Current Emergency and Hospital Medicine Reports (2020) 8:35–39
https://doi.org/10.1007/s40138-020-00204-7

CARDIOVASCULAR CARE (L ROEVER, SECTION EDITOR)

Updates on Technology for Diabetes Mellitus

Ghada Elshimy[1] · Ricardo Correa[1]

Published online: 10 February 2020

Abstract
Purpose of Review To update the medical community on the new and old technologies use for the control and management of diabetes mellitus.
Recent Findings Diabetes technology is defined as the different technology including hardware, devices, and software that are used by diabetic patients in order to help to manage blood glucose levels. This technology can be used in patients with any type of diabetes mellitus and, when applied appropriately, it can have a significant impact on these patients' health. They can be divided into different insulin delivery methods, blood glucose monitoring, and hybrid and implantable devices. Insulin delivery can be further subdivided into insulin pens, insulin syringes, or insulin delivery via a pump. New technology includes a bionic or "artificial" pancreas that has been introduced. This is an external device or system of devices that mimic the glucose regulating the function of a healthy pancreas.
Summary It is essential to deeply understand the use of each of the devices so you can recommend the best one that fits your patient.

Keywords Diabetes mellitus · Technology · Insulin pump · Continuous glucose monitoring

Introduction

Diabetes technology is defined as the different technology including hardware, devices, and software that are used by diabetic patients in order to help to manage blood glucose levels. This technology can be used in patients with any type of diabetes mellitus and, when applied appropriately, it can have a significant impact on these patients' health. New modalities have been emerging every day and they gained wide acceptance in diabetes mellitus care. The use of continuous glucose monitoring (CGM) systems has demonstrated to be clinically valuable in patients with diabetes given the improvement of blood glucose control with the reduction of the hypoglycemia episodes. In addition, the use of continuous subcutaneous insulin infusion (CSII) has shown an overall improvement of glycemic control. However, with every new modality, challenges and barriers can arise including the increased complexity and rapid changes in these technologies. These barriers to both the patients and the providers can cause some limitations and frustration. Historically, the two main categories of diabetes technology were insulin delivery and blood glucose monitoring. Insulin delivery methods were subdivided into insulin pens, insulin syringes, or insulin delivery via a pump. Blood glucose monitoring via meter or CGM was the method used by the patients to achieve better blood glucose control. More recently, more advances have been available including hybrid and implantable devices. These devices can act as artificial pancreas as they can combine the two above categories by monitoring the blood glucose continuously with automatic delivery of the insulin [1••].

Methodology

We conducted a narrative review searching all the available literature from January 2010 to December 2019 on the topic of new technology on diabetes. Screening and selection of studies was performed independently by the two authors. We limited the studies to English language. We included every type of article in our review. The search engines explored were

This article is part of the Topical Collection on *Cardiovascular Care*

✉ Ricardo Correa
riccorrea20@hotmail.com; ricardcorrea@email.arizona.edu

[1] Endocrinology, Diabetes and Metabolism Department, University of Arizona College of Medicine-Phoenix and Phoenix VAMC, Phoenix, USA

Medline/PubMed and EMBASE. The keywords that we used were "diabetes mellitus type 1," "diabetes mellitus type 2," "diabetes mellitus," "technology," "diabetes technology," "insulin pump," "CGM," and "continuous glucose monitoring."

Insulin Delivery

Insulin Syringes and Pens

There are different modalities for insulin delivery including syringes, pens, and insulin pumps. Most diabetic patients use either insulin syringes or pens [2]. The American Diabetes Association (ADA) guidelines recommended the proper choice of the method of insulin delivery after an informative discussion with the patient. Multiple factors should be taken into considerations including the patient's preferences and the cost. Other factors including the dose of the insulin and the insulin types should also be considered. More importantly, the self-management capabilities of the patient should be assessed prior to prescribing insulin. Given the easy use of insulin pens, they are recommended in patients with vision impairment or patients with any dexterity issues for accurate dosing of the insulin [1••, 2–4].

There are different sizes of insulin syringes available including 0.3, 0.5, and 1 ml. These syringes can allow doses of 30, 50, and 100 units of U-100 insulin, respectively. Currently, using the U-500 regular insulin, which is also called (U-500R), in insulin-resistant diabetic patients has gained popularity. It is used in patients requiring more than 200 units of insulin daily. It can be used as multiple daily injections (MDI) or via CSII. U-500 syringes were initially used; however, to avoid hypoglycemia and miscalculation of the insulin dose, the use of U-500 pens had gained more popularity and was considered as a more applicable method of delivery in comparison to syringes [5, 6]. In addition, smart pens are also available. Combining Bluetooth technology in an injector pen that can be connected to a smartphone app and can also provide bolus advisors are the advantages of these pens [7]. Another insulin delivery option called V-Go® (Valeritas, Inc., Bridgewater, NJ) is available in the market. This is a disposable waterproof spring-loaded patch-like device. It can provide a CSII of rapid-acting insulin which is considered basal insulin delivery method. The basal insulin delivery can be either 20 units/24 h, 30 units/24 h, or 40 units/24 h. Additionally, by pressing on a button, there are 2-unit increments of bolus insulin. This device runs without the use of batteries. In addition, there is no need for any computer software or any programming. It was launched in the USA in 2012 and it can be used by 21 years old diabetic patients or older patients. Since it is fully mechanical, easy to use, and tubeless, it is an acceptable method of insulin delivery for patients with adherence issues, questionable absorption of long-acting insulin, or patients with needle aversion [8, 9].

Insulin Pump/Continuous Subcutaneous Insulin Infusion

Since the 1970s, insulin pumps have been introduced in the market and were commercially available for diabetic patients. Continuous delivering of rapid-acting insulin was the main advantage of these devices. Different modalities of insulin delivery have been available including using a tube with a cannula at the end to deliver insulin or directly connecting to the skin (without tubing). Initially, manual calculation of the amount of bolus needed was done by the patients according to both the amount of carbohydrate intake and the blood glucose reading. Currently available pumps use an automatic bolus calculator. The patient can override the pump according to the need. In addition, with the new technologies, the basal insulin can be incremented in as little as 0.01 units/h [1••]. Different pumps are available in the market and each one of them has different advantages. There is a touch screen technology and tubeless, disposable pumps and hybrid approach closed-loop systems available for the patients [10, 11].

Commonly prescribe pumps are the Animas Vibe Brand and the Medtronic Minimed. There are three types of Medtronic pump. These are 530 G, 630 G, and the newest 670 G. Initially, 530 G pump was not waterproof but with the new advances in technology; the 630 G and 670 G became waterproof full-color screen pumps. The 670 G is a hybrid closed-loop pump with a Smart Guard Technology and automode feature, which automatically adjusts the basal insulin delivery according to GCM sensor glucose reading and recent insulin delivery (Fig. 1). It also has the advantage of working with Contour Next Link 2.4 Meter. This enables it to bolus remotely according to blood glucose reading. Additional features including suspend before low function. This allows stopping insulin delivery when hypoglycemia is predicted then allows the insulin delivery to be restarted once blood glucose normalizes [12•, 13].

Fig. 1 Hybrid closed-loop system, Medtronic 670G (sensor, insulin pump, and glucometer)

The advantage of the touch screen technology is seen in the Tandem T-Slim insulin pump. The tandem pump is waterproof for only three feet in depth and for a duration of 30 min or less. Patients can keep the pump during showering but it is not recommended to be kept during swimming. The Tandem T-slim X2™ insulin pump has the Basal-IQ® technology. This technology predicts the blood glucose levels, based on the last 4 consecutive CGM readings, almost 30 min ahead. If the predicted sensor glucose (SG) is less than 80 mg/dl, the insulin delivery will be suspended automatically. Additionally, if the observed SG is less than 70 mg/dl, the pump will suspend the insulin delivery and only resumes as soon as the SG begins to rise again. The pivotal trial (PROLOG) showed 3 weeks of Basal-IQ® use reduced SG time < 70 mg/dL by 31% compared with sensor-augmented pump [14, 15]. The only tubeless pump in the market is the Omnipod insulin pump. They are disposable pumps with single-use pods that need to be prefilled with insulin. These pods usually last for 72 h. Some of the disadvantages of the Omnipod are the inability to connect to CGM yet and that they are watertight [16].

The choice of the insulin pump is dependent on the provider, the patient, the insurance and the cost. The cost of an insulin pump on average is about US $6000. Additionally, the cost of the supplies can range between US $3000- $6000 annually. Despite that, switching from MDI to pumps can decrease the insulin expenditures of around US $657 per year [10, 11]. There are different complications that occur in patients using insulin pumps that can predispose to diabetes ketoacidosis including issues with infusion sets (dislodgement, occlusion), pump site infection and improper use of the pump due to inadequate patient's education. Education of the patients and close monitoring are required to prevent such complications [11, 17].

Glucose Monitoring

Self-monitoring of the blood glucose (SMBG) and CGM are integral components to prevent hypoglycemia and hyperglycemia in patients taking insulin to ensure effective therapy. However, routine glucose monitoring in patients with type 2 diabetes not using insulin may be of limited clinical benefit. SMBG should be done mainly prior to meals, at bedtime, and prior to snacks. Additional SMBG is needed in specific situations, namely, when hypoglycemia is suspected prior to exercise or prior to critical tasks and more importantly, prior to driving. The interstitial glucose is measured through CGM. This interstitial glucose, in turn, correlates well with plasma glucose. Two types of CGM devices are available, either a real-time CGM or intermittently scanning CGM (is CGM or also called flash CGM). Continuous reporting of the glucose level is provided by the real-time CGM. Additionally, it provides hypoglycemia and hyperglycemia alarms. Medtronic was approved for Guardian real-time sensor in 2005. Dexcom Seven sensor was approved in 2006. Dexcom G6 was approved in March 2018 (Fig. 2). CGM (also called FreeStyle Libre Flash) has been available in Europe since 2014 for adult use only. It has been approved by the FDA in the USA in 2017. The main disadvantage is that it does not communicate continuously, and it does not alarm like other GCM. It is only used on demand, but it has a lower cost in comparison to real-time CGM [1••, 18–20].

In addition, real-time CGM devices can be further subdivided into stand-alone units or an integrated part of an insulin pump. Stand-alone units are usually linked to a handheld receiver. The real-time CGM devices include Medtronic and Dexcom CGM. Both technologies use an enzyme-coated wire which measures interstitial glucose. This wire is inserted into the subcutaneous tissues and detects electrical current generation which occurs when the glucose reacts with the glucose oxidase enzyme. Using an algorithm, the current generated is converted to an estimated blood glucose level (some devices also require calibration by measurement of the capillary blood glucose). Subsequently, the sensor links to a transmitter, which sends signals to an insulin pump or a handheld receiver. Traditional older generation CGM (G4, G5 Dexcom, and Guardian Sensor) required calibration. The calibration can help to provide more accurate glucose reading by relating the glucose to the electrical current upon which the CGM measurements are based. However, new technologies have gained more accuracy. Currently, new CGM (Dexcom G6) and flash CGM (FreeStyle Libre Flash) do not require calibration [1••, 18–20].

Professional CGM includes FreeStyle Libre Pro, Dexcom G4 platinum, and IPRO 2(Medtronic). FreeStyle Libre Pro is inserted by the staff. The patient usually wears it for 2 weeks and data should be downloaded in 2 weeks to assess the blood glucose reading and help guide management. Dexcom G4 platinum is used for 7 days while IPRO is used for 6 days [21]. Recently in October 2019, Dexcom G6 Pro was approved for healthcare professionals to use with their patients aged 2 years and older.

New FDA-approved implantable personal CGM (The Eversense CGM) has been also available in the market. The system is a transcutaneous nighty day implantable CGM-

Fig. 2 Continuous glucose monitoring (CGM) Dexcom G6 (transmitter and sensor)

wired sensor containing glucose-sensing enzymes, an external transmitter, and a display device. The sensor is inserted in the subcutaneous fat, just below the skin. It is continuous with the transmitter base where the transmitter is placed afterward. The transmitter sends data wirelessly to a display device which can be either a smartphone or a dedicated receiver. Eversense is convenient for patients who do not desire to do frequent sensor insertion. Additional advantage is that the transmitter can be easily removed. There is no need for sensor replacement for 90 days. [22].

Barriers to CGM include cost and accuracy. It has been shown that CGM devices' accuracy approaches 10% mean absolute relative difference (MARD) between CGM readings and the capillary blood glucose reading at the same time, making them considered safe for insulin dosing. However, the accuracy may be altered in case of hypoglycemia or hyperglycemia according to different studies. [19].

Future Technology

New technology that includes a bionic or "artificial" pancreas has been introduced. This is an external device or system of devices that mimic a healthy pancreas and its ability to regulate glucose. Such systems provide continuous monitoring of the glucose levels and automatically provide either insulin alone or in combination with other blood-glucose stabilizing hormones to the body. Some studies have compared the bi-hormonal bionic pancreas (using CGM and mathematical algorithms to automatically administer both insulin and glucagon) to insulin pump therapy [23•]. There are promising results and further ongoing studies to explore the bionic pancreas are being held.

Diabetes technology is improving every day to make the life of the diabetic patient easier. Like any technology, there are positive and negative sides. It is essential to deeply understand the use of each of the devices so you can recommend the best one that fits your patient. The latest study published by New England journal of medicine in October 2019 showed that the closed-loop system increased time spent in target blood glucose range when compared with sensor-augmented pumps [24]. Other recently published study in December 2019 also stated similar results with improvement of A1C and decrease risk of hypoglycemia [25].

Limitation

The limitation of this article is that it is a narrative review. We selected articles that we found, and we include any type of articles from original articles to guidelines.

Future directions: more studies can be of great interest to find the most efficient technology and further studies are being held to explore different technology; for example, bionic pancreas, longer duration implantable CGM, etc.

Conclusion

Physician should be aware that it is essential to deeply understand the use of each of the devices so they can recommend the best one that fits their patient.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1.•• American Diabetes Association. Diabetes technology: standards of medical care in diabetes-2019. Diabetes Care. 2019;42(Supplement 1):S71–80. https://doi.org/10.2337/dc19-S007. **Most recent guidelines from the American Association of Diabetes on management and utilization of technology. The newest evidence is on this guideline.**
2. Lasalvia P, Barahona-Correa JE, Romero-Alvernia DM, Gil-Tamayo S, Castañeda-Cardona C, Bayona JG, et al. Pen devices for insulin self-administration compared with needle and vial: systematic review of the literature and meta-analysis. J Diabetes Sci Technol. 2016;10:959–66.
3. Pfützner A, Schipper C, Niemeyer M, Qvist M, Löffler A, Forst T, et al. Comparison of patient preference for two insulin injection pen devices in relation to patient dexterity skills. J Diabetes Sci Technol. 2012;6:910–6.
4. Williams AS, Schnarrenberger PA. A comparison of dosing accuracy: visually impaired and sighted people using insulin pens. J Diabetes Sci Technol. 2010;4:514–21.
5. Reutrakul S, Wroblewski K, Brown R. Clinical use of U-500 regular insulin: review and meta-analysis. J Diabetes Sci Technol. 2012;6(2):412–20.
6. Hirsch LJ, Strauss KW. The injection technique factor: what you don't know or teach can make a difference. Clin Diabetes. 2019;37(3):227–33.
7. Gildon BW. InPen smart insulin pen system: product review and user experience. Diabetes Spectr. 2018;31(4):354–8. https://doi.org/10.2337/ds18-0011.
8. Winter A, Lintner M, Knezevich E. V-Go insulin delivery system versus multiple daily insulin injections for patients with uncontrolled type 2 diabetes mellitus. J Diabetes Sci Technol. 2015;9:1111–6.
9. Sutton D, Higdon CD, Nikkel C, Hilsinger KA. Clinical benefits over time associated with use of V-Go wearable insulin delivery device in adult patients with diabetes: a retrospective analysis. Adv Ther. 2018;35(5):631–43.
10. David G, Gill M, Gunnarsson C, Shafiroff J, Edelman S. Switching from multiple daily injections to CSII pump therapy: insulin expenditures in type 2 diabetes. Am J Manag Care. 2014;20:e490–7.

11. McAdams BH, Rizvi AA. An overview of insulin pumps and glucose sensors for the generalist. J Clin Med. 2016;5(1):5. https://doi.org/10.3390/jcm5010005.
12.• Knebel T, Neumiller JJ. Medtronic MiniMed 670G hybrid closed-loop system. Clin Diabetes. 2019;37(1):94–5. **Strongest evidence showed that hybrid closed-loop system due better control on glucose level compared with other systems.**
13. Weaver KW, Hirsch IB. The hybrid closed-loop system: evolution and practical applications. Diabetes Technol Ther. 2018;20(Suppl. 2):S216–23.
14. Forlenza GP, Li Z, Buckingham BA, Pinsker JE, Cengiz E, Wadwa RP, et al. Predictive low-glucose suspend reduces hypoglycemia in adults, adolescents, and children with type 1 diabetes in an at-home randomized crossover study: results of the PROLOG trial. Diabetes Care. 2018;41(10):2155–61.
15. Müller L, Habif S, Leas S, Aronoff-Spencer E. Reducing hypoglycemia in the real world: a retrospective analysis of predictive low-glucose suspend technology in an ambulatory insulin-dependent cohort. Diabetes Technol Ther. 2019;21(9):478–84.
16. Zisser H. The OmniPod insulin management system: the latest innovation in insulin pump therapy. Diabetes Ther. 2010;1(1):10–24.
17. Wheeler BJ, Heels K, Donaghue KC, Reith DM, Ambler GR. Insulin pump-associated adverse events in children and adolescents—a prospective study. Diabetes Technol Ther. 2014;16:558–62.
18. Wood A, O'Neal D, Furler J, Ekinci E. Continuous glucose monitoring: a review of the evidence, opportunities for future use and ongoing challenges. Intern Med J. 2018;48(5):499–508. https://doi.org/10.1111/imj.13770.
19. Kovatchev BP, Patek SD, Ortiz EA, Breton MD. Assessing sensor accuracy for non-adjunct use of continuous glucose monitoring. Diabetes Technol Ther. 2015;17:177–86.
20. Fokkert MJ, van Dijk PR, Edens MA, et al. Performance of the FreeStyle Libre flash glucose monitoring system in patients with type 1 and 2 diabetes mellitus. BMJ Open Diabetes Res Care. 2017;5:e000320.
21. Carlson AL, Mullen DB, Bergenstal RM. Clinical use of continuous glucose monitoring in adults with type 2 diabetes. Diabetes Technol Ther. 2017;19(Suppl 2):S-4–S-11.
22. Kropff J, Choudhary P, Neupane S, Barnard K, Bain SC, Kapitza C, et al. Accuracy and longevity of an implantable continuous glucose sensor in the PRECISE study: a 180-day, prospective, multicenter, pivotal trial. Diabetes Care. 2017;40:63–8.
23.• El-Khatib FH, Balliro C, Hillard MA, Magyar KL, et al. Home use of a bihormonal bionic pancreas versus insulin pump therapy in adults with type 1 diabetes: a multicentre randomised crossover trial. Lancet. 2017;389(10067):369–80. **Study showed that relative to conventional and sensor-augmented insulin pump therapy, the bihormonal bionic pancreas was able to achieve superior glycemic regulation without the need for carbohydrate counting.**
24. Brown S, Kovatchev BP, Raghinaru D, Lum JW, Buckingham BA, Kudva YC, et al. Six-month randomized, multicenter trial of closed-loop control in type 1 diabetes. N Engl J Med. 2019;381:1707–17.
25. Akturk HK, Giordano D, Champakanath A, Brackett S, Garg S, Snell-Bergeon J. Long-term real-life glycemic outcomes with hybrid closed-loop system when compared with sensor-augmented pump therapy in patients with type 1 diabetes. Diabetes Obes Metab. 2019. https://doi.org/10.1111/dom.13933.