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Diabetes Care in 2050: A Human-Centered Road Map From Time in Range to Time in Happiness

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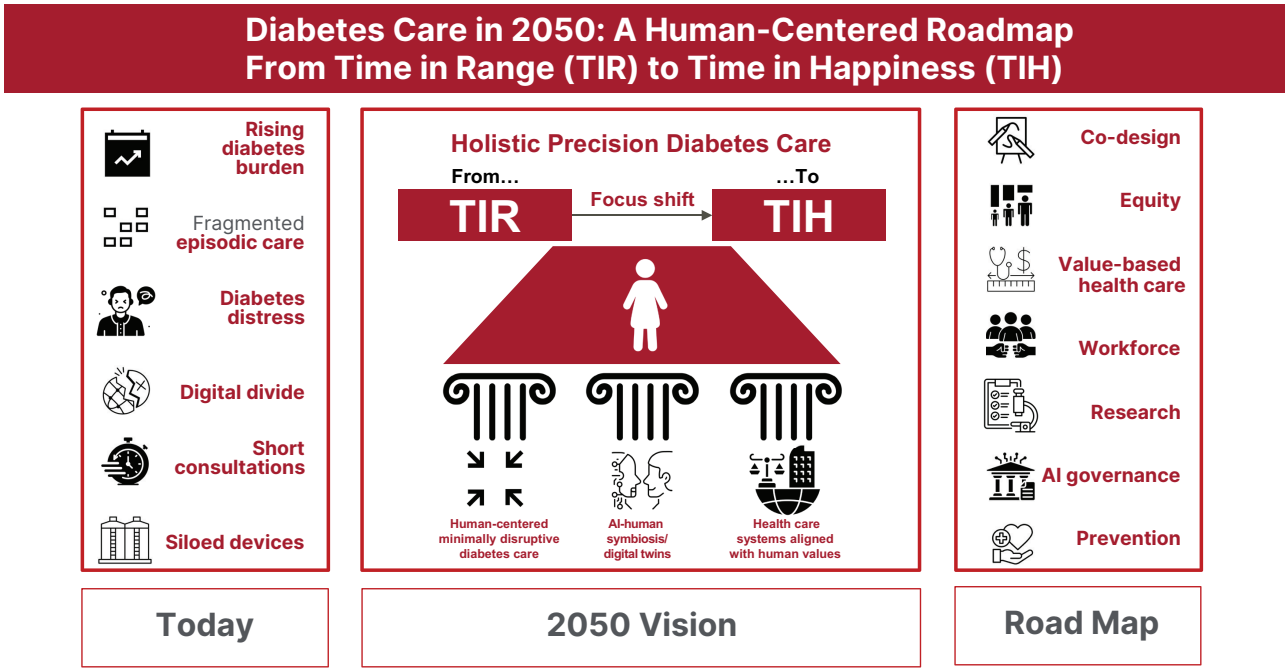

ARTICLE HIGHLIGHTS

- **Why did we undertake this study?**
  Despite technological advances, people with diabetes face significant burden, distress, and fragmented care, while health care systems struggle to deliver person-centered support to a growing population.

- **What is the specific question(s) we wanted to answer?**
  What would an ideal, human-centered diabetes care ecosystem look like by 2050, and what steps are needed to reach that vision?

- **What did we find?**
  We propose a "North Star" framework where artificial intelligence–augmented precision care, minimally disruptive medicine, and well-being shift success from time in range to "time in happiness."

- **What are the implications of our findings?**
  A road map is needed built on co-design, value-based health care, workforce empowerment, ethical artificial intelligence governance, and integrating person-reported outcomes alongside clinical metrics.

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Diabetes Care in 2050: A Human-Centered Road Map From Time in Range to Time in Happiness

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By 2050, diabetes care should transform into a human-centered, technology-augmented ecosystem focused on well-being. In this work, we first present a deliberately idealistic, forward-looking scenario in which advanced treatments, artificial intelligence, and integrated care delivery significantly reduce the burden on individuals with diabetes and enable person-centered health care. In this utopian vision, success in diabetes care is measured not only by glycemic metrics such as time in range but also by time in happiness, i.e., the quality time people spend unencumbered by their condition. Second, while such idealistic progress may be unlikely by 2050 due to socioeconomic and public health constraints, we build on existing gaps to outline a road map of co-designed solutions, health system reforms, and ethical innovations to move closer to it. This work serves as a "North Star" document that articulates the key values and next steps for achieving an ideal diabetes prevention and care ecosystem.

Diabetes remains a global health crisis: an estimated one in nine adults worldwide is living with the condition in 2024, and the number of people affected is projected to reach approximately 900 million by 2050 (1). While technological advances have greatly improved glucose management, with continuous glucose monitors (CGMs) and insulin pumps enabling data-driven optimization beyond the traditional focus on HbA_{1c} (2), people with diabetes continue to face significant burdens. Hybrid or fully closed loop systems exemplify how modern devices can efficiently improve glycemic control (3), yet paradoxically, people with diabetes experience substantial diabetes distress (4,5), affecting an average of 24.3% of people living with diabetes in the U.S. (6). Diabetes requires constant daily attention, including monitoring, dosing, dietary management, and more, while competing with the responsibilities of family, work, and life. Diabetes technologies are not always seamlessly integrated and can generate complexity, alarm fatigue, and further burden rather than relieve people with diabetes (7).

Today's advances already provide many people with diabetes with meaningful "time in happiness" (TIH). Closed loop systems improve time in range (time spent with glucose in target range [TIR]) by 6%–15% and reduce hypoglycemia by 30%–60% (8), and next-generation glucagon-like peptide 1 receptor agonists lower HbA_{1c} by 1.5%–2.0% while addressing obesity and cardiovascular risk with once-weekly dosing (9). The 2050 vision is therefore not a leap from zero but, rather, an extension of current gains to all, particularly the majority of people with diabetes worldwide who still lack access to these tools.

By 2050, the diffusion of automated insulin delivery and next-generation therapeutics should make TIR >70% widely achievable and possibly even a more ambitious target of normoglycemia (>70% of time spent with glucose in tight range [time in tight range]) for many for those with access to such tools, and the central

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debate should therefore shift. Rather than racing for ever-tighter targets, the priority should move toward individualized goals, the role of time in tight range, and the maximization of time without hypoglycemia, with HbA_{1c} near 7% as a reasonable population-level reference where appropriate. The Action to Control Cardiovascular Risk in Diabetes (ACCORD) trial, Action in Diabetes and Vascular Disease: Preterax and Diamicron MR Controlled Evaluation (ADVANCE) trial, and Veterans Affairs Diabetes Trial (VADT) remain a useful reminder that intensive glucose lowering (HbA_{1c} ~6.5%) did not yield consistent cardiovascular benefit over standard targets near 7%, with ACCORD's intensive arm halted early due to increased mortality (10–13). The pursuit of near-perfect glycemic control, partly driven by technology and pharmaceutical narratives, is also unachievable for many people with diabetes with limited resources and may impose additional burden and distress rather than clinical benefit. Establishing by 2050 the true risk-benefit ratio of tighter versus pragmatic glycemic goals across diabetes types and care settings, and rigorously quantifying the trade-off with treatment burden, should itself be a research priority.

In a world with rapidly changing demographics of people with diabetes —more people with diabetes overall, increased life expectancy for people with type 1 diabetes (T1D) thanks to better preventive care, more aggressive type 2 diabetes (T2D) at younger ages, one in five pregnancies with gestational diabetes mellitus (1)—health care systems already struggle to provide truly human-centered care. In many settings, consultation times are fleeting, with <5 min allocated to one-half of the world's population, leaving little room beyond triage and quick prescriptions (14). Such time constraints and fragmented care models make it challenging to address individual needs or psychosocial factors. This creates a paradox: while therapies and devices are better than ever, there is a clear need to focus more on caring for the person—not just for the disease or focusing on glucose control (Fig. 1).

Calls are growing for personalized (15), precision health approaches (16) that deliver the right intervention at the right time for each individual, and embracing concepts like minimally disruptive medicine, the aim of which is to achieve goals while minimizing disruption to the lives of people with diabetes (17).

Consequently, we propose a two-step approach to define future directions for global diabetes care. We first describe a purposefully utopian ecosystem serving as a "North Star" model that, while aspirational, is grounded in current trends and emerging innovations. In this future, technology and health care systems are aligned to empower people with diabetes, alleviate burden, and improve quality of life. Traditional clinical metrics remain essential but are balanced with human-centric outcomes, effectively shifting focus "From Time in Range to Time in Happiness." We then outline a road map highlighting key steps, including co-design with people with diabetes, ensuring equity and access, reorienting health systems toward value, upskilling the workforce, and embedding ethics and data privacy by design.

A UTOPIAN VISION FOR THE FUTURE OF DIABETES CARE

Human-Centered and Seamless Care

In this futuristic scenario, the person with diabetes sits firmly at the center of the care ecosystem. Every management element is designed to enable people with diabetes to live with minimal disease intrusions (following the concept of minimally disruptive medicine [18,19]). (See Fig. 2). Technology is widely available and sits in the background of daily life as much as possible. Devices are user-friendly, largely automated, and interoperable, and although technical issues, troubleshooting, and occasional malfunctions remain unavoidable, they are buffered by robust support so that managing diabetes feels less effortful in comparison with today.

Next-generation CGM sensors may be entirely noninvasive or implantable for long-term use and may be combined with continuous monitoring of ketones and other metabolites (20), while insulin delivery systems are self-regulating. Routine glycemic control is largely delegated to artificial intelligence (AI)-driven algorithms and smart insulin (or bihormonal insulin-glucagon or insulin with glucagon-like peptide 1 receptor agonists) pumps in fully automated delivery systems (8), which adjust doses in real time with precision far beyond human capability.

Beyond diabetes care, these technologies are expected to seamlessly integrate into broader digital assistants that support individuals in their everyday lives, coordinating health, lifestyle, and personal needs, so that diabetes management becomes just one unobtrusive component of holistic, AI-assisted living.

These advances free people with diabetes from the constant monitoring and decision-making required while reducing cognitive load through fewer alarms and device-related hassles, thereby lowering the treatment burden. The clinic time saved is administrative and routine, not relational: in 2050, that time is reinvested in continuous, asynchronous, and need-based contact with the care and psychosocial teams so that people with diabetes spend less time in waiting rooms and on logistics and proportionately more time living their lives while having more rather than less meaningful access to their clinicians.

Advanced Therapeutic Options

By 2050, scientific breakthroughs are expected to expand the therapeutic toolkit. Curative and disease-modifying therapies may be available for certain forms of diabetes. For instance, genetic typing will be standard practice, and precision diagnosis will guide clinicians in selecting glucose-lowering agents or disease-modifying therapies, such as immunotherapy and β-cell regeneration techniques, which could delay or even prevent T1D in high-risk individuals. Cell-based therapies, such as transplantation of stem cell–derived β-cells, may offer long-term insulin independence for certain people with diabetes (21,22). For those still requiring pharmacotherapy, treatment is far more effective and convenient. Precision medicine enables the tailoring of drug regimens to individual "omics" profiles and disease endotypes (23).

In T2D, powerful new agents, next-generation incretin analogs and metabolic modulators, control glucose while comprehensively targeting obesity and cardiovascular and renal risks (24). While available obesity treatments will delay and prevent T2D in many cases, prior incretin-based therapy or bariatric surgery will make the eventual T2D clinical onset milder. Many people with T2D achieve remission through early aggressive therapy, including medications and lifestyle interventions, guided by

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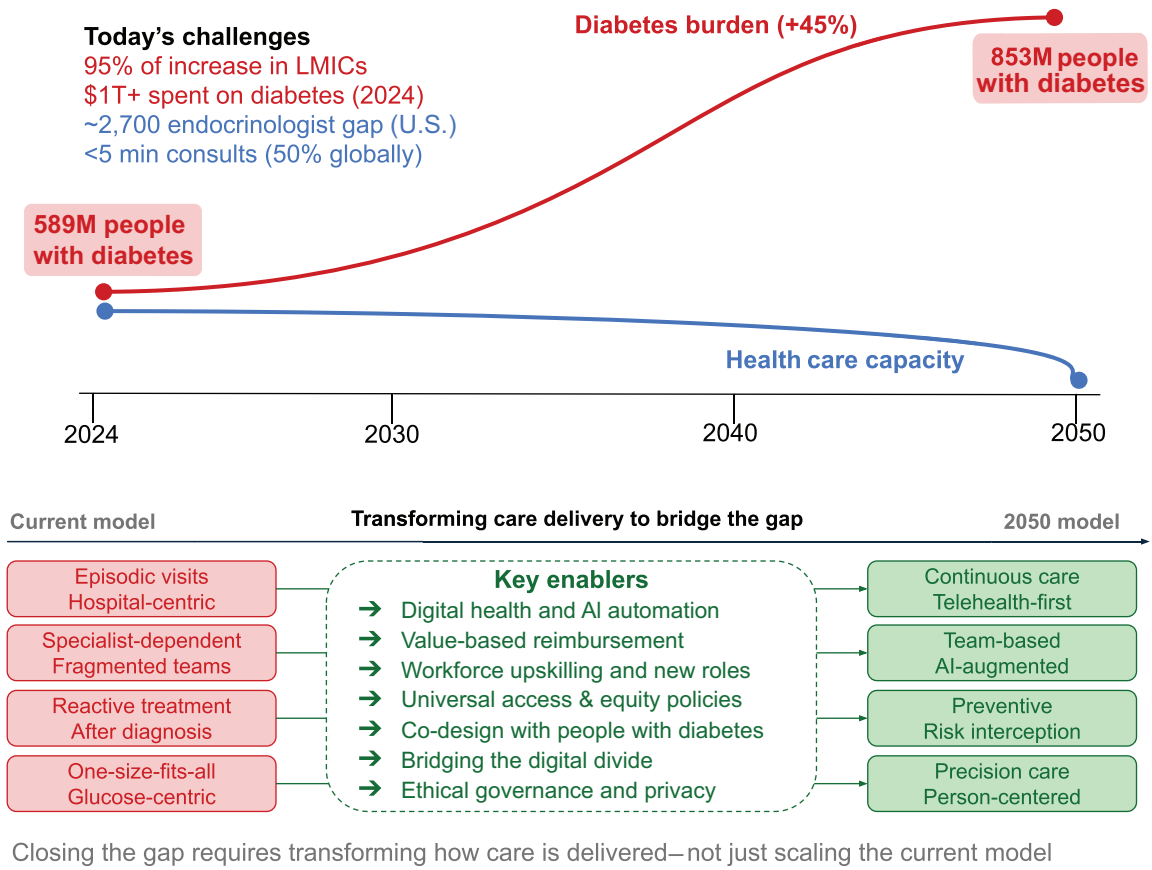

Figure 1—The changing landscape of diabetes care (today–2050). The upper panel illustrates the growing gap between the rising diabetes burden (589 million people with diabetes in 2024 to a projected 853 million by 2050 [+45%]) and the relatively flat health care capacity, highlighting current challenges including the endocrinologist workforce shortage (51), short consultation times, concentration of costs in low- and middle-income countries, and more than $1 trillion in annual diabetes expenditure. The lower panel presents the care model transformation required to bridge this gap. M, million; T, trillion.

predictive AI algorithms. People with T2D are guided through this process via admission to an integrated, multidisciplinary care pathway with provision of continuous, personalized support from early diagnosis.

Importantly, treatments have become safer and more tolerable, with fewer side effects and dosing schedules that fit the lives of people with diabetes, such as monthly or even yearly injections instead of daily administration.

In parallel, all injectable therapies, including incretin-based treatments, are designed to be connected, enabling real-time monitoring of drug administration, data integration with digital health platforms, and AI-driven support for follow-up, adherence, and individualized treatment optimization.

The result is that managing diabetes is both physiologically easier, with better tools for maintaining glycemic control and preventing complications, and practically more straightforward for people with diabetes, reducing the associated mental load—the so-called "diabetes burden."

In T2D, by 2050, monitoring beyond glucose alone becomes routine and home based: weight, blood pressure, and lipid profiles are tracked through connected devices, while structured remission programs combining incretin-based therapy, metabolic surgery where indicated, and digitally delivered lifestyle support are accessible at scale, including in low- and middle-income settings. T2D care is thereby even less hospital-bound and more population-level than today.

Precision Diabetes Prevention and Disease Interception

The paradigm of diabetes care is envisioned to shift fundamentally from reactive treatment of established disease to proactive prevention of its onset. Emerging technologies, particularly AI and digital biomarkers, enable the detection of T1D and T2D in their preclinical phases, well before the first symptoms appear, thereby significantly reducing the current global proportion of ~50% of undiagnosed cases and providing care for all (25). In T1D, advanced predictive models integrating genetic predisposition, immunologic markers (e.g., islet autoantibodies), and metabolic indicators could identify individuals developing autoimmunity long before β-cell destruction leads to hyperglycemia (26). This early recognition opens the door to timely interventions, such as immunotherapies and β-cell–protective treatments, to preserve pancreatic function and delay or prevent progression to clinical T1D (26). Sequential escalation therapies based on T1D stage will likely be adopted, relying on predictive biomarkers, and move from proof of concept to standard of care for at least a subset of people with T1D (27). Similarly, in T2D, continuous monitoring of subtle physiologic changes via wearable sensors

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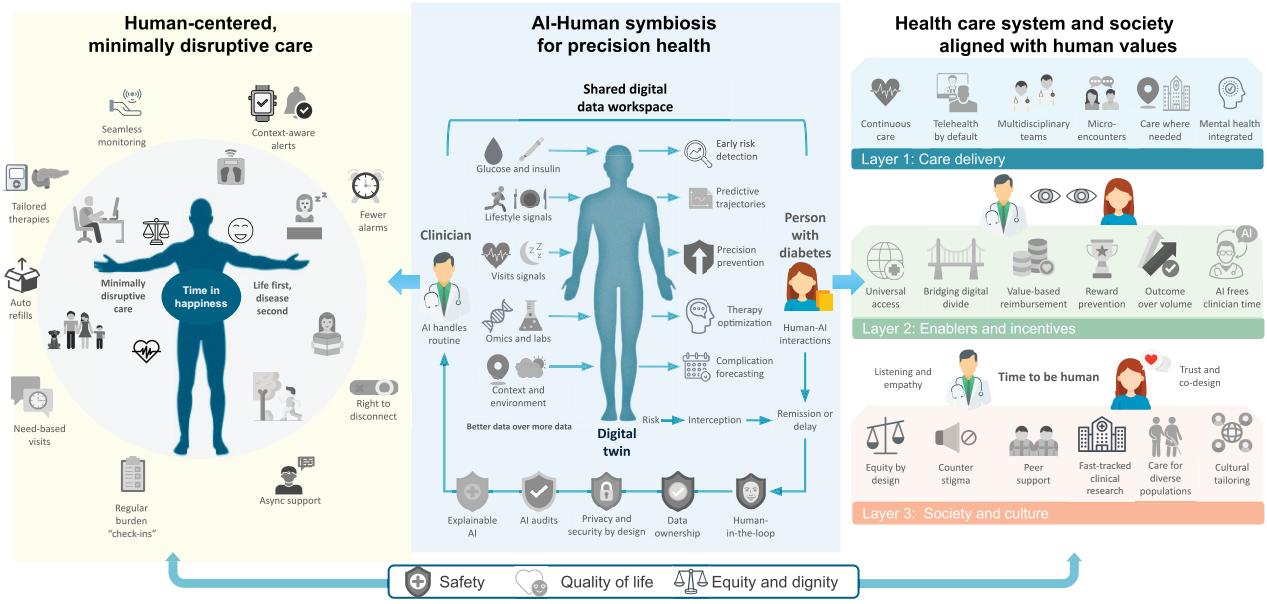

Figure 2—Diabetes care in 2050: from time in range to time in happiness. Overview of the envisioned ecosystem organized in three pillars (human-centered minimally disruptive care, AI-human symbiosis for precision health, and health care system and society aligned with human values), three layers (care delivery, enablers and incentives, and society and culture), and three foundational values (safety, quality of life, and equity and dignity). Asynch, asynchronous; labs, laboratories.

and AI-driven analyses could flag early insulin resistance or prediabetes risk (28). Prompt, personalized lifestyle adjustments or prophylactic treatments could then be deployed to intercept the disease trajectory, potentially halting its evolution toward full-blown diabetes. Such preemptive care not only targets root causes but also could fundamentally alter the natural history of diabetes (both T1D and T2D), thereby reducing incidence and complications. This optimistic vision features AI-augmented health care that identifies at-risk or presymptomatic individuals and intervenes before illness strikes, exemplifying a shift from reactive to preventive care (29).

Integrated Health Data, Technology, and AI

Digital technology and AI serve as the backbone of the 2050 ecosystem. All devices and data systems are interoperable and secure, allowing seamless data flow with individual consent. A continuous stream of multimodal health data, including but not restricted to glucose readings, drug and insulin doses, diet, physical activity, and heart rate, along with many other omics, contextual, social, and environmental insights, is collected and filtered by AI to provide meaningful insights at the right time—rather than generating information overload that creates unnecessary complexity. AI spans several complementary categories that operate together rather than as a single monolithic capability: predictive models for risk prediction and trajectory interception, generative AI for clinical documentation and patient communication, agentic AI for routine care logistics and follow-up, foundation models for multimodal data integration, and federated learning for privacy-preserving model training across institutions and countries. These tools support a range of clinical assists, including decision support, ambient documentation, patient-facing coaching, and audits, and interface with clinicians and people with diabetes through asynchronous chat, in-app notifications, electronic health record dashboard overlays, and privacy-preserving ambient listening. Required safeguards include explainability, audit trails, human-in-the-loop oversight, and red teaming for bias. Digital twins, described next, are one specific instantiation of this AI portfolio.

Personal health digital twins become a reality (see Fig. 3): virtual replicas of each individual with diabetes integrate multiple data sources (clinical history, genetics, lifestyle) to simulate and predict disease trajectories. These digital models help personalize care by predicting individual glucose responses to meals or exercise, optimizing disease-modifying therapies/insulin regimens, and forecasting the risk of clinical progression or complications to inform preventive interventions. AI virtual assistants serve as "digital coaches," supporting people with diabetes daily with tailored advice and gentle behavioral nudges.

These AI systems function as trusted partners in care, rigorously validated and regulated, and are transparent, explainable, and unbiased. Clinicians and people with diabetes have confidence that algorithms are designed to work in their best interest. Routine diabetes management represents collaboration between human caregivers and AI: current daily tasks (data analysis, insulin titration) are handled by AI, while humans focus on empathy, strategy, and complex decision-making. This human-AI symbiosis ensures that no aspect of health falls through the cracks.

Transformed Health Care Delivery Systems

The health care system itself has been redesigned to support continuous, human-centered care. Universal health coverage and innovative financing have meaningfully closed access gaps to essential technologies and medications across geographies and income levels, even if residual inequities persist and ongoing political and financial commitment is required. Recognizing digital

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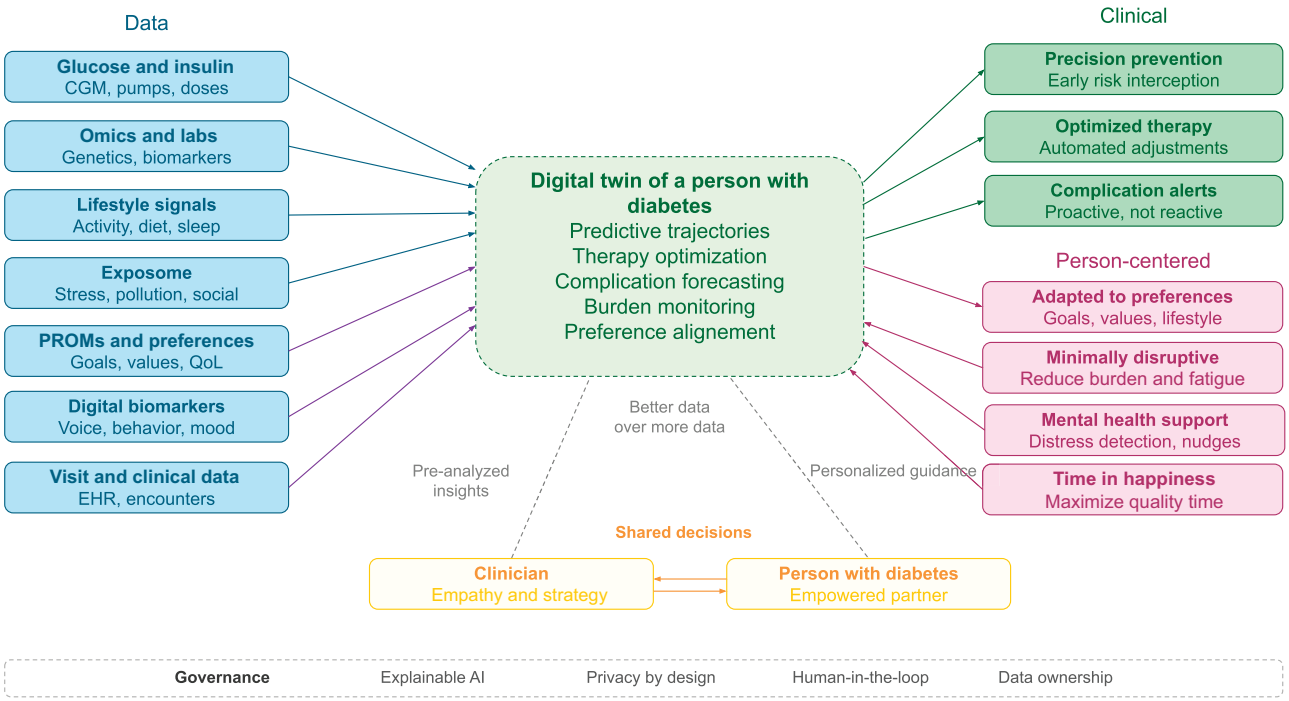

Figure 3—AI-human symbiosis: the digital twin in action for precision diabetes care. Schematic representation of how multimodal data inputs (biomedical: glucose, omics, lifestyle, exposome; person-centered: PROMs, preferences, digital biomarkers, clinical data) feed into a personal digital twin that generates both clinical outcomes (precision prevention, optimized therapy, complication alerts) and person-centered outcomes (adaptation to preferences, minimally disruptive care, mental health support, TIH). The clinician and person with diabetes interact as empowered partners through shared decision-making, supported by a governance layer (explainable AI, privacy by design, human-in-the-loop, data ownership). EHR, electronic health record; labs, laboratories; QoL, quality of life.

tools as lifesaving, policymakers have invested heavily to bridge the digital divide, providing connectivity, devices, and digital literacy and training programs in underserved communities so that no one is left behind due to a lack of internet access or technical skills (30).

Care delivery has shifted from episodic visits toward a continuous care paradigm. Multidisciplinary care teams, including endocrinologists/diabetologists, primary care professionals, diabetes educators, dietitians, mental health professionals, and community health workers, collaborate via connected platforms. People with diabetes receive support when and where needed through telemedicine, home visits, or community centers rather than the majority receiving support in hospital clinics.

Telehealth is no longer an adjunctive care mode but, rather, is a core approach: routine check-ins now occur virtually, and significant diabetes management is conducted remotely through data exchange and messaging. Physical clinic time is reserved for truly in-person interactions, physical examinations, procedures, or complex consultations. Minimally disruptive operations are now explicit design goals: short, targeted micro-encounters replace long, infrequent appointments; asynchronous messaging resolves most issues; and administrative tasks are automated, freeing clinician time for conversation with the individual with diabetes.

The economics of health care incentivize quality and outcomes over service volume. Many health systems have embraced value-based health care, moving from fee-for-service to outcome-based reimbursement models (31). Health care professionals and health organizations are rewarded for keeping people with diabetes healthy, preventing hospitalizations, achieving optimal control, and enhancing quality of life. This aligns financial incentives with chronic disease management goals and spurs greater investment in prevention and early intervention.

Holistic, Person-Centered Care

Perhaps the most defining feature of this futuristic vision is that diabetes care has expanded beyond glucose numbers to address the person as a whole. Health care professionals and people with diabetes pursue goals that matter to the latter, such as the ability to perform daily tasks, maintain beloved activities, or simply feel less encumbered by illness and live a life as close as possible to the life of a person without diabetes. Clinical encounters have evolved from rushed, checklist-oriented visits into richer interactions, thanks to AI augmentation, with a focus on individualized problem-solving and emotional support. Indeed, with mundane tasks automated by AI scribes (32) and data pre-analyzed prior to visits, clinicians can devote their full attention to people's narratives. They practice the long-neglected arts of empathy, compassion, and shared decision-making, supported rather than distracted by technology. Mental health support is integrated into standard diabetes care through regular screening for diabetes distress or depression, with on-demand access to mental health resources, including trained counselors, and AI-powered companions, who provide coaching and cognitive-behavioral therapy.

Capturing person-reported outcomes (PROMs) should not itself become a source of burden. By 2050, PROMs and

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digital biomarkers are collected through low-friction strategies that include respect for the principles of minimally disruptive medicine: passive sensing where appropriate, ecological momentary assessment with very short items, computerized adaptive testing rather than full-length questionnaires, conversational and voice interfaces, and integration into existing care touchpoints rather than separate assessment events. The aim is for listening to people with diabetes to become ambient—not an additional task layered on top of an already heavy treatment regimen.

In parallel, the stigma and blame once accompanying diabetes have been actively countered by public health campaigns and medical training emphasizing diabetes as a complex condition, deserving of empathy. These changes reflect a cultural shift: health care prioritizes "what matters to the individual" as much as biomedical metrics (33). PROMs and experience measures, quality of life, satisfaction, and sense of empowerment are tracked and valued equally with HbA_{1c} or blood pressure (34).

Minimally Disruptive Medicine by Design

A defining principle of this futuristic ecosystem is that care adapts to life—not the other way around. Systems are engineered to minimize treatment and workload burdens: alarms adapt to context to reduce fatigue, micro-automation handles routine decisions, documentation and supplies are generated and replenished automatically, and visit cadence is need based rather than calendar based. Interfaces default to single-action flows, and every new feature undergoes burden testing with people with diabetes and clinicians before release. The cumulative workload of illness and treatment is continuously monitored through brief "burden check-ins," and if it rises, care plans are deintensified while safety nets remain in place. The default operating mode of diabetes care is minimally disruptive, protecting time, attention, and dignity while maintaining clinical safety.

Special Considerations: Pediatrics and Diverse Populations

The envisioned ecosystem gives particular attention to children and youth with diabetes, as well as other groups with unique needs. Pediatric diabetes care is child friendly and family centric. For children with T1D, technologies such as closed loop insulin delivery systems are calibrated to their physiological and lifestyle needs, enabling safe management with minimal disruption to childhood activities. Schools and daycare centers are well equipped to assist children with diabetes, reducing parental anxiety. With appropriate permissions, digital tools enable real-time communication among parents, school nurses, and care teams, creating safety nets around each child.

Adolescents transitioning to adult care are supported by mentorship programs and AI guides that gradually build self-management skills. Digital twin approaches are powerful in pediatrics: virtual models of a child's metabolism could help anticipate changes during puberty or growth spurts and proactively adjust insulin delivery.

The ecosystem also adapts to elderly people with diabetes in simplifying regimens to prevent hypoglycemia in those with cognitive decline, and to culturally diverse populations in providing care and education tailored to language and cultural context. One-size-fits-all guidelines have given way to personalized care pathways that account for individual life stages, environments, and personal preferences.

Risks and Mitigation Measures

The most obvious risks are overautomation that erodes clinical judgment and creates deskilling, surveillance that exposes people with diabetes to commercial or political misuse of their health data, and the substitution of meaningful human contact by machine-based interactions. Our framework names these risks explicitly and matches each with a safeguard: human-in-the-loop oversight for high-stakes AI decisions, explainable and auditable AI as a regulatory requirement, a "right to disconnect" from devices and alerts, people with diabetes ownership of their data with portability across systems, and protected clinical time for empathy and shared decision-making.

Besides, as with any futuristic exercise, this 2050 diabetes care ecosystem is utopian and unlikely to materialize as described. However, framing and defining the values and workflows required to achieve the 2050 objectives will guide our actions over the next few years to improve the lives of people with diabetes.

Operationalizing TIH

We propose a three-dimensional definition for TIH; "time in happiness" can be defined as the time spent *1*) not disrupted by diabetes, *2*) in a state of subjective well-being, and *3*) in dignified and equitable care. TIH can therefore be captured with innovative PROMs. (See above). TIH is therefore distinct from, but complementary to, time in health, time not thinking about diabetes, and treatment satisfaction, taken in isolation.

ROAD MAP TO 2050

Transforming current diabetes care to align with the 2050 vision requires concerted effort across multiple domains. We outline key strategies and necessary changes, along with a road map from the present to the future (Fig. 4).

Co-design and Partnership

A fundamental shift involves actively including all end users, people with diabetes, caregivers, and health care professionals in designing solutions. Instead of top-down innovation, successful 2050 tools and programs will be co-created by end users. Co-design in health care means people with diabetes are equal partners in problem-solving, contributing unique insights and expertise. Growing evidence indicates that incorporating the perspectives of people with diabetes early leads to more usable, effective interventions while increasing empowerment and satisfaction (35). Co-design improves usability, appropriateness, safety, and adoption while surfacing workflow realities so that products are person-fit, clinician-fit, and health system–fit (36). Health care processes, clinic workflows, educational materials, and telehealth systems should be co-designed with input from people with diabetes. By 2050, this methodology should be standard practice: "Nothing about us without us" should be the norm in diabetes innovation (37). Programs such as #dedoc° voices, the International Diabetes Federation Young Leaders in Diabetes, the European Diabetes Forum patient panels, the Breakthrough T1D community programs, and the T1D Exchange Quality Improvement Collaborative (T1DX-QI) already prefigure this practice.

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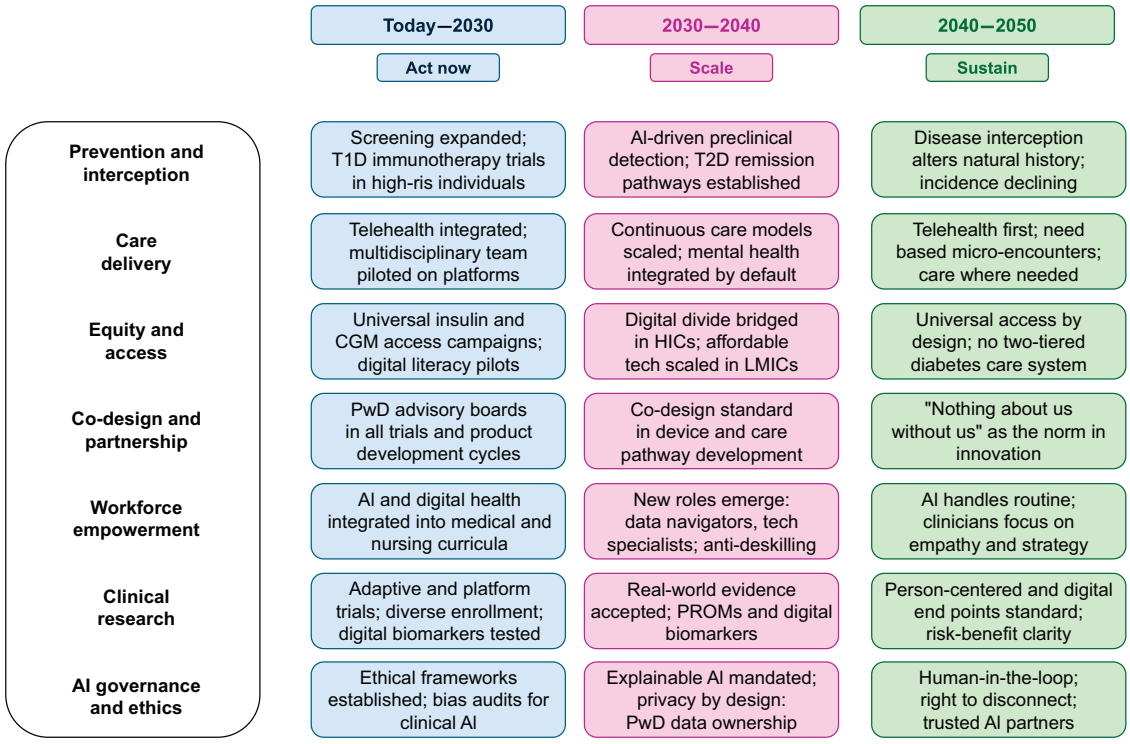

Figure 4—Road map to 2050: priorities and milestones. A timeline presenting key action items across seven domains (prevention and interception, care delivery, equity and access, co-design and partnership, workforce empowerment, clinical research, and AI governance and ethics), organized into three time horizons: today–2030 (act now), 2030–2040 (scale), and 2040–2050 (sustain). HICs, high-income countries; LMICs, low- and middle-income countries; PwD, people with diabetes.

Ensuring Equity: Universal Access and Bridging the Digital Divide

Achieving the 2050 vision for all people with diabetes requires directly addressing issues of access and equity. This starts with universal health coverage, ensuring cost is not a barrier to essential care. Insulin, newer medications, glucose monitors, and basic supplies must be accessible and affordable globally, a commitment already pursued through initiatives such as the Global Diabetes Compact of the World Health Organization or the *Lancet* Commission on diabetes (38). Simultaneously, the digital divide must be narrowed. As health care digitizes, there is a risk of those without internet access or tech literacy risk being left behind (39). Targeted policies are needed to provide connectivity (e.g., subsidized data plans or rural broadband) and to promote digital literacy training for people with diabetes and health care workers. Device interfaces and applications should be designed inclusively, with multilingual support and accommodations for diverse literacy levels and physical abilities. Community health programs can help by offering navigators or "digital health coaches" to assist people with diabetes new to technology. Ensuring equity also means focusing on global inclusion, not just high-income countries. By 2050, low- and middle-income countries should benefit from innovations in diabetes through knowledge transfer and affordable technologies. Without deliberate action, the risk is a two-tiered system in which some receive advanced care while others lack basic necessities. A failure to access appropriate care does not fuel empowerment but, rather, fuels frustration over lost opportunities.

Value-Based, Preventive, and Person-Centered Care

Health systems need to realign incentives and success measures. Widespread adoption of value-based health care approaches must encourage investments required for long-term benefits. In value-based health care models, the goal is to improve person outcomes at a given per-unit cost (40). Health services should invest more resources in prevention and early intervention, scaling programs for weight management, diabetes prevention, and complication screening, because these yield high value in avoided costs and improved quality of life over time. Payment models must reward complication-free survival and person-satisfaction rather than simply more clinic visits or prescriptions (41). Policymakers can support this by expanding bundled payments or outcomes-based contracts. Simultaneously, care must incorporate the values of people with diabetes. Using tools such as goal-setting discussions and person-reported outcome measures, health care professionals should customize care plans to each individual's life goals.

Empowering the Health Care Workforce

Even the most capable AI will not replace skilled, compassionate health care professionals. Instead, technology should augment human health care professionals by handling routine tasks so that clinicians can operate at the top of their license, where human judgment and empathy are irreplaceable (41,42). To achieve the 2050 vision, we must invest in workforce upskilling, address workforce shortages, and reorganize medical and paramedical education. This includes training clinicians in data science fundamentals, digital health tools, and interpreting AI outputs (human-in-

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the-loop [43]). Medical and nursing schools should, by design, integrate informatics and AI competencies into their initial curricula and then require ongoing training and regular simulation tests throughout careers to avoid deskilling (44).

Additionally, roles may evolve as new professions emerge, such as clinical data navigators or diabetes technology specialists who bridge between people with diabetes and their health care professionals and tech systems. Far from replacing clinicians, AI promises to "give doctors and nurses more time to be human." Studies show that AI can free clinicians' time to focus on empathy, communication, and trust building (45). By relieving clinicians of routine documentation, data triage, and administrative work, AI allows health care professionals to practice at the top of their license. Realizing this requires deliberate changes: redesigning workflows so that AI triages routine messages or flags people with diabetes in need of urgent outreach, allowing staff to concentrate on complex cases.

Rethinking Clinical Research and Product Development

The pathway to 2050 will also be accelerated by innovations in how we study and approve new interventions. Current clinical trials can be slow, be expensive, and often be disconnected from real-world experiences of people with diabetes. We should pursue adaptive trial designs, real-world evidence collection, and person-centered outcomes research to accelerate the understanding of effective treatments (46). With platform trials multiple emerging therapies or devices could be continuously evaluated in parallel, efficiently identifying winners. By 2050, regulatory agencies may accept real-world data from wearables, digital biomarkers, and electronic health records as evidence alongside traditional trials, reflecting typical use conditions. Significantly, the focus of studies must broaden beyond narrow glycemic end points to encompass primary and secondary outcomes, including quality of life, treatment burden, PROMs, digital biomarkers, and engagement. Inclusion of more diverse populations in research is needed to ensure new solutions are generalizable and equitable. Making diversity a priority in the 2020s and 2030s can help prevent a 2050 scenario in which innovations benefit only the most favored subsets of the population. Another crucial aspect of the vision is the involvement of people with diabetes in research design, with advisors who are also people with diabetes on clinical trial steering committees to ensure that studies address practical concerns of people with diabetes.

Governance, Privacy, and Ethical AI

Robust ethical guardrails are paramount. Privacy by design must be ingrained in all digital health systems, including data minimization, deidentification where possible, and the use of advanced privacy-preserving techniques. Federated learning enables training of AI models on distributed data sets from different clinics or countries without sharing raw person-level data, thus protecting privacy while reducing bias. Strong cybersecurity is nonnegotiable, as people with diabetes and health care professionals need confidence that medical devices and records cannot be hacked maliciously (47). Regarding AI ethics, developers should rigorously check algorithms for bias and fairness. There should be a focus on improving the quality of care through actual AI implementation rather than always racing for better technical performances. The challenge is to make better use of high-quality data, rather than simply providing more data to improve clinical decisions, without causing information overload. AI systems in 2050 should provide explanations for recommendations and be subject to audits, as human health care professionals are. An ethics framework should dictate when AI should be used independently (if it performs better or more safely than when combined with humans) and when it should not (human-in-the-loop [43]), for prevention of dehumanization. An ethical approach to diabetes care can be requiring a human clinician to sign off on substantial AI-driven insulin adjustments to prevent errors, or enforcing a "right to unplug." Transparency with people with diabetes is key: individuals should own their health data and be informed when AI is used in their care, including risks and benefits. With an increasing reliance on diabetes technologies, mitigation strategies must be built in by design to prevent alarm or technology fatigue and to offer a "right to disconnect" without compromising people with diabetes safety (48). With thoughtful governance, we can harness big data and AI to improve diabetes care while upholding trust and individual rights (49,50).

Focusing on Care Quality and the Human Touch

Amid all technological change, we must never lose sight of the human elements that define quality diabetes care. Empathy, compassion, and the therapeutic alliance between health care professionals and people with diabetes will remain as important as ever in 2050 in a "human-first" health care system. Health care systems should measure and incentivize these qualitative aspects, satisfaction of people with diabetes, and engagement scores, which could factor into provider reimbursement to promote attentive care.

Training programs might include modules on mindfulness, active listening, or communicating uncertainty to help clinicians forge better connections despite high-tech settings. There is encouraging evidence that AI could enhance empathy by freeing clinicians' time (45), but with this realization must come a conscious effort to use that free time for longer conversations rather than squeezing in more appointments.

Future systems can build in humanizing touches, e.g., sending clinicians prompts with each appointment about the personal context of the person with diabetes to reinforce personal connections. Community and peer support should also be integral in 2050, with leveraging of social networks to enable people with diabetes to learn from and encourage one another.

The destination is not an ultra-automated clinic devoid of people but, rather, is a harmonious blend of high-tech and high-empathy care.

CONCLUSIONS

The year 2050 might seem distant, but many seeds for this future of diabetes care are being sown today. The vision that we have outlined, a world where diabetes is managed in a highly personalized, proactive, and compassionate manner, is ambitious yet achievable if we prioritize the right goals collectively. It requires transdisciplinary collaborations and breaking silos: engineers with people with diabetes, clinicians and psychologists with data scientists, policymakers with communities, etc.

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Table 1—Key differences between current and envisioned diabetes care in 2050 across eight dimensions

Dimension	Current state	2050 vision
Monitoring and devices	CGM with frequent alarms, hybrid closed loop requiring meal input, siloed device data	Noninvasive/implantable sensors, fully automated delivery, seamless multimodal data integration
Therapeutics	Sequential pharmacotherapy, daily or weekly dosing, reactive approach, limited disease modification	Precision-matched agents by endotype, monthly or yearly dosing, early remission pathways, immunotherapy and cell-based cures for T1D
Prevention	∼50% of cases of diabetes undiagnosed, population-level screening	AI-driven preclinical detection, personalized risk interception, disease trajectory altered before onset
Care delivery and workforce	Episodic hospital visits, short consultations, fragmented teams	Continuous telehealth-first care, multidisciplinary teams on connected platforms, AI handles routine and humans focus on empathy
Mental health and well-being	Often unaddressed (∼24% experiencing diabetes distress), separate referral pathways	Integrated screening and support, stigma reduction, on-demand coaching, treatment burden actively monitored
Glycemic targets and outcomes	Focus on TIR >70% and HbA_{1c}, risk of target-driven burden, limited hard outcome evidence for very tight control	Pragmatic individualized targets, minimizing hypoglycemia, success measured according to PROMs, digital end points, and TIH
Equity and access	Major disparities, digital divide, technologies concentrated in HICs	Universal access by design, affordable innovation in LMICs, digital literacy programs
Governance and ethics	Emerging AI frameworks, limited regulation, data ownership unclear	Privacy by design, explainable AI, human-in-the-loop, right to disconnect, people with diabetes own their data

HICs, high-income countries; LMICs, low- and middle-income countries.

It also demands measuring success differently, not just in improved clinical metrics but also in improved lives.

The term "time in happiness," first coined by Kamil Armacky in 2024, encapsulates this philosophy: the ultimate aim is to maximize the time people with diabetes spend living happily and healthily, as much as possible, freed from the shackles of their condition, within a performing and humanistic health care system. Reaching this aim calls for innovation not only in science and technology but also in care delivery models, ethics, and individual empowerment. (See Table 1 for key differences between current and envisioned diabetes care in 2050).

The journey will not be without obstacles: cost constraints, entrenched practices, geopolitical considerations, business interests, and unforeseen challenges. Yet, the trajectory of current research and the resilience of the diabetes community give reason for hope. Twenty years ago, few imagined we would have today's tools, such as CGM and fully automated insulin delivery systems (45). Twenty years from now, with diligent work, we can similarly reinvent what it means to live with and manage diabetes. The trajectory to 2050 that we propose is therefore staged: a near-term horizon (today–2030, "act now") in which the foundations are laid (interoperability standards, equity baselines, co-design as default, value-based reimbursement pilots, AI governance frameworks); a midterm horizon (2030–2040, "scale") in which validated tools and care models are deployed at population level; and a long-term horizon (2040–2050, "sustain") in which preventive, curative, and human-centered care become the default rather than the exception. Figure 4 summarizes this staged road map.

This work is intended to serve as a general framework, stimulate thought, and guide action in the proper direction. By incentivizing human-centered design, equity, value, and ethics, we can ensure that high-tech advancements of the coming decades truly translate into high-touch, high-value care. If successful, the diabetes care ecosystem of 2050 not only will keep people in range more often but also will empower them to spend more of their lives in a state of happiness.

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