equipment and technology, while ensuring that the operators have the necessary professional knowledge and skills. By implementing strict quality control over the screening and treatment process, the accuracy of screening and the effectiveness of treatment can be greatly improved, thereby optimizing patient outcomes (Riordan et al., 2020b).

Patient follow-up: This includes providing the necessary treatment to patients with positive screening results and regularly reassessing patients to monitor changes in their condition and the effectiveness of treatment. Follow-up management not only helps physicians adjust treatment plans in a timely manner, but also provides patients with ongoing support and guidance to ensure they receive the best possible care (Piyasena et al., 2019).

In summary, clinical management ensures that DRSPs provide high-quality, personalized medical services to patients through comprehensive clinical evaluation, quality control, and continuous patient follow-up. This process not only improves the efficiency of screening and treatment but also provides the best treatment outcomes for patients, significantly improving their health and quality of life.

6.3. Screening tests

Screening tests are a core component of DR screening programs, and the key is to use high-precision medical technology to capture images of the retina to detect lesions early, before they cause noticeable symptoms. This process typically involves high-quality digital fundus photography, which provides clear retinal images that allow physicians to observe the retina in detail, including microvascular abnormalities, hemorrhages, leakage, and other potential signs of retinal lesions. The use of digital fundus photography not only improves the accuracy of screening, but also makes the process faster and more convenient. Compared to traditional fundus examinations,

digital fundus photography can provide high-quality screening services to a large number of patients in a short time, and it allows digital storage of images, which facilitates long-term tracking, follow-up, and remote consultation with experts (Srihatrai and Hlowchitsieng, 2018).

The main purpose of screening is to detect potential retinal lesions in the asymptomatic early stages of DR. This is critical because DR often causes no discomfort to patients in its early stages, and untreated DR can progress to severe retinal lesions and even irreversible vision loss. Therefore, early detection of lesions through screening tests allows for timely intervention, effectively preventing progression of DR and protecting patients' vision (Lee et al., 2019). In addition, screening tests provide important evidence for early intervention. By analyzing fundus images, doctors can develop personalized treatment plans based on the specific type and severity of DR. For early non-proliferative DR, regular monitoring and blood glucose control may be sufficient; however, more severe proliferative DR or cases with macular edema may require more aggressive treatments such as laser therapy, drug injections, or surgery (Ratanapakorn et al., 2019).

In summary, screening tests using high-quality digital fundus photography provide a reliable means for early detection and timely intervention of asymptomatic DR and are an indispensable key component of DRSPs.

6.4. Image grading

Image grading plays a crucial role in DR screening programs. By performing detailed analysis and evaluation of captured fundus images, image grading can accurately determine the presence and severity of DR. This process can be manually performed by specially trained professionals or automated using advanced computer software.

6.4.1. Manual image grading

Manual image grading is usually performed by medically trained and certified image graders. These graders identify and evaluate various features in the fundus images according to specific grading standards and guidelines, such as microvascular abnormalities, hemorrhages, hard exudates, cotton wool spots, and neovascularization. Based on these observations, graders classify DR into different levels, ranging from no DR to mild, moderate, severe non-proliferative DR, and proliferative DR and macular edema. The advantage of manual image grading lies in the ability to use the professional judgment and experience of human graders for more detailed analysis of complex or borderline cases (Olvera-Barrios et al., 2021).

6.4.2. Automated image grading

With the advancement of artificial intelligence and computer vision technology, automated image grading has become possible. These systems use advanced algorithms, such as deep learning models, to automatically identify and evaluate lesion features in fundus images and then classify the severity of DR based on preset standards. The main advantages of automated image grading systems are their efficiency and consistency, as they can process large volumes of images in a very short time and are not affected by human factors (Gulshan et al., 2019). However, automated systems may have limitations in identifying and analyzing certain complex cases, so

in practice, manual review is often required to ensure grading accuracy (Hathwar and Srinivasa, 2019).

6.4.3. The importance of accuracy

Whether manual or automated, the accuracy of image grading directly impacts screening results and subsequent treatment decisions. Accurate grading ensures that DR patients receive necessary medical interventions in a timely manner, preventing further disease progression while avoiding over-intervention for patients who do not require treatment. Additionally, high-quality image grading is fundamental for evaluating the effectiveness of screening programs, guiding public health decisions, and advancing DR treatment research (Heydon et al., 2021).

Therefore, regardless of the grading method chosen, ensuring high quality and accuracy in the image grading process is indispensable in DRSPs. Continuously optimizing grading standards and techniques, as well as providing ongoing training and evaluation for graders and automated grading systems, can significantly improve the overall quality of screening programs (Styles, 2019).

6.5. Monitoring pathways

In DR screening programs, it is crucial to appropriately monitor and manage patients based on screening results. To this end, different monitoring pathways have been developed based on the severity and progression risk of DR to ensure that each patient receives personalized attention and treatment appropriate for their condition. The main purpose of monitoring pathways is to effectively track patients through stratified management, thereby optimizing treatment outcomes and preventing disease progression.

6.5.1. Regular follow–ups

For patients with mild or moderate DR, immediate intervention may not be necessary, but regular follow-ups are needed to monitor changes in their condition. The frequency of follow-ups is usually determined by the severity and progression rate of DR; for example, patients with mild DR may be screened annually, while those with moderate DR may require follow-ups every six months or quarterly. Through regular monitoring, doctors can detect any changes in the condition in a timely manner and adjust treatment plans as necessary (Pires et al., 2019).

6.5.2. More intensive monitoring

For patients with more severe or higher-risk DR, such as those with severe non-proliferative DR, more intensive monitoring is required in addition to regular follow-ups. This may include more frequent fundus examinations and more detailed tests such as optical coherence tomography (OCT). More intensive monitoring helps doctors more accurately assess disease progression and treatment efficacy, allowing timely adjustments to treatment plans to maximize vision preservation (Nørgaard and Grauslund, 2018).

6.5.3. Direct referral to ophthalmic specialists

For patients identified during screening with proliferative DR or macular edema, immediate intervention is usually required to prevent rapid vision loss or other serious complications, so they should be directly referred to ophthalmic specialists for further

evaluation and treatment. Ophthalmic specialists may use treatments such as laser therapy, drug injections, or surgery to control or reverse the lesions. Rapid intervention for these high-risk patients is key to preventing vision loss (Keel et al., 2018).

Through these stratified monitoring pathways, the diabetic retinopathy screening program can provide personalized management plans for patients of different risk levels, thereby protecting patients' vision while optimizing the use of medical resources. The establishment and implementation of monitoring pathways require close cooperation among the medical team, including frontline screeners, ophthalmologists, and other relevant medical experts, to ensure that patients receive the most appropriate and effective medical care (Bellemo et al., 2019).

6.6. Ophthalmic referral

In DR screening programs, it is crucial to promptly refer patients whose screening results indicate the need for further evaluation or treatment to ophthalmic specialists. This process ensures that patients receive the necessary professional evaluation and treatment and is one of the key components for the successful implementation of the screening program.

6.6.1. The importance of timely referral

The primary goal of screening is to detect potential retinal lesions at an early stage of DR, especially in patients who have not yet exhibited obvious symptoms. For these patients, timely professional evaluation and treatment can effectively prevent disease progression and reduce the risk of vision loss. Therefore, ensuring that high-risk patients identified during screening can quickly receive further evaluation and treatment from ophthalmic specialists is crucial (Wong et al., 2018).

6.6.2. Referral process

Once screening identifies a patient who may have DR or other notable retinal issues, the screener should immediately initiate the referral process. This typically involves contacting local ophthalmic services, providing the patient's screening results and necessary medical records, and scheduling the referral appointment. In certain cases, especially for patients requiring urgent evaluation (such as those with proliferative DR or severe macular edema), the referral process should proceed as quickly as possible to ensure timely treatment (Bresnick et al., 2020).

6.6.3. Follow-up after referral

After referral to an ophthalmic specialist, the patient will undergo more detailed eye examinations and evaluations, including advanced diagnostic tools such as OCT and fluorescein angiography. Based on these evaluations, the ophthalmic specialist will develop a personalized treatment plan, which may include laser treatment, anti-VEGF injections, or surgery. During treatment, the patient's condition needs to be closely monitored, and the treatment plan should be adjusted as necessary (Keel et al., 2018).

Good communication and cooperation between the screening team and ophthalmic services are essential to ensure patients smoothly transition from screening to treatment. Additionally, follow-up with referred patients is indispensable to evaluate treatment effectiveness and patient satisfaction, as well as to promptly identify and

address any potential issues (Liu et al., 2021).

In summary, promptly referring patients who need further evaluation or treatment to ophthalmic specialists not only ensures they receive the best treatment outcomes but is also key to improving the success rate of DRSPs. Effective referral processes and close medical collaboration can maximize the reduction of DR's impact on patients' vision and quality of life.

6.7. Fail-safe measures

In DR screening programs, the implementation of effective fail-safe measures is critical to prevent information loss or patient neglect during the screening and treatment process. The primary purpose of fail-safe measures is to ensure that each patient receives timely screening and, if necessary, timely treatment, thereby minimizing the impact of DR on vision.

6.7.1. Establish an effective communication system

An effective communication system is the cornerstone of fail-safe measures and ensures the smooth flow of information between patients, screeners, and eye care professionals. This includes timely communication of screening results to patients, communication of treatment recommendations, and exchange of information regarding follow-up and treatment arrangements. To achieve this, the screening program may use various communication methods, such as emails, text message reminders, telephone notifications, or mailed letters, to ensure that patients receive all relevant information (Bastos de Carvalho et al., 2020).

6.7.2. Establish a comprehensive record system

A comprehensive record system is essential for tracking patients' screening and treatment histories. This system should be able to record detailed information about each patient's screening results, treatment recommendations, treatment progress, and follow-up arrangements. The use of an electronic medical record (EMR) system can effectively manage this information and make it easy for medical staff to access and update patient records. In addition, a good record system can provide valuable data resources for medical research (Petersen et al., 2022).

6.7.3. Regular follow-up and reminders

To ensure that patients do not miss screening and treatment, the screening program should include regular follow-up and reminder mechanisms. This can be achieved through an automated reminder system that sends regular reminders to patients about screening and treatment. In addition, proactive follow-up contact should be made with patients who miss their screening or treatment to understand the reasons and assist them in rescheduling (Liu et al., 2021).

6.7.4. Multiple review mechanisms

Implementing multiple review mechanisms during the screening and treatment process can further reduce omissions and errors. For example, multiple reviews of screening results can ensure the accuracy of classification, while multidisciplinary team discussions prior to treatment decisions can improve the appropriateness and effectiveness of treatment plans (Heydon et al., 2021).

By implementing the above fail-safe measures, the diabetic retinopathy screening

program can maximize the protection of patients' visual health and ensure that each patient receives timely and effective screening and treatment services. This not only improves the effectiveness of the screening program but also increases patient satisfaction and confidence.

6.8. Internal quality assurance

Internal Quality Assurance (IQA) plays a critical role in DR screening programs and is a fundamental mechanism for ensuring that the entire screening process meets the highest quality standards. By regularly evaluating and reviewing various stages of the screening process, IQA aims to identify and address issues that may affect the accuracy and efficiency of screening results, thereby continuously improving the quality of screening services and patient satisfaction.

6.8.1. Evaluation of the screening process

IQA covers all aspects of the screening program, including the appointment process, patient intake, performance of screening tests, and follow-up management. Regular evaluation of the effectiveness and efficiency of these processes ensures that patients receive a high standard of service throughout the screening cycle. In addition, analysis of patient feedback can provide a better understanding of patient needs and expectations, allowing for targeted service improvements (Pedrosa et al., 2018).

6.8.2. Checking image quality

Image quality is critical in DR screening and has a direct impact on the accuracy and reliability of image grading. Internal quality assurance mechanisms must regularly review the quality of captured fundus images to ensure that they are clear and detailed enough for accurate grading. When image quality is poor, it is necessary to promptly identify the causes (e.g., equipment problems, operating techniques, etc.) and take appropriate corrective action (Lin et al., 2019).

6.8.3. Data management quality control

Quality data management is essential to ensure the accurate collection and analysis of screening results. IQA should cover the entire process of data entry, storage, and processing, with regular checks on data quality, including data integrity, accuracy, and consistency. In addition, it is necessary to ensure data security and privacy in accordance with relevant laws, regulations, and best practice guidelines (Baxter et al., 2022).

6.8.4. Implementation of improvement actions

Internal quality assurance is not only about evaluation and review, but more importantly about taking actual improvement actions based on the evaluation results. This may include technical training, process optimization, equipment upgrades, etc. to address identified problems and improve service quality. Regular quality improvement cycles can ensure that the screening program continually adapts to new challenges and standards, thereby continuously improving the effectiveness and efficiency of screening (Lam et al., 2019).

By implementing comprehensive and effective internal quality assurance mechanisms, the diabetic retinopathy screening program can ensure the highest quality of service at all stages, thereby minimizing the impact of DR on patients' vision and

improving their quality of life.

7. Screening subjects and frequency

In DR screening programs, determining screening subjects and screening frequency are two core components. These decisions are usually based on the latest scientific research findings and national guidelines, aiming to minimize vision loss caused by DR. The following is a detailed discussion on screening subjects and screening frequency:

7.1. Screening subjects

One of the core goals of DR screening programs is to identify diabetic patients who may develop DR early, thereby allowing timely intervention to reduce the risk of vision loss. Determining the screening subjects is the first step in achieving this goal. The following describes the general requirements for screening subjects in detail, including factors such as age and type of diabetes.

7.1.1. General requirements for screening subjects

Age: The starting age for screening is based on the fact that the risk of developing DR increases with age. Although the risk of developing DR is relatively low in children and adolescents, regular screening from the age of 12 has been recommended by most guidelines. This recommendation is based on understanding the progression patterns of retinal lesions in diabetic patients and aims to ensure early detection and management of those who may show signs of DR starting in adolescence. For adult diabetic patients, screening should start immediately upon diabetes diagnosis to assess for any existing retinal changes (Januszewski et al., 2022).

Type of Diabetes: Both type 1 and type 2 diabetic patients should be included in the screening program. Both types of diabetic patients are at risk of developing DR, although the course and degree of risk may vary. Type 1 diabetic patients are usually diagnosed at a younger age, with the risk of DR increasing over time; type 2 diabetic patients may already have DR at the time of diagnosis, especially if diabetes is not well-controlled (Kreft et al., 2018).

7.1.2. Differences based on national guidelines

Different countries and regions may formulate different guidelines for the starting age and frequency of screening based on local disease burden, medical resources, and research findings. Therefore, when implementing DR screening programs, it is important to refer to local or national professional guidelines and best practices. Additionally, for specific groups such as pregnant diabetic patients, more specialized screening considerations and arrangements may be needed to monitor and manage potential retinal issues during this high-risk period (Chung et al., 2022).

In summary, including all diagnosed type 1 or type 2 diabetic patients as screening subjects, with regular screening starting from age 12 or adulthood, is key to the successful implementation of DR screening programs. Early identification and intervention can significantly reduce the impact of DR on the vision of diabetic patients and improve their quality of life.

7.2. Screening frequency

In DR screening programs, determining the screening frequency is a crucial step, as it directly impacts the efficiency of early detection and treatment of the disease. The screening frequency is usually personalized based on the patient's DR risk level to ensure rational allocation of resources and maximum benefit for the patient.

7.2.1. Risk-Based screening frequency

Adjusting the frequency of DR screening based on the patient's risk level is crucial. It is recommended that all diabetic patients, whether type 1 or type 2, undergo screening at least once a year to timely detect asymptomatic new or progressing retinal lesions at an early stage. For low-risk patients with no DR detected in consecutive screenings or only mild background retinopathy, biennial screening can be considered to effectively utilize medical resources. For high-risk patients, such as pregnant women, patients with rapidly progressing DR, or those with poor diabetes control, more frequent screenings may be necessary (Broadbent et al., 2019). Through such personalized adjustments in screening frequency, screening programs can provide customized monitoring plans for patients of different risk levels, effectively prevent disease progression, optimize resource allocation, and ensure timely attention and treatment for patients (Sharif et al., 2021).

7.2.2. Basis for adjusting screening frequency

When adjusting the screening frequency for diabetic retinopathy, factors such as the duration of diabetes, diabetes control status, presence of complications, and previous screening results need to be considered. Firstly, the longer the patient's history of diabetes, the higher the risk of developing DR. Secondly, poor blood sugar control increases the risk of DR development. Additionally, the presence of other diabetic complications may also increase the risk of DR. Lastly, the level of DR and the progression speed shown in previous screening results are important factors in adjusting the screening frequency (Schreur et al., 2021).

Through a risk-based screening program, high-risk patients can receive timely interventions and attention, while avoiding over-screening of low-risk patients, thereby optimizing the use of medical resources and improving the overall efficiency and effectiveness of the screening program. Considering the above factors, adjusting the screening frequency for diabetic retinopathy will help provide tailored monitoring plans for patients of different risk levels, thereby enabling early detection and management of DR, significantly improving patients' quality of life, and preventing vision loss.

In summary, adjusting the screening frequency for diabetic retinopathy and customizing monitoring plans based on individual risk is of great significance for disease management and prevention. Moreover, such a screening program helps improve the efficiency of medical resource utilization, ensuring better treatment and attention for patients.

7.3. Screening models

Globally, screening models for DR vary by region and resources. The main screening models include mobile screening and fixed optometric screening, each with

its unique advantages and potential limitations. The following is a detailed introduction to these screening models and an analysis of their advantages and disadvantages:

7.3.1. Mobile screening

Mobile screening is a flexible screening method, particularly suitable for remote areas or resource-limited settings, bringing screening equipment and professionals to patient communities, usually conducted at community centers, medical facilities, or other temporary locations.

Advantages:

1) Increased accessibility: Direct reach to patient communities, reducing missed screenings due to transportation difficulties.

2) Flexible scheduling: Screening times and locations can be adjusted based on regional needs, effectively increasing coverage.

Disadvantages:

1) Resource allocation: Requires effective management and deployment of mobile equipment and personnel.

2) Logistics costs: Potentially high costs for transportation and setup.

3) Variability in screening quality: Results can vary across different locations, affecting stability and consistency (Bellemo et al., 2019).

7.3.2. Fixed optometric screening

Fixed optometric screening is conducted at specific medical facilities, such as hospitals, specialized eye clinics, or optometric centers, often equipped with advanced ophthalmic equipment to provide precise and reliable screening services.

Advantages:

1. 1) Advanced equipment: Use of more advanced screening tools enhances the accuracy and reliability of screening.
2. 2) Consistency and standardization: Screening processes are standardized at fixed locations, ensuring high-quality control.

Disadvantages:

1) Accessibility issues: Patients living in remote areas may face transportation and time challenges.

3. 2) Participation rates: Patients must actively travel to screening locations, which may affect overall screening rates (Keel et al., 2018).

7.3.3. How to choose a screening model

Choosing the screening model that best suits the needs of specific populations and regions is a complex and multi-dimensional decision-making process involving comprehensive consideration of factors such as population density, geographic location, resource availability, patient needs and preferences, and cost-effectiveness.

Remote or Low-Density areas: Mobile screening is more suitable due to its high accessibility, directly reaching patient communities and reducing missed screenings due to transportation difficulties (Bellemo et al., 2019).

Resource-Rich areas: Establishing fixed optometric points using advanced equipment for precise screening can be considered, ensuring screening quality while maintaining the standardization and consistency of the screening process (Schreur et

al., 2021).

Understanding the specific needs and preferences of the target population is crucial for choosing a screening model that maximizes patient participation. Additionally, conducting cost-benefit analyses to evaluate the economic feasibility and efficiency of different screening models is a key step to ensuring that the screening program is both economical and effective. Ultimately, the chosen screening model should aim to ensure that the screening program effectively covers the target population, detects and addresses DR in a timely manner, reduces vision loss, and improves patients' quality of life (Baxter et al., 2022).

8. Screening pathways and standards

Establishing clear screening pathways and standards is crucial for any DR screening program. These pathways and standards not only provide clear guidance for screening but also ensure the accuracy and reliability of screening results, thereby improving screening quality and efficiency.

8.1. The importance of screening pathways

Screening pathways define the complete process from patient screening to final treatment, including patient identification, execution of screening tests, evaluation of results, and further examination and treatment if necessary. Clear screening pathways ensure that each step is performed according to predefined standards, reducing the risk of missed diagnoses and misdiagnoses.

Standardized procedures: Clear operational guidelines for each step, standardizing the process and improving overall screening quality and efficiency (Raman et al., 2021).

Stratified Risk management: Appropriate screening pathways enable stratified risk management for patients, ensuring that high-risk patients receive timely and appropriate attention while rationally allocating medical resources (Chung and Dang, 2020).

8.2. The importance of screening standards

Screening standards include regulations on screening subjects, screening frequency, technologies used, and methods for evaluating results. These standards are key to ensuring the quality and accuracy of screening results.

Quality assurance: By setting strict screening and result evaluation standards, errors and biases can be minimized, ensuring the accuracy and reliability of screening results (Kárason et al., 2022).

Consistency and comparability: Unified standards make screening results comparable across different times and locations, aiding in the aggregation and analysis of screening data (Boucher et al., 2020).

8.3. The role of technological advancements in improving screening quality

In recent years, technological advancements, particularly the development of digital imaging technology, have greatly improved the quality of DR screening.

Digital fundus photography: Provides high-definition retinal images, making early detection of lesions possible. Digital imaging technology supports remote diagnosis, allowing experts to evaluate images from different locations, which is especially important for patients in resource-limited or remote areas (Heydon et al., 2021).

Artificial intelligence and machine learning: Using AI for image analysis can automatically identify retinal lesions, improving the efficiency and accuracy of screening. AI-based systems can handle large volumes of data and provide rapid, accurate assessments (Liu et al., 2021).

By establishing clear screening pathways and standards and utilizing advanced technologies such as digital imaging, the quality and efficiency of DR screening can be significantly improved, providing better prevention and treatment services for diabetic patients, ultimately reducing vision loss and blindness caused by diabetic retinopathy.

9. Roles and responsibilities

In DR screening programs, each role bears specific responsibilities, and their collaboration is key to ensuring the smooth operation and achievement of program goals. Below is a detailed description of some key roles and their responsibilities:

9.1. Responsibilities of the clinical lead

In the diabetic retinopathy screening program, the responsibilities of the clinical lead are crucial. They are responsible for developing and overseeing the medical protocols and guidelines of the screening program, ensuring that all screening activities comply with the latest medical standards and practices. This includes selecting appropriate screening technologies, setting screening frequencies, and developing screening strategies for specific populations. During the review of screening results, the clinical lead provides expert opinions, particularly making precise judgments on complex or borderline cases, to ensure that each patient receives appropriate follow-up management and treatment. Additionally, the clinical lead acts as a bridge between the medical team and the project management team, ensuring strict adherence to medical guidelines while promoting communication and collaboration among teams to ensure the smooth implementation of the screening program (Pedrosa et al., 2018).

9.2. Responsibilities of the project manager

In the DR screening program, the project manager's responsibility is to ensure the smooth operation and efficient implementation of the screening program. This includes managing daily operations, personnel scheduling, budget control, and resource allocation, as well as adjusting screening locations and schedules to ensure that screening services cover all target populations. Additionally, the project manager is responsible for data collection, recording, and reporting, ensuring the accuracy and completeness of information, and handling administrative tasks and patient inquiries related to screening. Through the fulfillment of these responsibilities, the project manager plays a central role in ensuring the smooth operation of the screening program

and the achievement of its predetermined goals (Gupta et al., 2022).

9.3. Responsibilities of screeners/graders

Screeners play a key role in DR screening programs. Their primary responsibilities include administering screening tests, ensuring high quality retinal image capture, and ensuring patient comfort and safety. In addition, graders must perform preliminary grading and classification of captured retinal images to identify potential lesions according to predefined standards. If necessary, complex or uncertain cases are referred to clinical leads or higher-level graders for further evaluation.

Deep learning algorithms can provide accurate and reliable diagnoses of retinal images, which is critical to the work of screeners/graders. Studies have compared the performance of various deep learning models in diagnosing DR, demonstrating their high accuracy and reliability. During the preliminary evaluation and classification phase, screeners/graders identify potential lesions according to predefined standards, and familiarity with relevant technologies and processes is critical to improving screening quality and efficiency. When dealing with complex or uncertain cases, the use of operational mechanism models and computer simulations of safety screening systems can help to effectively manage safety checkpoints (Egunsola et al., 2021).

9.4. How to collaborate

In the successful implementation of DR screening programs, collaboration among team members is crucial. To achieve this goal, a series of collaborative strategies have been adopted to ensure efficient team operations.

Regular meetings and communication platforms: Team members can ensure that everyone is kept up-to-date on project progress, challenges encountered, and resource needs. This information and resource sharing mechanism strengthens cooperation and trust within the team (Pedrosa et al., 2018).

Clear communication channels: Established to ensure that relevant personnel can be quickly contacted when rapid decision-making or problem-solving is required (Valpuesta Martin et al., 2020).

Training and continuing education: Regular training and continuing education for team members to keep them abreast of the latest medical guidelines, screening techniques, and operational procedures, thereby enhancing the overall capability and service quality of the team (Nørgaard and Grauslund, 2018).

Quality control processes: Quality control processes and regular feedback mechanisms help assess the effectiveness of the screening program, identify opportunities for improvement, and take corresponding measures for optimization (Gupta et al., 2022).

Through the implementation of these strategies, close cooperation and coordination among various roles are achieved, enabling the effective conduct of DR screening programs. This not only ensures that patients receive high-quality screening services, allowing timely detection and management of retinal lesions, but also achieves the ultimate goal of reducing vision loss caused by diabetic retinopathy, thereby significantly improving the quality of life for patients.

10. Challenges and future directions

10.1. Challenges

Implementing DR screening programs faces multiple challenges, especially in resource-limited low- and middle-income countries. These challenges include, but are not limited to, resource constraints, technology acceptance, and the need for training medical personnel.

Resource constraints: Specialized equipment, qualified personnel, and their training costs required for screening often exceed the financial budgets of many regions, making it difficult for these areas to implement effective screening programs. This not only affects the promotion of screening programs but also limits their coverage and frequency, thereby impacting the ability to identify and treat DR early (Egunsola et al., 2021).

Technology acceptance: The introduction of new technologies may be met with unfamiliarity and hesitation from patients, as well as resistance from medical personnel. Patients may hesitate to participate in screening due to a lack of understanding of the benefits of new technologies, while medical personnel may find it difficult to adopt new technologies due to the need for additional training and adaptation periods (Riordan et al., 2020a).

Training needs of medical personnel: High-quality DR screening relies on capable and experienced professionals, but in many regions, especially resource-limited areas, there is a lack of adequate training facilities and expertise to provide necessary training to medical personnel, thereby affecting the quality and efficiency of screening (Capellan et al., 2024).

In summary, although implementing DR screening programs has clear benefits, various challenges, including resource constraints, technology acceptance, and the training needs of medical personnel, need to be overcome in practice. Addressing these issues requires efforts and collaboration from all parties, including governments, health organizations, technology providers, and community involvement.

10.2. Future directions

With the advancement of technology, future development trends in DR screening programs show several innovative trends that are expected to significantly improve screening efficiency and accuracy while expanding coverage.

Artificial intelligence (AI) and machine learning: The development of AI and machine learning technologies, especially in the application of automated analysis of fundus images, indicates a reduced reliance on professionals in future screening processes. This technology can not only assist or accelerate the lesion detection process, but also improve the accuracy of screening (Liu et al., 2021).

Remote screening services: Remote screening services can overcome geographical limitations and bring expert knowledge and skills to remote areas, greatly increasing the accessibility of screening. The remote transmission and evaluation of digital images not only speeds up the diagnostic process but also enables patients to receive timely treatment recommendations (Bastos de Carvalho et al., 2021).

Patient education and engagement: Digital tools such as mobile applications and

online platforms can provide easy-to-understand health information and the importance of screening, motivating patients to actively participate in screening programs. This participation not only helps to increase screening rates but also promotes patient understanding and management of their own health conditions (Lake et al., 2018).

Personalized screening and intervention plans: The application of AI and data analytics technologies suggests that future screening programs may evolve in a more personalized and tailored direction. By analyzing large amounts of patient data, AI can help identify high-risk populations and provide them with customized screening and intervention plans. This personalized approach can not only better utilize medical resources but also ensure that patients receive the most appropriate screening and treatment for their conditions (Sharif et al., 2021).

In summary, while the implementation of DR screening programs faces several challenges, technological advances, particularly innovations in artificial intelligence, telemedicine, and digital patient education, offer new opportunities to address these challenges. The integration of these technologies is expected to make future screening programs more efficient, accurate, and able to serve a broader population.

11. Conclusion

This comprehensive review and analysis highlight the critical importance of effective DRSPs as a public health strategy to combat the global rise in diabetes-related vision loss. Incorporating advanced screening technologies like digital fundus photography and artificial intelligence significantly improves early detection rates, ensuring timely intervention and treatment of DR. A cohesive approach involving ophthalmologists, diabetes specialists, primary care physicians, and other healthcare professionals is essential for the successful implementation and sustainability of DRSPs. This collaboration ensures comprehensive patient care and maximizes program effectiveness. Ensuring universal access to screening services, regardless of geographic location, is fundamental. This involves using mobile screening units and telemedicine to reach underserved and remote populations, thus increasing coverage and reducing disparities in healthcare access. Establishing standardized screening protocols, quality control measures, and robust data management systems is pivotal. These elements ensure reliable and accurate screening results, facilitating better patient outcomes and efficient program management. Enhancing patient awareness and engagement through education about the importance of regular screenings and the potential consequences of untreated DR is crucial. Informed patients are more likely to participate in screening programs and adhere to recommended follow-up treatments. Addressing the challenges faced by developing countries in implementing DR screening programs requires innovative solutions and increased international cooperation. Enhanced funding, resource allocation, and technology transfer are necessary to overcome barriers and improve program effectiveness.

Funding: This work was supported by the Ministry of Science and Technology of the Peoples Republic of China [grant number 2018YFC0114500]; Henan Provincial Medical Science and Technology Research Joint Co-construction Project [grant

number LHGJ20220085]; the Basic Science Project of Henan Eye Institute/Henan Eye Hospital [grant number 22JCQN004 and 21JCZD001]; and the National Natural Science Foundation of China [grant numbers 82171014, 81470603, and 81770962]. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest: The authors declare no conflict of interest.

References

Arrigo, A., Aragona, E., & Bandello, F. (2022). VEGF-targeting drugs for the treatment of retinal neovascularization in diabetic retinopathy. Annals of Medicine, 54(1), 1089–1111. https://doi.org/10.1080/07853890.2022.2064541

Bastos de Carvalho, A., Lee Ware, S., Belcher, T., et al. (2021). Evaluation of multi-level barriers and facilitators in a large diabetic retinopathy screening program in federally qualified health centers: a qualitative study. Implementation Science Communications, 2(1). https://doi.org/10.1186/s43058-021-00157-2

Bastos de Carvalho, A., Ware, S. L., Lei, F., et al. (2020). Implementation and sustainment of a statewide telemedicine diabetic retinopathy screening network for federally designated safety-net clinics. PLOS ONE, 15(11), e0241767. https://doi.org/10.1371/journal.pone.0241767

Baxter, S. L., Quackenbush, Q., Cerda, J., et al. Implementing Clinical Informatics Tools for Primary Care–Based Diabetic Retinopathy Screening. (2022). The American Journal of Managed Care, 28(10), e355–e362. https://doi.org/10.37765/ajmc.2022.89253

Bellemo, V., Lim, Z. W., Lim, G., et al. (2019). Artificial intelligence using deep learning to screen for referable and vision-threatening diabetic retinopathy in Africa: a clinical validation study. The Lancet Digital health, 1, e35-e44. https://doi.org/10.1016/s2589-7500(19)30004-4

Boucher, M. C., Qian, J., Brent, M. H., et al. (2020). Evidence-based Canadian guidelines for tele-retina screening for diabetic retinopathy: recommendations from the Canadian Retina Research Network (CR2N) Tele-Retina Steering Committee. Canadian Journal of Ophthalmology, 55(1), 14–24. https://doi.org/10.1016/j.jcjo.2020.01.001

Bresnick, G., Cuadros, J. A., Khan, M., et al. (2020). Adherence to ophthalmology referral, treatment and follow-up after diabetic retinopathy screening in the primary care setting. BMJ Open Diabetes Research & Care, 8(1), e001154. https://doi.org/10.1136/bmjdrc-2019-001154

Broadbent, D. M., Sampson, C. J., Wang, A., et al. (2019). Individualised screening for diabetic retinopathy: the ISDR study—rationale, design and methodology for a randomised controlled trial comparing annual and individualised risk-based variable-interval screening. BMJ Open, 9(6), e025788. https://doi.org/10.1136/bmjopen-2018-025788

Broadbent, D. M., Wang, A., Cheyne, C. P., et al. (2021). Safety and cost-effectiveness of individualised screening for diabetic retinopathy: the ISDR open-label, equivalence RCT. Diabetologia, 64(1), 56–69. https://doi.org/10.1007/s00125-020-05313-2

Capellan, P., Dillon, A. B., Rodriguez, G., et al. (2024). Implementation of a Teleophthalmology Screening Program for Diabetic Retinopathy in New York City. Journal of VitreoRetinal Diseases, 8(1), 34–44. https://doi.org/10.1177/24741264231208253

Chalke, S. D., & Kale, P. P. (2021). Combinational Approaches Targeting Neurodegeneration, Oxidative Stress, and Inflammation in the Treatment of Diabetic Retinopathy. Current Drug Targets, 22(16), 1810–1824. https://doi.org/10.2174/1389450122666210319113136

Chung, A. J., & Dang, M. N. (2020). Type 2 Diabetic Retinopathy Screening in a General Practice: A Five-Year Retrospective Analysis. Cureus. https://doi.org/10.7759/cureus.11713

Chung, Y. C., Xu, T., Tung, T. H., et al. (2022). Early Screening for Diabetic Retinopathy in Newly Diagnosed Type 2 Diabetes and Its Effectiveness in Terms of Morbidity and Clinical Treatment: A Nationwide Population-Based Cohort. Frontiers in Public Health, 10. https://doi.org/10.3389/fpubh.2022.771862

Dai, L., Wu, L., Li, H., et al. (2021). A deep learning system for detecting diabetic retinopathy across the disease spectrum. Nature Communications, 12(1). https://doi.org/10.1038/s41467-021-23458-5

Deswal, J., Narang, S., Gupta, N., et al. (2020). To study the impact of diabetic retinopathy on quality of life in Indian diabetic patients. Indian journal of ophthalmology, 68, 848-853. https://doi.org/10.4103/ijo.IJO_1553_19

Egunsola, O., Dowsett, L. E., Diaz, R., et al. (2021). Diabetic Retinopathy Screening: A Systematic Review of Qualitative

Literature. Canadian Journal of Diabetes, 45(8), 725-733.e12. https://doi.org/10.1016/j.jcjd.2021.01.014

Elsharkawy, M., Sharafeldeen, A., Soliman, A., et al. (2022). A Novel Computer-Aided Diagnostic System for Early Detection of Diabetic Retinopathy Using 3D-OCT Higher-Order Spatial Appearance Model. Diagnostics, 12(2), 461. https://doi.org/10.3390/diagnostics12020461

Fenner, B. J., Wong, R. L. M., Lam, W. C., et al. (2018). Advances in Retinal Imaging and Applications in Diabetic Retinopathy Screening: A Review. Ophthalmology and Therapy, 7(2), 333–346. https://doi.org/10.1007/s40123-018-0153-7

Granado-Casas, M., Castelblanco, E., Ramírez-Morros, A., et al. (2019). Poorer Quality of Life and Treatment Satisfaction is Associated with Diabetic Retinopathy in Patients with Type 1 Diabetes without Other Advanced Late Complications. Journal of Clinical Medicine, 8(3), 377. https://doi.org/10.3390/jcm8030377

Gulshan, V., Rajan, R. P., Widner, K., et al. (2019). Performance of a Deep-Learning Algorithm vs Manual Grading for Detecting Diabetic Retinopathy in India. JAMA Ophthalmology, 137(9), 987. https://doi.org/10.1001/jamaophthalmol.2019.2004

Gupta, V., Azad, S. V., Vashist, P., et al. (2022). Diabetic retinopathy screening in the public sector in India: What is needed? Indian journal of ophthalmology, 70, 759-767. https://doi.org/10.4103/ijo.IJO_1298_21

Hathwar, S. B., & Srinivasa, G. (2019). Automated Grading of Diabetic Retinopathy in Retinal Fundus Images using Deep Learning. In: Proceedings of the 2019 IEEE International Conference on Signal and Image Processing Applications (ICSIPA). https://doi.org/10.1109/icsipa45851.2019.8977760

Heydon, P., Egan, C., Bolter, L., et al. (2021). Prospective evaluation of an artificial intelligence-enabled algorithm for automated diabetic retinopathy screening of 30 000 patients. British Journal of Ophthalmology, 105(5), 723–728. https://doi.org/10.1136/bjophthalmol-2020-316594

Huemer, J., Wagner, S. K., & Sim, D. A. (2020). The Evolution of Diabetic Retinopathy Screening Programmes: A Chronology of Retinal Photography from 35 mm Slides to Artificial Intelligence. Clinical Ophthalmology, Volume 14, 2021–2035. https://doi.org/10.2147/opth.s261629

Islam, F. M. A., Kawasaki, R., & Finger, R. P. (2018). Factors associated with participation in a diabetic retinopathy screening program in a rural district in Bangladesh. Diabetes Research and Clinical Practice, 144, 111–117. https://doi.org/10.1016/j.diabres.2018.08.012

Januszewski, A. S., Velayutham, V., Benitez-Aguirre, P. Z., et al. (2022). Optimal Frequency of Retinopathy Screening in Adolescents with Type 1 Diabetes: Markov Modeling Approach Based on 30 Years of Data. Diabetes Care, 45(10), 2383–2390. https://doi.org/10.2337/dc22-0071

Kárason, K. T., Vo, D., Grauslund, J., et al. (2021). Comparison of different methods of retinal imaging for the screening of diabetic retinopathy: a systematic review. Acta Ophthalmologica, 100(2), 127–135. https://doi.org/10.1111/aos.14767

Kashim, R., Newton, P., & Ojo, O. (2018). Diabetic Retinopathy Screening: A Systematic Review on Patients' Non-Attendance. International Journal of Environmental Research and Public Health, 15(1), 157. https://doi.org/10.3390/ijerph15010157

Keel, S., Lee, P. Y., Scheetz, J., et al. (2018). Feasibility and patient acceptability of a novel artificial intelligence-based screening model for diabetic retinopathy at endocrinology outpatient services: a pilot study. Scientific Reports, 8(1). https://doi.org/10.1038/s41598-018-22612-2

Kreft, D., McGuinness, M. B., Doblhammer, G., et al. (2018). Diabetic retinopathy screening in incident diabetes mellitus type 2 in Germany between 2004 and 2013 - A prospective cohort study based on health claims data. PLOS ONE, 13(4), e0195426. https://doi.org/10.1371/journal.pone.0195426

Lake, A. J., Browne, J. L., Abraham, C., et al. (2018). A tailored intervention to promote uptake of retinal screening among young adults with type 2 diabetes - an intervention mapping approach. BMC Health Services Research, 18(1). https://doi.org/10.1186/s12913-018-3188-5

Lam, C. K. L., Zborovski, S., Palmert, M. R., et al. (2019). Seeing Clearly: Effects of Initiatives to Improve Diabetic Retinopathy Screening at a Pediatric Center. Clinical Diabetes, 37(3), 287–290. https://doi.org/10.2337/cd18-0084

Lanzetta, P., Sarao, V., Scanlon, P. H., et al. (2020). Fundamental principles of an effective diabetic retinopathy screening program. Acta Diabetologica, 57(7), 785–798. https://doi.org/10.1007/s00592-020-01506-8

Lawrenson, J. G., Graham-Rowe, E., Lorencatto, F., et al. (2018). What works to increase attendance for diabetic retinopathy screening? An evidence synthesis and economic analysis. Health Technology Assessment, 22(29), 1–160. https://doi.org/10.3310/hta22290

Lee, J. C., Nguyen, L., Hynan, L. S., et al. (2019). Comparison of 1-field, 2-fields, and 3-fields fundus photography for detection and grading of diabetic retinopathy. Journal of Diabetes and Its Complications, 33(12), 107441.

https://doi.org/10.1016/j.jdiacomp.2019.107441

Lin, J., Yu, L., Weng, Q., et al. (2019). Retinal image quality assessment for diabetic retinopathy screening: A survey. Multimedia Tools and Applications, 79(23–24), 16173–16199. https://doi.org/10.1007/s11042-019-07751-6

Liu, J., Gibson, E., Ramchal, S., et al. (2021). Diabetic Retinopathy Screening with Automated Retinal Image Analysis in a Primary Care Setting Improves Adherence to Ophthalmic Care. Ophthalmology Retina, 5(1), 71–77. https://doi.org/10.1016/j.oret.2020.06.016

Mansour, S. E., Browning, D. J., Wong, K., et al. (2020). The Evolving Treatment of Diabetic Retinopathy. Clinical Ophthalmology, Volume 14, 653–678. https://doi.org/10.2147/opth.s236637

Nørgaard, M. F., & Grauslund, J. (2018). Automated Screening for Diabetic Retinopathy – A Systematic Review. Ophthalmic Research, 60(1), 9–17. https://doi.org/10.1159/000486284

Olvera-Barrios, A., Heeren, T. F., Balaskas, K., et al. (2021). Diagnostic accuracy of diabetic retinopathy grading by an artificial intelligence-enabled algorithm compared with a human standard for wide-field true-colour confocal scanning and standard digital retinal images. British Journal of Ophthalmology, 105(2), 265–270. https://doi.org/10.1136/bjophthalmol-2019-315394

Pan, C. W., Wang, S., Wang, P., et al. (2018). Diabetic retinopathy and health-related quality of life among Chinese with known type 2 diabetes mellitus. Quality of Life Research, 27(8), 2087–2093. https://doi.org/10.1007/s11136-018-1876-6

Pandey, R., Morgan, M. M., Murphy, C., et al. (2022). Irish National Diabetic RetinaScreen Programme: report on five rounds of retinopathy screening and screen-positive referrals. (INDEAR study report no. 1). British Journal of Ophthalmology, 106(3), 409–414. https://doi.org/10.1136/bjophthalmol-2020-317508

Pedrosa, M., Silva, J. M., Silva, J. F., et al. (2018). SCREEN-DR: Collaborative platform for diabetic retinopathy. International Journal of Medical Informatics, 120, 137–146. https://doi.org/10.1016/j.ijmedinf.2018.10.005

Petersen, G. B., Byberg, S., Vistisen, D., et al. (2022). Factors Associated with Nonattendance in a Nationwide Screening Program for Diabetic Retinopathy: A Register-Based Cohort Study. Diabetes Care, 45(2), 303–310. https://doi.org/10.2337/dc21-1380

Pires, R., Avila, S., Wainer, J., et al. (2019). A data-driven approach to referable diabetic retinopathy detection. Artificial Intelligence in Medicine, 96, 93–106. https://doi.org/10.1016/j.artmed.2019.03.009

Piyasena, M. M. P. N., Murthy, G. V. S., Yip, J. L. Y., et al. (2019). Systematic review on barriers and enablers for access to diabetic retinopathy screening services in different income settings. PLOS ONE, 14(4), e0198979. https://doi.org/10.1371/journal.pone.0198979

Raman, R., Ramasamy, K., Rajalakshmi, R., et al. (2021). Diabetic retinopathy screening guidelines in India: All India Ophthalmological Society diabetic retinopathy task force and Vitreoretinal Society of India Consensus Statement. Indian journal of ophthalmology, 69, 678-88. https://doi.org/10.4103/ijo.IJO_667_20

Ratanapakorn, T., Daengphoonphol, A., Eua-Anant, N., et al. (2019). Digital image processing software for diagnosing diabetic retinopathy from fundus photograph. Clinical Ophthalmology, 13, 641–648. https://doi.org/10.2147/opth.s195617

Riordan, F., Racine, E., Phillip, E. T., et al. (2020a). Development of an intervention to facilitate implementation and uptake of diabetic retinopathy screening. Implementation Science, 15(1). https://doi.org/10.1186/s13012-020-00982-4

Riordan, F., Racine, E., Smith, S. M., et al. (2020b). Feasibility of an implementation intervention to increase attendance at diabetic retinopathy screening: protocol for a cluster randomised pilot trial. Pilot and Feasibility Studies, 6(1). https://doi.org/10.1186/s40814-020-00608-y

Rodriguez-Acuña, R., Mayoral, E., Aguilar-Diosdado, M., et al. (2020). Andalusian program for early detection of diabetic retinopathy: implementation and 15-year follow-up of a population-based screening program in Andalusia, Southern Spain. BMJ Open Diabetes Research & Care, 8(1), e001622. https://doi.org/10.1136/bmjdrc-2020-001622

Safi, H., Safi, S., Hafezi-Moghadam, A., et al. (2018). Early detection of diabetic retinopathy. Survey of Ophthalmology, 63(5), 601–608. https://doi.org/10.1016/j.survophthal.2018.04.003

Schreur, V., Ng, H., Nijpels, G., et al. (2021). Validation of a model for the prediction of retinopathy in persons with type 1 diabetes. British Journal of Ophthalmology, 105(9), 1286–1288. https://doi.org/10.1136/bjophthalmol-2018-313539

Sharif, A., Jendle, J., & Hellgren, K. J. (2021). Screening for Diabetic Retinopathy with Extended Intervals, Safe and Without Compromising Adherence: A Retrospective Cohort Study. Diabetes Therapy, 12(1), 223–234. https://doi.org/10.1007/s13300-020-00957-0

Simó, R., & Hernández, C. (2022). New Insights into Treating Early and Advanced Stage Diabetic Retinopathy. International Journal of Molecular Sciences, 23(15), 8513. https://doi.org/10.3390/ijms23158513

Srihatrai, P., Hlowchitsieng, T. (2018). The diagnostic accuracy of single- and five-field fundus photography in diabetic retinopathy screening by primary care physicians. Indian journal of ophthalmology, 66, 94-97. https://doi.org/10.4103/ijo.IJO_657_17

Styles, C. J. (2019). Introducing automated diabetic retinopathy systems: it's not just about sensitivity and specificity. Eye, 33(9), 1357–1358. https://doi.org/10.1038/s41433-019-0535-7

Tomita, Y., Lee, D., Tsubota, K., et al. (2021). Updates on the Current Treatments for Diabetic Retinopathy and Possibility of Future Oral Therapy. Journal of Clinical Medicine, 10(20), 4666. https://doi.org/10.3390/jcm10204666

Tymchenko, B., Marchenko, P., & Spodarets, D. (2020). Deep Learning Approach to Diabetic Retinopathy Detection. Proceedings of the 9th International Conference on Pattern Recognition Applications and Methods. https://doi.org/10.5220/0008970805010509

Valpuesta Martin, Y., Pacheco Callirgos, G. E., Maroto Martín, T. M., et al. (2020). Satisfaction of patients and primary care professionals with a teleophthalmology-based screening programme for diabetic retinopathy in a rural area in Castilla y León, Spain. Rural and Remote Health. https://doi.org/10.22605/rrh5180

Wang, W., & Lo, A. C. Y. (2018). Diabetic Retinopathy: Pathophysiology and Treatments. International Journal of Molecular Sciences, 19(6), 1816. https://doi.org/10.3390/ijms19061816

Wong, T. Y., Sun, J., Kawasaki, R., et al. (2018). Guidelines on Diabetic Eye Care. Ophthalmology, 125(10), 1608–1622. https://doi.org/10.1016/j.ophtha.2018.04.007

Zago, G. T., Andreão, R. V., Dorizzi, B., et al. (2020). Diabetic retinopathy detection using red lesion localization and convolutional neural networks. Computers in Biology and Medicine, 116, 103537. https://doi.org/10.1016/j.compbiomed.2019.103537