The Perioperative Insulin Pump: Is it an Option?

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Abstract

Continuous subcutaneous insulin infusion (CSII) therapy has become increasingly widespread in the management of diabetes in recent years. However, there is limited published literature outlining the appropriate perioperative use of insulin pumps. Recognizing a need to standardize care, this article aims to assist anesthesiologists in caring for patients with CSII therapy in the perioperative period.

A literature search was conducted in the PubMed database, with the MeSH terms "insulin infusion systems", "diabetes mellitus" and "hyperglycemia". The search was limited to articles published in Portuguese, English and German. The initial search yielded 67 articles that were later selected based on their relevance. Ultimately, 23 articles were addressed.

Answering the question posed in the title of the article: yes, maintaining the insulin pump in the perioperative period is an option. It is important for the hospitals to develop clear protocols for inpatient and perioperative management of patients on CSII, bring forward initiatives to educate healthcare professionals that are likely to encounter this technology and closely liaise with diabetes team. Education is paramount for all staff involved in the care of patients with insulin pumps.

A protocol can contribute to reduce therapeutic misadventures by clinical personnel which are not familiar with CSII therapy, as well as guide goal-directed glycemic and surgical outcomes.

Keywords: Continuous subcutaneous insulin infusion, insulin pump, diabetes mellitus, hyperglycemia.

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Introduction

Continuous subcutaneous insulin infusion (CSII) therapy, introduced in the 1970s, has become increasingly widespread in the management of diabetes in recent years (1). Its use is predominant in patients with type 1 diabetes with particular effectiveness on patients which have not yet achieved target HbA1c levels, although use is increasing in type 2 diabetics (2-5).

Patients with diabetes have a higher propensity to require surgery during their lifetime4. In order to reduce the risk of postoperative complications such as infections and delayed wound healing, it is important to maintain perioperative glycemic control. Due to stress of surgery and reduced food intake, perioperative insulin requirements will most likely differ from usual insulin requirements (4,6).

Despite increased use of CSII, there is limited published literature outlining the appropriate perioperative use of insulin pumps. Recognizing a need to standardize care, this article aims to assist anesthesiologists in caring for patients with CSII therapy in the perioperative period.

This article is based on a review of existing literature and aims to discuss anesthesiologic general decision-making for the perioperative management of CSII. It will explain how the insulin pump works, its benefits and risks for perioperative use and propose recommendations for CSII perioperative management.

Methods

A literature search was conducted in the PubMed database, with the MeSH terms "insulin infusion systems", "diabetes mellitus" and "hyperglycemia". The search was limited to articles published in Portuguese, English and German. The initial search yielded 67 articles that were later selected based on their relevance. Ultimately, 23 articles were addressed.

Insulin Pump: How it works and principles

The insulin pump is a small battery-operated external device containing a refillable insulin reservoir (1,5). Subcutaneous insulin infusion pumps mimics normal physiologic insulin delivery, allowing for convenient subcutaneous insulin administration with enhanced flexibility in dosing and without injections (7). CSII involves a continuous basal infusion of short acting insulin (Novorapid®, Humalog®, Apidra®), in combination with meal-time boluses of the same insulin (5).

Basal insulin infusion is the absolute requirement for a low insulin concentration - even in the fasted state - to maintain euglycemia and prevent ketosis, but a sufficiently low concentration to allow hepatic gluconeogenesis to supply the brain and vital organs (8). The basal rate is programmed to deliver small doses at constant infusion over 24h. It can be temporarily increased/decreased to accommodate fluctuations in blood glucose levels. The hourly infusion rate is tailored-made, according to variables such as insulin sensitivity, the dawn phenomenon and regular daily activity. The basal infusion usually accounts for approximately 50% of the total daily requirement for insulin, although this may vary (8).

Bolus dose of insulin is required to maintain euglycemia and absorb carbohydrate load, being administered at or just before meal time. Following a pre-meal blood test, bolus dose may be subject to correction due to hyperglycemia levels above a predetermined level8. Doses are calculated based on carbohydrates ingested and according to the carbohydrate-to-insulin ratio. This ratio and the insulin-sensitivity factor are calculated from the total daily dose of insulin and thus reflect patient's sensitivity to insulin. Insulin-sensitivity factor provides a unique measure of the extent of decrease of blood glucose with 1 unit of insulin infusion and enables blood sugar correction above a prespecified target, before next meal intake. Both are individualized and preprogrammed into the pump (5,8).

Insulin pump also contains a pre-set memory system which calculates the time and amount of the last insulin dose, therefore allowing to estimate the level of insulin still present. This system aims to prevent excessive or extensive corrections, thus harnessing protection from hypoglycaemia (2,8).

Such a device may be used alongside self-monitored blood glucose or continuous glucose monitors (CGM) which assess subcutaneous interstitial glucose concentrations.

Insulin infusion is performed through a catheter, or directly via a pod. Both the tubing and pod attach to a fine bore subcutaneous plastic or metal cannula (typically replaced every 2-3 days) (5).

Although pumps may be placed in a variety of locations, the abdomen is the most prevalent site among patients (5).

Insulin pump in the perioperative period

Outlining a well-designed plan to maintain glycemic control in surgical patients using CSII is vital to minimize potential risks related to such method of insulin delivery.

There are 2 courses of action available to the healthcare team during perioperative period (3,8):

1. Maintaining CSII during the procedure;
2. Discontinuing CSII during the procedure;
   2.1. Disconnecting patients from their insulin pump and replacement with an intravenous insulin infusion;
   2.2. Discontinue the pump with or without intermittent insulin boluses for blood glucose correction.

The choice of anesthetic technique will impact the effect on glucose homeostasis during surgery. Effects are usually mediated by stimulation or inhibition of hormones such as cortisol and growth hormone, change in sympathetic nervous system tone, and influence on hypothalamic-pituitary-adrenal axis.

The anesthetic technique per se - general anesthesia (GA) or regional anesthesia (RA) - does not present as a decision criterion in favor or against perioperative CSII and, therefore, the method of choice for glycemic control. Yet, GA is associated with increased insulin resistance, glucose intolerance, and postoperative hyperglycemia. In turn, RA has residual effect on metabolism and changes in blood glucose are less common4. Patients using insulin pumps may present increased surgical risk as complications may arise, either from diabetes or other comorbidities. Surgical procedures vary in type (elective, emergent), duration, and time required for anesthesia, as well as the need for prolonged postoperative fasting (9). Therefore, understanding patient comorbidities, together with their cognitive, emotional and physical ability to manage the insulin pump, and the idiosyncrasies of the surgical procedure is imperative to make the decision to continue or discontinue insulin infusions via pump during the perioperative period.

1. Maintaining CSII during the procedure

a) Benefits of maintaining CSII during the procedure:

CSII pumps can be safely used during the perioperative period, provided an established protocol is in place. Generally, pump users are motivated and educated around managing their diabetes. Hence, this option increase patient satisfaction (3,4,10,11,12).

Maintaining CSII will rely on the ability of the patient to safely operate the pump and the familiarity of the healthcare provider with CSII (10).

Retrospective studies have shown no difference in glycemic control and increased patient satisfaction when maintaining CSII, in comparison with patients who switched to another insulin therapy regimen during hospitalisation (3,13). Thus, CSII allows glycemic control comparable to IV insulin infusions(3,14).

Evidence points to benefits in maintaining CSII during surgery in lieu of discontinuing, with decreased fasting glucose on day 1 post-op and more stable blood glucose levels during surgery. Yet, these studies showed ambiguity in design and data collected was not confirmed by other studies (6,13,15).

Studies also showed that hyperglycemia is less frequent when maintaining CSII/IV infusion, when compared with intermittent insulin boluses (3). Other studies indicated that even though mean blood glucose levels remained unchanged in patients who kept CSII compared with those that discontinued, more episodes of severe hyperglycemia and hypoglycemia in patients who discontinued were experienced (14). Increasing evidence strengthens the recommendation to maintain CSII as retrospective studies and case reports have shown that CSII can be maintained safely during perioperative period (10).

In addition, maintaining CSII contributes to reducing risks caused by transition issue to and from another insulin therapy regimen, such as hospital acquired diabetic ketoacidosis, electrolyte and fluid abnormalities, hypoglycemia. Lastly, it also unburdens day surgery with its intrinsic benefits (16).

In short, maintaining CSII may prove beneficial in the following scenarios (3,4,5,10):

1. Elective surgery;
2. Outpatient surgery;
3. Non-cardiac surgery;
4. Noncritically ill patients;
5. Short-term procedures <2h;
6. No postoperative fasting required – suspension of only 1 meal or none at all.

b) Recommendations while maintaining CSII:

Preoperative setting:

- Patient should be subject to endocrinology consultation (3,5);
- Upon admission, perform an HbA1C if none was was not performed in the prior 3 months. Elevated HbA1c is correlated with adverse surgical outcomes (3).
- Patient enquiry concerning their diabetes type, duration and current glucose control. It is also advisable to obtain information on episodes of hypoglycemia (9);
- Upon admission, the presence, duration of use and infusion set location of CSII should be documented (3,10);
- Establish a consistent blood glucose level during a fasting period (days to weeks before surgery) in order to set a baseline rate. If this test is not performed, baseline rate should be temporarily reduced to 80% until patient resumes handling the insulin pump;
- Signed patient consent outlining conditions for CSII use in the hospital (5,14);
- Hospital provider should obtain a detailed record of the pump brand, type of rapid-acting insulin formulation and the pump settings, basal rate, carbohydrate ratio (i.e., grams of carbohydrate for 1U of insulin – amount of insulin needed to counter the amount of carbohydrate in a meal or snack in order to keep the blood glucose at an acceptable level after eating) and the correction or sensitivity factor (3,5,10);
- Patient should provide their own insulin pump supplies (14);
- Request the patient to insert the infusion set outside the surgical field as appropriate (9);
- Ensure subcutaneous CSII cannula is placed away from surgical field and accessible to healthcare team (4,5);
- Patient should use a plastic subcutaneously-inserted cannula, not a steel one;
- Throughout hospital stay, the pump should be inspected regularly by nursing staff with a view to ensure proper functioning (10);
- Infusion site should be inspected for signs of inflammation or leakage. Also, date and time of cannula insertion should be properly documented (5,10);

- Surgery should be scheduled at the first time in the morning, if possible.
- Patient should have a light meal up to 6 hours before surgery.
- CSII should be continued at usual basal rates3. The patient should administer the usual basal and correction insulin until midnight of the night before and should then continue the usual basal infusions overnight (17);
- Measurement of blood glucose should occur every 2 hours until the day of surgery;

Intraoperative setting:

- On surgery day, basal insulin infusion rate should be 80% of the usual rate. Based upon the assumption that the average patient using an insulin pump has a supraphysiological basal rate (5,8).
- During intraoperative period, the anesthesia team must take responsibility for CSII and assess the insulin pump infusion site (8,9,13). Patients undergoing surgical procedures are unable to appropriately self-manage their pump as they often evidence altered levels of consciousness for variable time periods (4).
- Before, during and after the procedure, the healthcare team must inspect the skin insertion site and the connection to the device (13).
- Correct connection and functioning of pump should be monitored (18);
- On an hourly basis at least, the healthcare team must monitor patient's capillary glucose levels. For the majority of critically ill patients and non-critically ill patients, the recommended target glucose range is 140-180 mg/dL (19).
- If glucose levels are not within the acceptable range, bolus correction via the CSII is allowed (10,20):

Blood glucose	Recommendation
<100 mg/dL	Turn off infusion pump. Check every 30 min.
101-140 mg/dL	Decrease basal rate by 25%.
141-180 mg/dL	Maintain basal rate.
181-220 mg/dL	Verify correct functioning of insulin pump. Increase basal rate by 25%.
>220 mg/dL	Verify correct functioning of insulin pump. Increase basal rate by 25-50% and give 2-4U as bolus insulin.
>300 mg/dL	Measure electrolytes and blood ketones. Start IV insulin infusion.

- In the event of uncontrolled hyperglycemia, it may be necessary to disconnect CSII and convert to an insulin infusion (5,13,18). Although software interface varies among pumps, the main basic functions are easily operated on all, with the "stop" or "suspend" basal function being easily engaged (8).
- For all cases, hypoglycemia (<70 mg/dL) or symptoms and signs of hypoglycemia at ≥70 mg/dL should be immediately treated, by means of suspending insulin pump infusion and treating hypoglycemia in accordance with local protocol. Glycemia should be re-checked after 5 minutes (5);

Post-operative setting:

- Correct connection and functioning of pump should be monitored;
- Hourly assessment of glycaemia levels. After the procedure and up until the patient is eating and drinking again and able to manage their own glucose control, capillary blood glucose monitoring should be maintained on a frequent basis (13).
- If possible, patient should initiate liquid diet 1 hour after surgery and initiate solid diet 2 hours post-op (20).
- Postoperatively, and from starting oral intake, prandial boluses should be initiated according to the usual schedule. Intravenous fluids can be discontinued (13,17).
- On first- and second-day post-op, patient should plan to check glycaemia more frequently in order to re-establish baseline status (17).

c) Hazards of maintaining CSII during the procedure:

- **Disconnection of insulin pump:**

  Dislodgement of the catheter from the insulin pump (9,14) may occur inadvertently due to patient movement. Therefore, it is of utmost importance to inspect the pump insertion site and connection before, during and after the procedure.
  Patients on CSII do not take any long-acting insulin. Hence, any interruption of insulin delivery can offset to develop hyperglycemia very quickly, which might lead to ketoacidosis (5). Disconnection, occlusion (kinking of infusion catheter) or cessation of the pump will cause relative insulin deficiency within 1h and absolute insulin deficiency within 4h, causing a severe risk of hyperglycemia and ketosis (8).
  Moreover, excessive sweating that may occur during or after surgery can cause displacement of the subcutaneous needle or catheter (5,8).

- **Malfunctioning of insulin pump:**

  Radiation exposure in intraoperative procedures such as cardiac catheterization, mammography, fluoroscopy, cardiac defibrillation, intra-op X-ray, CT or MRI may cause damage to the pump or prevent correct functioning5,9. Most pump manufacturing companies recommend no radiation exposure (5). Often, the need for intra-op radiation exposure may be anticipated and the pump may be disconnected, removed from the OR, or covered in advance. In the event of exposure to electromagnetic radiation, the pump may be temporarily removed during radiation exposure and stored outside the OR, being connected afterwards. CSII can be safely removed for up to one hour consecutively, without alternative insulin being required. Electrocautery use may increase the risk of pump damage or cause intra-op malfunction9. Electrocautery may cause pump malfunctioning depending on the brand of insulin pump, therefore any guidelines or protocols should account for recommendations provided by manufacturers of the specific pump in use.
  Damage to the CSII caused by heat has been reported, so it is important to take into account the OR conditions and other variables such as the use of heating blankets1. Additionally, since insulin is sensitive to temperature it is advisable to avoid large temperature variations in the OR. Development of diabetic ketoacidosis from exposure of insulin pumps to heat and sunlight have been reported (22).

- **Mismanagement of insulin pump:**

  Healthcare team may not be familiar with CSII and the alarm signals of the insulin pump. Moreover, a healthcare team unfamiliar with CSII may not be able to easily titrate and to counter the glycemic variability that occurs during major surgery (5,16).

2. Discontinuing CSII during the procedure:

Prolonged surgical procedures and opioid administration post-op for pain management may influence the decision to discontinue the insulin pump during the intraoperative period. In case of elective surgery, such variables may be foreseen. Conversion from insulin pump to IV insulin infusion is a preferred option in patients who are scheduled to undergo major/emergent surgery, which may face hemodynamic instability or are critically ill.

In short, discontinuing CSII may prove beneficial in the following scenarios:

1. Emergency surgery (9).
2. Major surgery (5,8): Major surgery triggers large inflammatory response and often results in difficulty controlling glycemia, particularly when glucocorticoids or beta agonists are used in the perioperative setting. On the other hand, minor surgery results in slim or no change in metabolism, and therefore, entails minimal impact on insulin needs.
3. Procedures lasting >2 hours (4,5,10): Long-term procedures are associated with greater surgical stress and a higher risk of perioperative hyperglycemia.
4. Procedures likely to miss more than one meal or cause significant ileus (8): Prolonged postoperative fasting while maintaining basal rate via insulin pump may inevitably lead to postoperative hypoglycemia. Counteracting hypoglycemia with glucose infusions is more expensive and more prone to failure than turning-off CSII with conventional diabetes management.
5. Critically ill patients (5,10): Subcutaneous absorption of insulin is unreliable in hemodynamically unstable patients.
6. Depression of the state of consciousness, confusion or incapacity (5).
7. Surgery requiring electrocautery.
8. MRI, CT scan, X-Ray or any other type of radiation exposure (5).
9. Lack of trained health care providers, diabetes educators or diabetes specialist.

Recommendation while discontinuing CSII:
In the event of pump disconnection, the device should be labeled and stored together with the patient's personal belongings, along with corresponding documenting. The pump together with its tubing may be removed, being only the SC cannula left in place, unless the cannula site is infected or placed in the surgical field. Cut tubing or pump disconnection should be avoided as the remaining insulin in the tube may infuse quickly and risk hypoglycemia.

When compared with sample groups where the insulin pump was maintained or replaced by IV insulin infusions, discontinuation of the insulin pump and administration of intermittent insulin boluses proved to be less effective in preventing hyperglycemia.

Conversion from insulin pump to IV insulin infusion is a preferable option in patients who are scheduled to undergo major/emergent surgery, which may face hemodynamic instability or are critically ill. Concerning patients with poor metabolic control or in critical condition, IV blood glucose correction is advisable as it proved to be faster and more reliable. In these cases, insulin infusions are preferred since absorption and distribution of subcutaneous insulin may be adversely affected.

2.1 Disconnecting patients from their insulin pump and replacement with an intravenous insulin infusion

Transition from CSII to insulin infusion regimen (4,5):

- Start of IV insulin at least 30 min before removing the pump;
- If CSII basal rate <1 unit/h: start IV insulin at 0.5 U/h;
- If CSII basal rate >1 unit/h, start IV insulin at 2/3 of the basal rate. Variability in bioavailability and pharmacokinetics between IV infusion and subcutaneous infusion, fasting status, residual subcutaneous insulin at infusion site of the insulin pump, patient safety, tendency to avoid hypoglycemia, are all in the basis of the rationale for reducing the dose of basal rate.
- In case of hyperglycemia or hypoglycemia, follow insulin intravenous infusion hospital protocol.
- In the recovery room, the patient should continue insulin infusion.

2.2 Discontinue the pump with or without intermittent insulin boluses for blood glucose correction

Transition from CSII to SC insulin regimen:

- The 24-h basal dose of insulin delivered by the pump should be replaced by long-acting basal insulin (glargine, detemir or degludec). The insulin pump should be discontinued at least 2h after the first injection of basal insulin.
- Subcutaneous rapid-acting insulin (aspart, lispro or glulisine) bolus can be administered according to the hospital protocol to maintain perioperative glycemia between 110-180 mg/dL.

Restarting CSII:
After recovery from anesthesia, the restart of the pump may only occur provided that: patient is cognitively alert, physiologically stable, without inotropes and is able to resume to autonomous pump management or at hospital discharge (21,23).

In addition, if transferring from IV insulin infusion, an additional hour is required before discontinuing IV insulin. If transferring from subcutaneous insulin, it may be required to temporarily reduce background insulin infusion rate while long-acting subcutaneous insulin is still active. Start basal rate CSII 12-24 hours after last administration of long-acting SC insulin (20). Mealtime boluses are not given until patient is being kept in a fasting state (17).

Conclusion

Answering the question posed in the title of the article: yes, maintain the insulin pump in the perioperative period is an option. Most healthcare professionals have not seen an insulin pump and most certainly will not be familiar with the wide variety of different pumps. Under such circumstances, the majority of non-specialist staff will most likely discontinue pump therapy in favor of familiar therapies, such as variable rate intravenous insulin infusion or intermittent boluses of subcutaneous insulin.

Thus, hospitals need to develop clear protocols for inpatient and perioperative management of patients on CSII, bring forward initiatives to educate healthcare professionals that are likely to encounter this technology and closely liaise with diabetes team. Education is paramount for all staff involved in the care of patients with insulin pumps.

A protocol can contribute to reduce therapeutic misadventures by clinical personnel which are not familiar with CSII therapy, as well as guide goal-directed glycemic and surgical outcomes4.

Randomized controlled trials are needed to determine whether CSII therapy in the hospital is associated with improved clinical outcomes, when compared with intermittent monitoring and conventional insulin treatment or demonstrates a favorable cost-benefit ratio.

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