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The use of insulin pumps as an innovative approach of diabetes therapy to improve glycemic control, patients' comfort of life and daily activity

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Abstract

Introduction and Purpose of Research.

There are diverse types of insulin pumps available, such as traditional pumps with tubing, tubeless pumps or continuous glucose monitoring (CGM) systems, pumps with automated insulin suspension. Diabetes complications lead to raised death rates, and overall decreased quality of life among patients. The aim of the study is to examine the impact of insulin pump usage including the effects on glycemic control, quality of life and limitations in daily life. Our work aims to emphasize the importance of using appropriate therapies in patients with diabetes.

Material and Methods.

The review was based on the analysis of materials collected in the Google Scholar and,, PubMed''. The following keywords were entered during the search for scholarly articles: insulin pump, continuous glucose monitoring, quality of life, diabetes mellitus and insulin therapy. A total of 36 articles were considered for the study and verified for their relevance to the topic.

Brief description of the state of Knowledge.

The use of an insulin pump as an innovation can simplify tasks to manage the process and to maintain desired levels of blood glucose. Patients using a pump have more flexible possibilities regarding meals and diet. Additional non-health-related benefits, such as reduced worry about supplies while traveling, can significantly improve patients’ QoL as well activities, and community integration, as the pump aids in refining self-care habits.

Conclusions.

In this study, we investigated the impact of wearable technology of insulin pumps on metabolic management, the quality-of-life patients' comfort of life and daily activity in children and adolescents with diabetes. The quality of life can substantially increase when the performances of advanced devices and algorithms are associated with considerable support from family and healthcare providers.

Keywords: Insulin pump; Continuous glucose monitoring; Diabetes mellitus; Insulin therapy; Quality of life

Introduction and purpose of Research

Diabetes is a chronic noncommunicable disease (NCD) of the endocrine system diagnosed by abnormally high blood glucose levels. Diabetes is caused by increased autoimmune destruction of pancreatic beta cells, eliminating insulin production and leading to hyperglycemia or not effectively utilizing the insulin produced [1]. It is divided into an early-onset autoimmune form (T1D) and a late-onset non-autoimmune form (T2D), additional subtypes are monogenic diabetes (e.g. Maturity-onset Diabetes of the Young), gestational diabetes, and possibly a late-onset autoimmune form (LADA). Currently exist insulin pumps which are a development in diabetes mellitus treatment. Pumps deliver a continuous small insulin quantity as a "background insulin" to retain the basal metabolic rate and bolus insulin doses when needed to metabolize the absorbed nourishment [2]. To facilitate glucose measurement were created continuous glucose monitors (CGMs). Devices measure subcutaneous interstitial glucose levels throughout the day. Most connect wirelessly to a phone or receiver that reveals the current interstitial glucose and current trend of sensor glucose values. Some have predictive alarms for hypo- or hyperglycemia, which permit patients the opportunity to take action in advance an event occurs. CGMs have also been shown to reduce hemoglobin A1c and increase time in range [3]. Such control provides for continuous glucose monitoring and a fast reaction at any time. Diabetes is a major global health problem impacting approximately 463 million adults and a rising number of younger individuals worldwide. Almost 90% of all cases of diabetes are type 2 (T2D) and the overall number is rapidly increasing [4]. Diabetes could be a reason for a variety of psychological agitations in the people suffering from it. One such psychological disturbance is called diabetes distress (DD). DD is a major issue that is associated with emotional disturbances, stress, guilt feelings, and avoidance of treatment [5].) Diabetes complications lead to raised death rates, sight loss, kidney malfunction, and overall decreased quality of life among patients managing diabetes. Furthermore, research indicates diminished quality of life (physical and social functioning and perceived physical and mental wellbeing) among diabetic patients [6]. The study aims to examine the impact of insulin pump usage including the effects on glycemic control, quality of life and limitations in daily life. Our work aims to emphasize the importance of using appropriate therapies in patients with diabetes, improving their comfort of life and enabling normal functioning.

Material and methods

The review was based on the analysis of materials collected in the Google Scholar and,, PubMed''. The following keywords were entered during the search for scholarly articles: insulin pump, continuous glucose monitoring, quality of life, diabetes mellitus and insulin therapy. A total of 36 articles were considered for the study and verified for their relevance to the topic of insulin pumps as an innovative approach of diabetes therapy.

Description of the state of Knowledge

Types of insulin pumps

There are diverse types of insulin pumps available, such as traditional pumps with tubing, tubeless pumps, hybrid closed-loop pumps, pumps integrated with continuous glucose monitoring (CGM) systems, pumps with automated insulin suspension, and advanced dual-hormone pumps delivering both insulin and glucagon. There are two main types of insulin pumps, the first type is a pump with a narrow pipe linking the pump with a cannula which a patient can fasten to a belt. Another type is pump without tubing or with very short flexible plastic tube (cannula) inserted under the skin. The pump commonly sticks to the skin with a bonding patch and is wirelessly controlled with a handheld controller unit [7]. The new version of the insulin pump has a built-in Continuous Glucose Monitor (CGM). The pump is delivered with an alarm system activated when the blood glucose reaches a predetermined low or high level [8]. Some pumps allow choosing an exercise sequence to change the person's glucose target [9]. There exist two varieties of artificial pancreas, single-hormone systems (SH) that infuse insulin and dual-hormone systems (DH) that infuse both insulin and glucagon. Two meta-analyses concluded that the artificial pancreas systems could advance glucose control compared with conventional insulin pump therapy in outpatients with type 1 diabetes, but only seven studies evaluating DH were considered [10,11]. Advanced diabetes innovations, such as continuous glucose monitoring and sensor-augmented insulin pumps with low-glucose suspension systems, can reduce the frequency of hypoglycemia and the occurrence of severe reduced glucose levels without intensifying glycemic control. The hybrid closed-loop system, an automated insulin delivery system, must be the most promising means to ensure adequate glycemic management while preventing severe hypoglycemia. The use of these advanced diabetes technologies could improve glycemic outcomes and the quality of life in children and adolescents with type 1 diabetes [12].

TABLE 1. Types of Insulin Pumps

Type of Insulin Pump	Mechanism of Action	Suitability for Conditions	Advantages	Limitations
Traditional Pump with Tubing	Delivers insulin through a tube and cannula placed under the skin.	People with type 1 diabetes and some with type 2 diabetes.	Precise control of basal and bolus doses.	Risk of mechanical failure.
Tubeless Pump	Wireless insulin delivery via a patch adhered to the skin.	Active and those seeking convenience patients.	Discreet and easy to use.	Shorter use duration for patches.
Hybrid Closed-Loop Pump	Automatically adjusts basal insulin based on CGM data.	Patients with unstable glucose levels.	Reduces risk of hypoglycemia.	Requires calibration.
Pump Integrated with CGM System	Synchronizes insulin delivery with real-time glucose data.	Continuous glucose monitoring and adjustment needed.	Trends analysis.	Additional sensors required.
Pump with Automated Insulin Suspension	When low glucose levels are detected pauses insulin delivery.	Patients with hypoglycemia or with impaired awareness.	Minimizes risk of severe hypoglycemia.	Potential delay in system response.
Dual-Hormone Pump	Delivers both insulin and glucagon based on	Patients with frequent hypoglycemia.	Glucose control through two-way action.	Complex system.

	glucose levels.			

Insulin pumps as an innovative approach

The majority of updated insulin pump models are compatible via Bluetooth with smartphones with different applications such as the CareLink Connect app, which allows family members or permits caregivers to access patient information, visualize all data, and manage alarms and notifications. People also can supply insulin remotely using a smartphone-like Personal Diabetes Manager device. The suitable age for the pump use differs according to the pump type and version, in which the manufacturers determine the appropriate age of use according to each pump's features [13]. Insulin pumps facilitate flexible meal planning, extended catheter use, and programmable basal insulin delivery [14]. Compared with conventional insulin pumps, patch pumps show advantages like being smaller and lighter, no tubing, and no device that must be carried in the pocket or elsewhere, but there are also limitations like more waste [15].

Indications to use insulin pump

More than 25% of patients with type I DM are currently using insulin pump therapy. It is especially indicated in the occurrence of high hemoglobin A1C, poor glycemic control with problematic hypoglycemia such as nocturnal hypoglycemia, recurrent hypoglycemia, activity-induced hypoglycemia, frequent diabetic ketoacidosis, recurring hospitalization, large total daily dose, presence of progressive difficulties such as gastroparesis, inability to self-administers insulin (such as in pre-school or grade-school children), the need for more meal time flexibility, or the inability to predict food or meal intake [16]. About 1/1000 of patients with DM are currently using insulin pumps, and their count is increasing; 90% have type I DM, while only 10% have type II [17]. Nevertheless, benefits of CSII that have primarily been proven in patients with T1DM might also be applicable to patients with T2DM. Consequently, the number of patients with T2DM using an insulin pump is increasing and the first insulin pumps especially designed for patients with T2DM are now accessible [18,19].

Glycemic control

The use of an insulin pump as an innovation can simplify tasks to manage the process and to maintain desired levels of blood glucose [20]. Insulin pumps are a good option especially for people unable to reach optimal glycemic control with MDI, for example, due to repeated omission of insulin delivery, potentially caused by fear of daily injections, irregular insulin injections, or absent insulin administration devices. It is an effective alternative for patients with T2DM failing glycemic control with other types of antidiabetic therapy due to the challenge of transporting insulin and its delivery device are reduced with a portable insulin pump [21,22,23]. Aim for glycated hemoglobin (HbA1c) levels below 7% without an unacceptable rate of hypoglycemia [24]. In patients dealt with an insulin pump, severe hypoglycemia episodes were rare, indicating better glycemic control and lower incidence of nocturnal hypoglycemia [25].

Comfort of life and Daily activity

Continuous glucose monitoring systems provide an improved comprehension of daily glycemic variations for children and adults and can be easily used. These systems reduce diabetes distress and improve diabetes control by decreasing hypoglycemia. Continuous subcutaneous insulin infusions have demonstrated their advantages in selected patients. There is a tendency to use more complex systems, such as hybrid closed-loop systems that can modulate insulin infusion reliant on glycemic readings and artificial intelligence-based algorithms. It can help people handle the burdens associated with T1DM management, such as fear of hypoglycemia, exercising, and long-term complications. The prospects are optimistic, aiming to craft more intricate systems for automated control of glycemic levels to diminish the distress of individuals living with diabetes [26]. Patients using a pump have more flexible possibilities regarding meals and diet. Additional non-health-related benefits, such as reduced worry about supplies while traveling, can significantly improve patients' QoL as well activities, and community integration, as the pump aids in refining self-care habits [27,28]. Therefore, basal insulin can be programmed to match the person's activity, the changing daily requirement, hormonal changes, puberty-related growth spikes, anxiety, health issues, trips, and any other situations. At the same time, insulin bolus can be delivered in different ways considering various conditions such as gastroparesis, nutrient malabsorption, or even aligning with the ingested foods. On the other hand, insulin delivery can be temporarily reduced or suspended in certain situations, such as hypoglycemia [29]. This incredible adaptability in insulin delivery system and the marked less in blood glucose variability permits a better quality of life. Using rapid-acting insulin delivered in a low volume tailored to the individual needs allows the insulin pump to overcome the diversity in insulin uptake that is usually observed with long-acting insulin, resulting in more consistent and reliable insulin absorption and consequently less fluctuation of both insulin profile and blood glucose level [30]. This feature also helps to decrease the need for snacks, especially before exercise, subsequently minimizing the rate of weight gain [31]. Pumps can easily transition to the new technology, so they can link easily with blood glucose measuring technology, bolus advisors, and wizards for diabetes management, forming a closed-loop system like an artificial pancreas which significantly improves the patient's quality of life [32].Being worn all the time (24 h a day/7 day a week), even during sleep, showering, and sports, with continuous reminders of being diabetic, can influence body image and self-confidence. Fortunately, a variety of accessories are available to make wearing the pump discreet and accessible [33]. Exercise has a long-term beneficial effect on blood glucose regulation regardless of the type of exercise. However, it has a short-term modification on the blood glucose level to be considered. While undergoing pump therapy, two major challenges confront children with type I diabetes who are willing to exercise regularly [34]. The basal rate may be increased by 10%-20%, 30-90 minutes before the exercise, and continue at this rate when post-exercise hypoglycemia continues. In the case of combined aerobic and anaerobic exercise, hypoglycemia is more frequent but less than pure aerobic exercise. Hypoglycemia can be prevented with a reduction of basal insulin by up to 50 [35]. However, significant challenges have been documented, such as trust in the control algorithm, alarm burden, size and appearance of the closed-loop mechanisms. Patient input for mealtime insulin blousing for hybrid closed loop, management of CSII/CGM devices (i.e. changing infusion sets, calibrating sensors) and inherent risks (i.e. cannula occlusion leading to hyperglycemia and ketonemia) remain and need to be addressed. Above all the systems need to be recognized for how much of a person’s life they get to take back from diabetes [36].

Conclusions

In this study, we investigated the impact of wearable technology of insulin pumps on metabolic management, the quality-of-life patients' comfort of life and daily activity in children and adolescents with diabetes. Diabetes is a major health concern that adversely affects the well-being of patients and their families, resulting in long-term health issues and, as a result, decreased life expectancy. We found that the use of wearable technology lowered the HbA1c levels. The insulin pump is a significant discovery in DM management. The insulin pump provides less frequent injections and can deliver very small doses of insulin doses. It provides a convenient and more flexible way to modify the needed insulin physiologically, like the human pancreas it can provide sufficient and ideal glycemic control to reduce the risk of metabolic derangements in different tissues. We presented significant evidence to support the beneficial effect of diabetes technology among patients with T1D and T2D. Presented data evidence that current emerging technologies and control systems significantly improve diabetes self-management. The quality of life can substantially increase when the performances of advanced devices and algorithms are associated with considerable support from family and healthcare providers. Nonetheless, the constraints of technological systems and possible negative impacts and complications lead to continuous worldwide research on finding alternative approaches.

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