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Insulin Pump Therapy in Non-Pregnant Hospitalized Adults: A Review of the Literature

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Abstract

The use of continuous subcutaneous insulin infusion (CSII) (i.e. insulin pump) therapy, continues to grow among patients with type 1 and type 2 diabetes increasing the likelihood that these patients will be encountered in the hospital setting. Prior to the development of protocols, guidelines and order sets that standardize the inpatient management of this group of patients, the decision to continue CSII during an inpatient admission was often arbitrary. While many patients wish to continue pump therapy when admitted to the hospital, lack of familiarity with these devices led to therapeutic misadventures, such as abrupt discontinuation of CSII without transition to scheduled subcutaneous (SC) insulin increasing the risk for both hypoglycemia and hyperglycemia. This review provides information regarding the basics of CSII therapy and summarizes the literature describing the current practice standards and recommendations that have been published as a way of guiding the safe use of these devices in the inpatient setting. Proper assessment of patients who are able to safely manage their pump during admission is critical. The availability of hospital personnel who are knowledgeable in CSII therapy allows for ongoing assessment of the continued safety of CSII use and can guide transition to scheduled SC insulin therapy when patients are no longer capable of self-management. For patients who are unable to self-manage their pump therapy in the hospital, guidelines for transition to conventional subcutaneous insulin therapy is provided. We conclude that these devices can be safely used in the hospital provided that there is a standardized approach to patient selection and that there is a process for assessing glycemic control throughout the hospital stay.

Introduction

Hospital admissions for people with diabetes continue to climb. The number has nearly doubled in U.S. hospitals from 1988 through 2009 [1]. The majority of these individuals relinquish control of their dietary and medication regimens to hospital personnel at the time of hospital admission [2,3].

While this is often necessary in the setting of acute illness, many patients who previously used multiple daily injections (MDI) or continuous subcutaneous insulin infusions (CSII) via insulin pump therapy find it difficult to cede control to personnel who are often less knowledgeable about diabetes management. This includes use of carbohydrate counting or sensitivity factors for calculating premeal insulin doses [4-6]. The number of patients who use CSII continues to increase, making it more likely that these patients will be seen in the hospital setting, where the majority of health care personnel are unfamiliar with this form of therapy [5,7-11]. This lack of familiarity with CSII can lead to therapeutic misadventures that increase the risk of both severe hypo- and hyperglycemia [2].

The purpose of this article is to review the literature that addresses the safety and efficacy of CSII continuation in hospitalized patients and to identify processes of care that have been implemented in several institutions that can serve as a guide to this form of therapy in the hospital setting. Throughout this article the terms CSII and pump or insulin pump will be used interchangeably.

Overview of pump therapy

An insulin pump offers an alternative to usual MDI of subcutaneous insulin delivery. Pump devices include an internal computer that can be programmed to deliver a continuous flow of insulin (usually rapid-acting insulin, but Regular and Regular U-500 insulin preparations may also be used) according to individual variation in insulin sensitivity throughout the day and night [12-14]. This continuous infusion represents the basal rate of an insulin pump. Bolus doses of insulin are administered based on planned carbohydrate intake and home blood glucose levels. Insulin is infused via a subcutaneous catheter or needle which is changed every two to three days for most patients [12]. These bolus doses can be administered using bolus calculators that are programmed as insulin to carbohydrate ratios, sensitivity factors, and insulin "on board" functions in many of the newer "smart" pump devices.

Patients who use CSII devices exhibit variable skill levels when it comes to managing their pumps [9,15]. Some patients will make few if any changes to the pump settings without direct instructions from their managing physician. On the other hand, there are patients who are skilled with making independent pump adjustments, based on glycemic patterns. An assessment of a patient's skill at managing their device is an important determinant of whether or not it is safe for a patient to use the device when hospitalized [2,16]. Some of the recommendations for determining a patient's ability to continue insulin pump therapy include direct observation of specific tasks such as providing information regarding basal rates, calculating a bolus dose, or changing sites [2,16]. There are several insulin pump models

available on the market today making it difficult for inpatient providers and health care personnel to maintain up-to-date skill for the technology associated with each device. This makes patient self-management a key component of the ability to continue CSII.

CSII use in the hospital setting

While some hospitals allow patients to continue use of their insulin pump in the hospital, there are few reports on the safety and efficacy of this practice [2,9,11,16-18]. Allowing patients to manage their own High-Alert Medication while navigating the complexities of a hospital environment during an acute illness raises concerns for the safety of this practice [19]. However, patients who continue insulin pump therapy during a hospital stay have been observed to have lower rates of both hypoglycemia and hyperglycemia when compared to those who are transitioned to conventional subcutaneous (SC) insulin regimens [17,20,21].

One of the first initiatives to create guidelines for CSII therapy in the hospital setting recommended that non-critically ill patients be allowed the choice of either continuing their pump device or transitioning to multiple daily injections (MDI) with basal bolus insulin (BBI) [20]. Discontinuation of pump therapy with transition to an IV insulin infusion was recommended in the setting of critical illness with resumption based on a patient's mental ability to manage the device and approval of an endocrinologist. These early recommendations for documentation of all basal and bolus insulin doses by nursing personnel and involvement of a diabetes care team have been incorporated into more recent guidelines discussed below [2,16,20].

The Mayo Clinic published their initial protocol for inpatient insulin pump therapy in 2005 and has continued to monitor compliance with these guidelines [11,16,17,22]. The investigators reviewed the care and glycemic outcomes of 136 patients using insulin pumps in 253 separate hospitalizations [17]. The pump was continued in 65% of hospitalizations. They observed overall improvements in guideline compliance between 2005 and 2011, including 100% compliance with endocrinology consults and 100% use of the insulin pump order set by 2011. There were persistent deficiencies in recording dosing information by patients on the bedside flow sheet. Mean glucose values were similar among patients who used the pump and those who were converted to conventional SC insulin regimens; however, episodes of severe hyper and hypoglycemia were less frequent among those continuing CSII. There were no serious adverse events related to the pump.

At the University of Pittsburgh Medical Center (UPMC), a quality improvement approach was used to investigate the safety and efficacy of an Inpatient Insulin Pump Protocol [2]. A formal policy (Appendix A) outlining provider, nurse and patient responsibilities was drafted and approved by the system-wide UPMC Diabetes Patient Safety Committee. These responsibilities are outlined in Table 1. This protocol includes a recommendation for consultation with the inpatient diabetes service. Glycemic outcomes and pump related adverse events were compared among fifty consecutive inpatients admitted to the hospital with CSII based on whether they received all components of the protocol, some components of the protocol, or usual care in which no protocol components were found in the medical record. Mean blood glucose levels were similar between all groups, but the usual care group had the greatest number of days with blood glucose levels >300 mg/dl. The frequency of hypoglycemia did not differ among the groups and there were no serious adverse events related to pump use. Patient satisfaction with the ability to continue CSII use was high [2].

CSII Responsibilities in the Hospital Setting [2]
Provider Responsibilities:
Assess patient for appropriate use of insulin pump (awake, alert, oriented and physically able to manage the device, completion of bedside pump log)
Complete preprinted CSII order set (pump settings on admission, brand/model of pump, type of insulin)
Consult Endocrinology/Diabetes Consult service, if available
Nursing Responsibilities
Assess patient for appropriate use of insulin pump (awake, alert, oriented and physically able to manage the device, completion of bedside pump log)
Obtain initial insulin pump information from patient
Assess infusion site every 8 hours
Provide insulin (from hospital pharmacy) for insulin cartridge change
Contact provider if patient experiences any situation that may alter continuation of the pump
Patient/Significant Other Responsibilities
Provide insulin pump information (pump brand/model, type of insulin, pump settings)
Sign agreement to continue pump in the hospital
Provide all pump supplies, except insulin
Change infusion site every 48-72 hours and/or as needed
Complete bedside insulin pump log sheet

Table 1: CSII Responsibilities in the Hospital Setting.

In the only prospective, randomized open-label study, 27 hospitalized patients with uncontrolled type 2 diabetes were randomized to receive new CSII therapy, intravenous insulin infusions, or premixed insulin administered twice daily with a correction scale [23]. The group treated with CSII had the greatest improvement in BG and also reported higher quality of life (QOL)

scores. No information was provided as to who managed CSII therapy in this study.

Recognizing the variability in how patients who use CSII devices are managed, one institution without diabetes consultation services collected patient data prior to and following implementation of a standardized order set and guideline [10]. Prior to implementation there was little documentation of CSII use. Following implementation of the protocol, significant improvements were observed in glycemic control with the majority of blood glucose levels within target range of >60 mg/dl and ≤180 mg/dl. While hypoglycemia rates, defined in this study as BG ≤ 60 mg/dl, were low during early (1%) and late (1.4%) implementation phases, severe hyperglycemia (>300 mg/dl) accounted for approximately 10% of all BG values over a 2 year period of observation [10].

Current guidelines for Inpatient CSII

Recommended glucose levels for non-critically ill hospitalized patients are less than 140 mg/dl before meals and with random levels less than 180 mg/dl, which can be applied to patients who use CSII (24-26). A formal policy that guides CSII therapy during periods of hospitalization can help achieve these glycemic goals while reducing risk for glycemic misadventures such as severe hypo- and hyperglycemia [2,9,16,27,28]. Important components of these policies include guidance as to who will manage the pump (patient or family member), contraindications for continuation of the device, the use of standardized printed or computerized order sets, and the need for an inpatient diabetes service consultation or diabetes educator.

These policies also provide information detailing the responsibilities of patient, nurse and physician [2,9-11,16,20,29]. Patients are required to sign an agreement indicating that they accept responsibility for diabetes self-management and agree to communicate any dose changes and bolus doses to nursing personnel in written form. Patients are asked to provide information regarding their basal rates, bolus calculations with insulin to carbohydrate ratios, and correction doses. This information is recorded in the patient record at admission.

The most important aspect of these guidelines is an ongoing assessment of a patient's mental and physical ability to continue self-management with CSII over the course of the hospital stay. It is important to note that not all patients are candidates for continuation of CSII therapy in the hospital setting. Many patients may be too ill or on sedating medications that affect the mental capacity to accurately manage their pump. Patients with altered mental status, severe illness, or high suicide risk require transition to scheduled insulin therapy. If it is determined that a patient or significant other is not able to operate the pump safely even with medical oversight and guidance, it is recommended that the pump be discontinued and basal bolus or basal plus correction insulin therapy initiated [30,31].

When transitioning patients from CSII to BBI, the dose of basal insulin (i.e. glargine, detemir, NPH) can be based on pump basal rates (Table 2). Dose of prandial insulin can be based on the premeal doses a patient was taking at home as either a fixed dose or as insulin-to-carbohydrate ratios. In situations in which a patient is unable to provide this information, weight-based calculations can be used to determine insulin doses [26,32] (Table 3). The availability of hospital personnel who are knowledgeable in CSII therapy allows for ongoing assessment of the continued safety of CSII use by an individual patient and can guide transition to scheduled SC insulin therapy when patients are no longer capable of self-management.

Basal Insulin Dose Calculation from CSII to SC Injection [40,41]	
Long acting insulin Use unit for unit conversion of current 24 hour basal rate (glargine or detemir)	**Example Basal Rates:** 12A-4A 0.6 units/hr (2.4 units) 4A-6P 1.2 units/hr (16.8 units) 6P-12A 0.9 units/hr (5.4 units)
The basal rate is typically 50-60% of the total daily dose (TDD) of insulin.	Basal Rate = 24.6 units (Round dose up or down)
Intermediate acting insulin Use 60% of basal rate for morning dose and remaining 40% for evening dose (NPH insulin)	**Using above example:** Basal rate = 24.6 units 24.6 x 0.6 = 14.76 units AM dose 24.6 x 0.4 = 9.84 units PM dose (Round doses up or down)

Table 2: CSII Continuous subcutaneous insulin infusion. SC Subcutaneous.

Weight-Based Total Daily Dose (TDD) Insulin Calculation [42]	
Renal insufficiency or Lean body type	Calculate 0.2-0.3 units/kg
Obese	Calculate 0.4-0.5 units/kg

Table 3: Weight-Based Total Daily Dose (TDD) Insulin Calculation.

Once the TDD of insulin is calculated, administer 50 to 60% as the basal insulin and 40 to 50% as premeal insulin doses divided over 3 meals.

Insulin pumps require discontinuation for certain procedures that may cause damage to the internal mechanics of a pump device. According to pump manufacturers, these procedures include X-rays, or high electromagnetic fields associated with MRI. Since a pump should not be disconnected for more than 1 hour without an alternative insulin source, the pump should be removed immediately prior to the procedure and reconnected immediately afterwards. Communication and shared responsibility with other hospital departments regarding CSII therapy can help prevent misadventures with these devices.

At UPMC, a Continuous Subcutaneous Insulin Pump Order Set is available to all medical and nursing personnel on the hospital electronic medical record (EMR) within the computerized physician order entry (CPOE) section (2). The guideline strongly recommends consultation with an inpatient diabetes service where this is available, as recommended by the American Association of Clinical Endocrinologists (AACE)/ American College of Endocrinology (ACE) insulin pump management task force [7,33]. The American Association of Diabetes Educators (AADE) recommends involvement of a diabetes educator when insulin pump therapy is utilized in the hospital [28].

Included within the UPMC order set is a form requesting patient documentation of their device settings, the pump brand and model, type of insulin used in the pump, and whether they have adequate pump supplies available. Patients are required to sign an attestation statement stating they are trained and willing to manage their pump in the hospital and that they will alert the hospital team if they become

unable to manage the pump. Patients are asked to record carbohydrate consumption, insulin boluses, basal rate changes, and pump site changes on a bedside log which then serves as a medication administration record that is eventually scanned to the permanent record after discharge.

The insulin pump management task force endorses the need to standardize training and assessment programs for inpatient CSII use among hospital providers and recommends that outpatient providers be contacted to discuss insulin infusion adjustments at the time of admission [7,33]. However, this is not always practical as the outpatient provider, even if they are available, will not always be aware of the reason for hospitalization or the patient's ability to manage their pump during an acute illness.

Staff Education

There are few studies specifically addressing the educational needs of nursing staff when caring for patients admitted with insulin pumps [5]. In one survey measuring nurse knowledge and attitudes towards CSII in hospitalized patients among 123 nurses, overall knowledge scores were low with a median score of 33% [5]. Higher scores were observed among nurses reporting previous experience with CSII. There was overall agreement that CSII is a good way to control blood glucose levels, but many nurses expressed discomfort in caring for patients treated with an insulin pump [5].

In another study, one on one education was provided to nursing personnel in addition to providing a centralized computer-based education program [10]. These educational sessions were not mandated by the hospital raising concern for the ability to maintain staff competence on an ongoing basis.

In response to the increasing use of CSII in the pediatric population, one hospital offered an 8-hr insulin pump practicum for pediatric nurses that included the availability of wearing a saline-filled insulin pump for approximately one week [34]. Following implementation of this program, there were fewer pump related medication errors, more reported comfort with CSII therapy, and improved knowledge scores [34]. Patients who use CSII are admitted only to specific inpatient units where nurses have received this training.

Nurse knowledge and confidence with inpatient insulin pump therapy was investigated on a kidney-pancreas transplant unit before and after a didactic and hands-on educational intervention [15]. Significant improvements in nurse knowledge and confidence were observed following the intervention. When asked for suggestions for improvement in the care of these patients, nurses identified the need for more multidisciplinary education and a desire for more hands-on practice in use of these devices.

Safety of Inpatient CSII Use

Patients using CSII for glycemic control are low volume-high risk patients. With the increased use of insulin pumps in the inpatient setting, it has become imperative that hospital staff become familiar with insulin pump therapy [7]. The published experiences at some hospitals can provide some guidance in the formulation of policies and procedures at other institutions. The available data described in this review indicates that insulin pump therapy guided by these protocols can be safely used in the hospital setting with proper patient selection. While the majority of patients who use CSII are often better prepared at managing these devices than hospital providers and staff, they may still need assistance with basal and bolus dose adjustments. Without inpatient guidelines for CSII, patients admitted to the hospital are at increased risk for abrupt discontinuation of the device without initiation of scheduled SC insulin or for continuation of the pump device when they are too ill to self-manage their insulin doses. Many nurses express anxiety when assigned to a patient with CSII, which can be alleviated with ongoing staff education and the availability of hospital personnel who are well versed in this form of therapy. CSII units staffed with an endocrinologist, diabetes educator, nutritionist and nurse have been proposed but may not be realistic for the wide variety of admission diagnoses that often dictate unit assignment [27].

Perioperative Setting

While insulin pumps have been used during surgery, these experiences have been underreported [35]. As with CSII use in the hospital setting, there is little available data to guide perioperative CSII use [29,35-39]. The Mayo Clinic identified a need for perioperative-specific policies and protocols with a goal of maintaining patient safety during elective surgical procedures [35,37,39]. They recommend assessment and documentation of pump settings at each level of perioperative care. If the device is removed, it is labeled and placed with the patient's belongings and alternative insulin administration is initiated to avoid severe hyperglycemia. The focus of these recommendations is on improving communication and documentation of the pump throughout each phase of care.

Other institutions have developed specific policies and procedures for the perioperative setting [29,36,38]. Some algorithms for perioperative pump management are based on length of the surgical procedure, post op recovery time and anticipated exposure to X-rays, MRI, or cardiac defibrillators (29, 36). Another published algorithm for continued pump use bases this on anticipated duration of NPO status, allowing continuation of CSII if only one meal will be missed and glucose level is in target range [18]. For procedures associated with longer periods of fasting, the recommendation is to remove the device and initiate a variable rate intravenous insulin infusion [18].

Final Recommendations and Future Direction

There is a need for standardized policies and protocols with accompanying staff education to ensure safe use of CSII. Inpatient policies and protocols for use of CSII are in place in many hospitals. Despite the recent CSII consensus statement, there are currently no national guidelines for use of these devices in the hospital setting [33]. The literature published to date demonstrates that hospital use of CSII is safe in selected patients when guidelines for this practice are in place [2,9,11,16,18,21,22,27,33,35,37]. Many patients express a high degree of satisfaction with the ability to continue CSII therapy when they are hospitalized [2]. Glycemic control may actually be better with continued use of the pump [17,27]. When available, personnel with expertise in CSII therapy should be included as part of the health care team during hospitalizations. It was noted by two separate institutions [2,10] that there were higher rates of hyperglycemia >300 mg/dl in CSII patients who did not have a consult to a diabetes specialist [2,10].

Communication with patients to assess patient knowledge and skills at time of admission is an important way of identifying candidates for inpatient CSII therapy. The availability of a diabetes educator and unit specific resource staff can help establish and maintain skill among hospital nurses who provide care to this group of patients [10]. When

allowances were made for nurses to have hands on practice with these devices or annual competency reviews, favorable improvements in confidence levels and knowledge were observed [15,34].

Consultation with the endocrine or diabetes inpatient services is very helpful in institutions where this is available. Personnel on these services have more experience with these devices and can provide assistance with changes in pump settings based on a patient's clinical status. Initiation of steroid therapy, planned surgical procedures, or abrupt discontinuation of oral nutrition all provide unique challenges to the management of these patients.

Summary of Recommendations for Management of Insulin Pump Therapy in the Hospital:

- All patients who are treated with insulin pump therapy in the outpatient setting will require continuation of scheduled insulin therapy in the hospital, either via their pump device or with conversion to basal bolus insulin regimens.
- It is essential that patients be assessed for their mental and physical capacity to continue pump therapy in the hospital.
- Involvement of personnel who are knowledgeable with insulin pumps can contribute to the safety of their continued use in the hospital setting.
- Patients should provide a written signature attesting to their willingness to continue insulin pump therapy and their understanding of their responsibilities during hospitalization.
- Daily review of the patients pump settings and bedside blood glucose readings is required to guide changes to basal or bolus infusion rates to ensure that glycemic goals are achieved without undesired hyperglycemia or hypoglycemia.

Conclusions

With more insulin treated patients with diabetes opting for CSII therapy for glycemic management, the likelihood that hospital personnel will encounter these devices for elective and non-elective conditions is increasing. While more research is needed to guide inpatient CSII therapy, currently published protocols can provide the basis for coordinating the care of these patients [28,33]. These protocols have the potential to improve the patient experience in the hospital setting.

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