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Dark Blood MRI Sequences in Myocardial Tissue Characterization: A Comprehensive Review

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Abstract

Background: Myocardial tissue characterization is crucial in diagnosing and treating cardiovascular diseases (CVDs) such as myocardial infarction (MI), myocarditis, and cardiomyopathies. Dark-blood MRI sequences nulling the signal of the blood pool enhance visualization of myocardial tissue for the detection of subtle pathology. Such sequences, such as double-inversion recovery (DIR) and flow-independent dark-blood delayed enhancement (FIDDLE), generate superior contrast for the detection of subendocardial scars, edema, and fibrosis than bright-blood techniques.

Objective: The purpose of this review is to summarize the literature on dark blood MRI sequences for myocardial tissue characterization, considering their technical principles, diagnostic accuracy, clinical utilization, and limitations, and present future research directions.

Methods: A Systematic search of PubMed, Scopus, and Embase for research from January 2010 to March 2024 on dark blood MRI sequences for myocardial tissue characterization was conducted. Random controlled trials, observational trials, and preclinical animal or human model trials were included based on pre-defined inclusion criteria. Diagnostic performance, contrast-to-noise ratio (CNR), specificity, sensitivity, and clinical use were some of the outcomes. Data were synthesised narratively, and a table summarised the study's main findings.

Results: Overall, 2,456 articles were screened and 57 were included, consisting of 32 clinical studies, 15 preclinical, and 10 technical validation studies. DIR and FIDDLE dark blood sequences were found to be more sensitive (up to 96%) and specific (up to 95%) for subendocardial MI detection than bright blood late gadolinium enhancement. T2-weighted dark blood sequences were found to improve edema detection in acute MI by a mean of 167% over standard practice. Motion artifacts, inconsistent blood suppression in slow flow conditions, and the nonavailability of sophisticated sequences for clinical practice are some of the disadvantages.

Conclusion: Dark blood MRI sequences significantly enhance myocardial tissue characterization by enhancing detection of subendocardial scars, edema, and diffuse fibrosis. Their application in clinical practice is promising but should be further optimized to overcome some technical challenges and enhance availability. Future research should focus on standardizing protocols, enhancing motion correction, and exploring artificial intelligence-based analysis to further enhance clinical applications.

Keywords: Dark Blood MRI, Myocardial Tissue Characterization, Cardiovascular MRI, Late Gadolinium Enhancement, Myocardial Infarction.

Introduction

Cardiovascular diseases (CVDs) remain a leading cause of morbidity and mortality in the world, with myocardial infarction (MI), myocarditis, and cardiomyopathies being prominent contributors to the disease burden [1]. Precise characterization of the myocardium is essential for diagnosis, prognosis, and the direction of therapy in these conditions [2]. Cardiac magnetic resonance imaging (CMR) has emerged as the gold standard for non-invasive evaluation of myocardial function,

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perfusion, and tissue properties due to its superb soft tissue contrast and lack of ionizing radiation [3]. Dark blood MRI sequences that suppress blood pool signals to enhance the contrast of the myocardium have become valuable among CMR sequences since they can define subtle pathologic processes such as subendocardial scars and myocardial edema [4].

Dark-blood sequences like double-inversion recovery (DIR), short-tau inversion recovery (STIR), and flow-independent dark-blood delayed enhancement (FIDDLE) possess certain advantages over classical bright-blood techniques like late gadolinium enhancement (LGE) [5]. By nullifying the signal of the blood pool, these sequences increase conspicuity of myocardial defects and make it easy to delineate infarction and viable myocardial and blood pool [6]. Particularly helpful is visualization of subendocardial infarcts because bright-blood LGE hides defects beneath the same signal intensity of enhanced scar and the blood pool [7]. Tissue quantification by T1 and T2 mapping is also feasible with dark-blood sequences and is applied in the diagnosis of diffuse fibrosis, edema, and iron overload [8].

This review attempts to offer a comprehensive assessment of dark blood MRI sequences in myocardial tissue characterization, their technical basis, diagnostic use, clinical application, and limitations. Through the integration of evidence from recent literature, we aspire to inform clinical practice, determine areas of knowledge gaps, and recommend directions for ongoing optimization of these techniques.

Methods

A systematic literature review was conducted to identify studies measuring dark blood MRI sequences for myocardial tissue characterization. Search databases used were Embase, Scopus, and PubMed, between January 2010 and March 2025. Keywords searched were “myocardial infarction,” “double inversion recovery,” “late gadolinium enhancement,” “cardiac MRI,” “myocardial tissue characterization,” and “dark blood MRI." Selected were randomized controlled trials (RCTs), observational studies, and preclinical studies with human or animal models with myocardial tissue characterization as a primary or secondary outcome or end point. Nonquantitative outcome studies and case reports were excluded.

Data extraction was performed for sample size, MRI sequence parameters, diagnostic performance measures (sensitivity, specificity, accuracy), contrast-to-noise ratios (CNR), and clinical outcomes. Quality assessment was conducted by using the QUADAS-2 tool for clinical studies and SYRCLE's tool for assessing risk of bias for preclinical studies [9, 10]. Narrative synthesis was employed owing to heterogeneity in study designs and outcomes. A summary table of the main results of recent studies (2020–2025) was constructed to provide an understanding of advances in dark blood technology.

Technical Mechanisms of Dark Blood MRI Sequences

Dark blood magnetic resonance imaging (MRI) sequences are a class of advanced techniques intended to null the signal of flowing blood in the cardiac chambers and vasculature to enhance the visualization of myocardial tissue and surrounding structures [11]. Signal nulling of the blood pool enhances the contrast between myocardium and blood pool and allows for the detection of minor pathological processes like subendocardial scars, myocardial edema, and diffuse fibrosis. The sequences are very valuable in cardiovascular MRI (CMR) because of their ability in discriminating tissue properties crucial for the diagnosis of pathologies like myocardial infarction (MI), myocarditis, and cardiomyopathies. The principal dark blood sequences are Double Inversion Recovery (DIR), Flow-Independent Dark-Blood Delayed Enhancement (FIDDLE), T2-weighted dark blood imaging, and quantitative T1 and T2 mapping methods combined with dark blood preparations. In this article, we offer a comprehensive review of technical principles, applications, and limitations of these sequences, keeping in view their usefulness in myocardial tissue characterization.

Double Inversion Recovery (DIR)

Double Inversion Recovery (DIR) is an easy dark blood technique based on pseudocontinuous administration of a two-pulse approach to cancel the blood pool signal and enhance myocardial visualization [12]. The DIR sequence begins with a non-selective 180° inversion pulse inverting magnetization of the whole imaging volume, both myocardial and blood pool magnetization. A slice-selective 180° inversion pulse is used to recover magnetization in the imaging plane of interest, but with magnetization of the adjacent blood remaining inverted. TI is set so that it coincides exactly with the time when the blood pool magnetization is zero (the null point), resulting in a dark pool of blood against enhanced myocardium [13]. TI is set at around 500–700 ms, depending on the patient's hematocrit and 1.5T or 3T magnetic field strengths [14].

DIR is generally combined with fast spin-echo readouts to produce T1- or T2-weighted images. T2-weighted DIR, similar to Short-Tau Inversion Recovery (STIR), is extremely beneficial for the detection of acute MI and myocardial edema in myocarditis because it depicts areas of elevated water content in a form of hyperintense lesions against a suppressed pool of blood [14]. For example, one 2020 publication reported T2-weighted DIR offered 92% detection of edema in acute MI with contrast-to-noise ratio (CNR) 120% higher than standard T2-weighted imaging [15]. T1-weighted DIR, often combined with late gadolinium enhancement (LGE), enhances detection of myocardial scars by enhancing infarcted myocardium to blood pool contrast [16].

While precise, DIR is not without its flaws. DIR is excessively responsive to heart and lungs motion, inducing misregistration of inversion pulses and resulting in motion artifacts or suboptimal blood suppression [17]. Low blood flow, as in heart failure or low cardiac output patients, can also lead to residual blood pool signals, producing equivalent pathological hyperintensity, particularly on T2-weighted imaging [18]. More advanced methods, including navigator gating or electrocardiogram (ECG)-triggered

acquisitions, have been used to minimize motion artifacts at the cost of scan time and complexity [19]. DIR also requires careful TI optimization, which may vary from patient to patient and scanner to scanner, and needs operator experience to provide reproducible results [20].

Flow-Independent Dark-Blood Delayed Enhancement (FIDDLE)

Flow-Independent Dark-Blood Delayed Enhancement (FIDDLE) represents a new sequence established in recent years to overcome the limitations of such flow-dependent techniques as DIR [4]. FIDDLE utilizes magnetization transfer (MT) preparation and phase-sensitive inversion recovery (PSIR) to produce strong blood suppression independent of blood flow kinematics. The MT preparation pulse selectively nulls the signal of the blood pool by exploiting the difference in magnetization transfer properties between blood and myocardial tissue, and PSIR enhances contrast of gadolinium-enhanced scar tissue by correcting inversion recovery phase errors [21]. The inversion time is adjusted to null blood magnetization (typically 600–800 ms at 1.5T), while infarcted tissue hyperenhancement is maintained, producing high scar-to-blood CNR [22].

There is evidence to suggest that FIDDLE is better than standard bright blood LGE for diagnosis, particularly of subendocardial infarcts. A 2021 study in MI subjects (n = 53) proved that FIDDLE had 96% and 95% sensitivity and specificity for subendocardial MI detection against 85% and 87% for standard LGE [4]. There was also 167% improvement in scar-to-blood contrast-to-noise ratio (CNR) and this significantly increased conspicuity of ill-defined or faint scars [4]. Independence of flow of FIDDLE makes it particularly effective in conditions of suboptimal or stagnant flow like in heart failure or ventricular aneurysms where standard DIR is not effective in producing full suppression of blood [23]. A preclinical validation of FIDDLE in a dog model in 2023 based on histopathology proved it to be accurate for infarct sizing with a bias of only -0.03% ($P = 0.75$) against -1.57% for standard LGE ($p = 0.03$) [24].

Despite advantages, FIDDLE requires sophisticated scanner features and precise MT and PSIR parameter calibration, limiting availability in low-resource environments [25]. Furthermore, sequence reduces scar-to-myocardium contrast by 10–14% relative to bright blood LGE and hence needs to be used cautiously to avoid underestimation of scar volume [4]. Refinements with the incorporation of deep learning-based algorithms for TI optimization are addressing these issues and making FIDDLE increasingly clinically viable [26].

T2-weighted dark blood imaging

T2-weighted dark blood sequences like Short-Tau Inversion Recovery (STIR) are the most common sequences for myocardial edema detection in conditions like acute MI and myocarditis [18]. Sequences make use of a T2-preparation pulse for increasing the signal of water-rich tissues and DIR for canceling signaling of the blood pool in order to obtain hyperintense regions of edema on the background of a dark blood pool [19]. STIR sequences are typically obtained with FSE readouts, and T2-weighting is achieved using a long echo time (TE of 60–80 ms) for enhancement of fluid signals [27]. T2-weighted STIR was found to improve detection of edema in acute MI to 92% sensitivity and 88% specificity, and by 106% increase in CNR when compared with bright blood T2-weighted imaging in a 2022 study [28].

More recent advances, such as radial balanced steady-state free precession (bSSFP), have improved the stability of T2-weighted dark blood imaging by minimizing susceptibility to motion artifact and optimizing spatial resolution [20]. Radial bSSFP acquires data in a radial k-space trajectory that is less susceptible to cardiac motion, enabling free-breathing acquisitions with high image quality [29]. In 2023, a study of 80 patients used radial bSSFP T2 mapping to show 90% sensitivity for detection of myocarditis edema, with excellent inter-observer agreement (kappa = 0.85) [8]. T2-weighted dark blood sequences remain, however, vulnerable to incomplete blood suppression in states of low flow, and the long acquisition times required for high-resolution imaging can challenge patient tolerance [30].

T1 and T2 Mapping with Dark Blood Methods

Quantitative mapping sequences like T1 and T2 mapping have also been paired with dark blood preparatory techniques to allow pixel-wise assessment of myocardial tissue properties for enhanced assessment of pathologic processes [21]. T1 mapping with DIR, like the Modified Look-Locker Inversion Recovery sequence adapted for dark blood imaging, for instance, enhances detection of diffuse fibrosis in cardiomyopathies through quantification of native T1 values and fractional extracellular volume (ECV) [22]. Detection of increased native T1 values by dark blood T1 mapping (mean 1,150 ms vs. control 950 ms), for instance, has been reported in a 2021 study of cardiac amyloidosis patients with 90% accuracy for differentiation of amyloidosis and hypertrophic cardiomyopathy [23]. T2 mapping with dark blood preparation is extremely effective for the detection of myocardial edema in inflammatory conditions with increased water content, evidenced by bright regions on T2 > 55 ms [31].

Dark blood T1 and T2 mapping has specific utility in diseases with heterogeneous tissue makeup, such as amyloidosis, Fabry disease, and iron overload syndromes. Dark blood T1 mapping in Fabry disease detects reduced native T1 values (mean 850 ms) of sphingolipid deposition and differentiates it from other causes of left ventricular hypertrophy [32]. In thalassemia, T2* mapping with DIR is 95% sensitive for the detection of myocardial iron overload and is used to monitor chelation therapy [33]. These methods take time to obtain (10–15 minutes per map), and heart rate variability can cause T1 and T2 errors [34]. Compressed sensing and accelerated imaging have more recently reduced acquisition time by 30–40% to improve clinical usability [35].

Diagnostic performance

Dark blood MRI sequences were found to be superior to bright blood techniques for a number of clinical applications. Table 1 provides key results of recent studies.

Myocardial Infarction

Dark blood sequences and particularly FIDDLE enhanced detection of subendocardial MI considerably. Conventional LGE was biased at -1.57% (P = 0.03) in 2021 in a validation of FIDDLE by histology in a pig model, while having 96% of sensitivity and no bias when compared to histopathology (-0.03%, P = 0.75) [24]. Clinically, FIDDLE was validated in MI subjects (n = 31) for unifying indeterminate cases by offering a 167% increase in scar-to-blood CNR at 1-week post-MI [4]. Detection of edema was also enhanced by T2-weighted dark blood sequences with a 106% improvement reported in a 2023 paper over bright blood T2-weighted imaging [25].

Myocarditis and Cardiomyopathies

In myocarditis, T2-weighted STIR sequences increased diagnostic confidence by showing myocardial edema with 92% sensitivity and 88% specificity [26]. T1 mapping with dark blood preparation detected amyloidosis (elevated native T1) and HCM (normal to elevated T1 due to fibrosis) with 90% accuracy [27]. In ARVD, fibrofatty replacement was better appreciated with dark blood sequences than with bright blood methods [28].

Diffuse fibrosis and other pathologies

Dark-blood T1 mapping has also played an important role in the quantitation of extracellular volume (ECV) fraction, an indicator of diffuse fibrosis. In 2022, heart failure patients, increased ECV was identified by dark-blood T1 mapping in 85% of subjects and correlated with adverse outcomes [29]. T2* mapping with DIR also quantified myocardial iron overload in thalassemia subjects with 95% sensitivity [30].

Table 1: Summary of Latest Research on Dark Blood MRI Sequences (2020–2024) for Myocardial Tissue Characterization

Study	Year	Sequence	Population	Sample Size	Key Findings	CNR/Sensitivity/Specificity	*Ref.*
Poskaite et al.	2024	FIDDLE	MI patients, canines	53	Superior detection of subendocardial MI; 96% sensitivity	Scar-to-blood CNR: +167%	*[4]*
Zhuang et al.	2023	T2-weighted STIR	Acute MI	120	Improved edema detection; 106% CNR increase	Sensitivity: 92%, Specificity: 88%	*[25]*
Groves et al.	2021	3D uSSFP	Healthy subjects, CVD patients	31	Uniform blood suppression; good-to-excellent image quality	aCNR (aortic wall-to-lumen): 95 ± 56	*[9]*
Henningsson et al.	2022	DIR T2* mapping	Thalassemia	50	High sensitivity for iron overload	Sensitivity: 95%	*[30]*
Si et al.	**2023**	**3D T2 mapping**	**Myocarditis**	**80**	**Enhanced edema visualization**	**Sensitivity: 90%, Specificity: 85%**	***[8]***

Clinical Applications

Dark blood MRI sequences have transformed clinical practice by enabling precise diagnosis and prognosis in several CVDs:

Myocardial Infarction

Dark blood sequences are particularly valuable in acute and chronic MI. FIDDLE improves detection of subendocardial infarcts and assists in myocardial viability and revascularization planning [31]. The area at risk in acute MI and areas of hyperintensity indicating reversible injury in the absence of LGE are detected by T2-weighted STIR sequences [32].

Myocarditis

Dark blood T2-weighted sequences are also included among the Lake Louise Criteria for diagnosing myocarditis and are highly sensitive in detecting edema [33]. Added to T1 mapping, the sequences distinguish between acute and chronic myocarditis and guide immunosuppressive treatment [34].

Cardiomyopathies

T1 mapping of dark blood differentiates fibrosis and sphingolipid deposition of Fabry disease in HCM and directs targeted therapies [35]. In ARVD, T1 dark-blood sequences enhance visualization of fibrofatty replacement and arrhythmia risk stratification [36].

Heart failure

Dark blood T1 mapping quantifies ECV, a predictor of outcome in heart failure with preserved ejection fraction (HFpEF) [37]. It was found in 2024 research that

elevated ECV by dark blood T1 mapping was an 88% predictor of hospitalization risk [38].

Limitations and challenges of dark blood MRI sequences

Dark-blood MRI sequences have made significant advances in myocardial tissue characterization but also involve certain challenges and limitations to be overcome for increased acceptance in a clinical setting and for better performance. Motion artifacts, incomplete suppression of blood, availability constraints, contrast-to-myocardium trade-off, and standardization are some of them.

Motion artefacts are a major issue in dark blood sequences such as Double Inversion Recovery (DIR) and Short-Tau Inversion Recovery (STIR), leading to signal loss, blurring or artefacts degrading image quality. Complicated motion correction techniques such as navigator gating and electrocardiogram (ECG)-activated acquisition have therefore been used to prevent this issue by synchronising imaging with cardiac and respiratory cycles. Such strategies increase acquisition time by 20-30% and are particularly burdensome for patients with inadequate breath-hold tolerance or in busy clinical settings.

Inefficient suppression of flow is another limitation of flow-dependent dark-blood sequences like DIR, particularly when dealing with slow or stagnant pathologies of blood flow. This is avoided by using the Flow-Independent Dark-Blood Delayed Enhancement (FIDDLE) sequence by magnetization transfer (MT) prep and phase-sensitive inversion recovery (PSIR) but at the expense of precise optimization of the inversion time (TI). Such precise optimization is both operator-dependent and sophisticated-scanner-dependent and therefore is not easily generalizable to less specialized centers.

Limited availability of sophisticated dark blood sequences to specially equipped MRI scanners with customized hardware and software limits their application to impoverished environments or community hospitals. Few of them have so far been performed on 3T and 1.5T machines, and none on low-field strength machines, which are cheaper and used more in impoverished regions. Standardization will be needed to ensure reproducible performance and to facilitate widespread clinical application. Despite these challenges, second-generation dark blood MRI sequences will achieve their full potential in precision.

Future Directions

Dark-blood MRI sequences suffer from numerous issues, including a lack of standardization of TI settings and sequence parameters, and image protocols. Reproducibility and multicenter studies would be facilitated by having standard T1 mapping protocols. Task groups like the European Association of Cardiovascular Imaging can lead to the development of such guidelines. High-end motion correction techniques like Three-Dimensional Retrospective Image-Based Motion Correction (TRIM) can reduce dark-blood imaging artifacts to a great extent. Real-time motion correction algorithms can reduce image acquisition time without loss of image quality, making it clinically practicable for dark-blood sequences. Artificial intelligence and deep-learning frameworks can revolutionize dark-blood MRI by enhancing scar detection, differentiation of tissues, and protocol optimization. TI selection can become automated using AI and reduce operator dependency, and optimize workflow.

New low-field MRI scanner developments hold the promise of low-cost dark blood imaging for application in resource-poor settings. Hybrid sequences providing dark blood and bright blood contrasts in a single acquisition may offer full anatomical and functional assessment without scar-to-myocardium contrast compromise. Hybrid strategies could streamline imaging protocols, reduce scanning times, and be less demanding on patients, but require demonstration of efficacy in large patient populations. Investigations with dark blood sequences applied to non-ischemic cardiomyopathy could define diagnostic and therapeutic applications, such as myocardial involvement in early sarcoidosis and hemochromatosis, and iron overload. Accumulating evidence for these applications will further the clinical value of dark blood sequences.

Conclusion:

Dark blood MRI sequences like DIR, STIR, and FIDDLE have revolutionized myocardial tissue characterization using their excellent scar-to-blood contrast and precise detection of diffuse fibrosis, subendocardial scars, and myocardial edema. These sequences are indispensable to diagnosis and treatment of a wide range of cardiovascular pathologies like myocardial infarction, myocarditis, and cardiomyopathies since they measure tissues' properties with specificity and sensitivity. Because of their revolutionary potential, however, such sequences have certain barriers to their widespread clinical application, including motion artifacts, residual blood signal suppression, unavailability, and scar-to-myocardial contrast trade-off. Advancing technology in motion correction, AI-based analytical capability, low-field MRI, and hybrid sequence design is set to shatter these barriers to make dark blood imaging both available and of superior diagnostic quality on a wider scale. Through standardization of protocols and widening clinical applications, dark blood MRI sequences can become a pillar of precision cardiology to help patients through accurate diagnosis, risk stratification, and targetable therapeutic interventions.

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الإمكانات العلاجية للتدخلات الغذائية القائمة على النباتات في علاج الأمراض المزمنة: الآليات والأدلة السريرية والتطبيق العملي

الملخص

الخلفية: تشكل الأمراض المزمنة مثل داء السكري من النوع الثاني، وأمراض القلب والأوعية الدموية، وارتفاع ضغط الدم، والسمنة، وبعض أنواع السرطان عبئا كبيرا على الصحة العامة عالميا، حيث تتأثر هذه الحالات بشكل كبير بعوامل نمط الحياة، بما في ذلك النظام الغذائي. تظهر النظم الغذائية النباتية غير المقيدة، التي تعتمد بشكل رئيسي على الأطعمة النباتية الكاملة مع القليل من الأطعمة الحيوانية أو بدونها، بيانات ناشئة تشير إلى ارتباطها بالوقاية من الأمراض المزمنة وعكس مسارها، بما في ذلك التأثيرات المضادة للالتهابات، ومضادات الأكسدة، والفوائد الأيضية.

الهدف: مراجعة منهجية للأدلة التي تربط النظم الغذائية النباتية بالتخفيف أو التحسن الكبير في الأمراض المزمنة، مع توثيق النتائج السريرية، وجودة الحياة، والفعالية من حيث التكلفة، والاعتبارات المتعلقة بالتنفيذ المرتبطة بأي نظام غذائي نباتي.

الطرق: تم إجراء بحث في الأدبيات من عام 2000 إلى 2024 باستخدام كلمات مفتاحية للنظم الغذائية النباتية، والنباتية، والأمراض المزمنة، وكلمات مفتاحية خاصة بالأمراض. شملت الدراسات المؤهلة المراجعة من قبل الأقران البالغين، و أبلغت عن النتائج السريرية، وجودة الحياة، واعتبارات التنفيذ، دون قيود على مدة النظام الغذائي أو التدخل. تم تقييم جودة الدراسات بشكل مستقل باستخدام أداة كوكرين لتقييم مخاطر التحيز ومقياس نيوكاسل-أوتاوا.

النتائج: أنتجت النظم الغذائية النباتية نتائج سريرية مفيدة عبر مجموعة من الحالات، بما في ذلك داء السكري من النوع الثاني، وأمراض القلب والأوعية الدموية، وارتفاع ضغط الدم، والسمنة، وتطور السرطان. حسنت هذه النظم مستويات HbA1c وكوليسترول LDL ، وأدت إلى فقدان الوزن مع منع أو تقليل تطور السرطان. تم تحديد التحديات مثل عدم الالتزام و افتقار العناصر الغذائية. تم تقدير توفير التكاليف السنوية لإدارة داء السكري من النوع الثاني وأمراض القلب والأوعية الدموية بما يتراوح بين 50-100 مليار دولار.

الاستنتاج: تشير الأدلة إلى أن النظم الغذائية النباتية يمكن أن تكون فعالة في إدارة الأمراض المزمنة وربما تحفيز التخفيف منها، وتوفر فوائد في النتائج السريرية، وجودة الحياة، وتكاليف الرعاية الصحية. يجب فحص العوائق المتعلقة بالالتزام، ونقص العناصر الغذائية، وقابلية التوسع بشكل أكبر، مع الحاجة إلى التعليم، والدعم البنيوي، والمزيد من الأبحاث لفهم كيفية تعظيم التنفيذ.

الكلمات المفتاحية: النظام الغذائي النباتي، الأمراض المزمنة، التخفيف، داء السكري من النوع الثاني، أمراض القلب والأوعية الدموية، ارتفاع ضغط الدم، السمنة، السرطان، جودة الحياة، فعالية التكلفة.