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Title: Time requirements for perioperative glucose management using fully closed-loop versus standard insulin therapy: A proof of concept time-motion study.

Short running title: Time requirements for perioperative glucose control

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Novelty statement:

- Fully closed-loop systems can manage inpatients' glucose levels without the need for staff involvement for glucose monitoring or insulin dose adjustment
- In this work, we provide evidence that the use of a fully closed-loop insulin delivery system substantially lowers the time spent for glucose management by more than 2-fold compared to conventional approaches
- The present study underscores the great potential of fully closed-loop insulin therapy for hospital care in periods with limited staff resources

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Authors contributions

Conception and design: JR, DS, DH, AF, AV and LB; Data acquisition: JR, DS and SL; Data analysis: JR, DS, DH, AF and LB; Interpretation: JR, DS, SL, AF, AV, MS and DH and LB; drafting the article: JR, DS, DH and LB; Supervision: DH and LB; All authors critically revised the manuscript and approved its final version.

Abstract

Aims

To compare the time required for perioperative glucose management using fully automated closed-loop versus standard insulin therapy.

Methods

We performed a time-motion study to quantify the time requirements for perioperative glucose management with fully closed-loop (FCL) and standard insulin therapy applied to theoretical scenarios. Following an analysis of workflows in different periods of perioperative care in elective surgery patients receiving FCL or standard insulin therapy upon hospital admission (pre- and intra-operatively, at the intermediate care unit and general wards), the time of process-specific tasks were measured by shadowing hospital staff. Each task was measured 20 times and its average duration in combination with its frequency according to guidelines was used to calculate the cumulative staff time required for blood glucose management. Cumulative time were calculated for theoretical scenarios consisting of elective minor and major abdominal surgeries (pancreatic surgery and sleeve gastrectomy, respectively) to account for the different care settings and length of stay.

Results

FCL insulin therapy reduced the time required for perioperative glucose management compared to standard insulin therapy, across all assessed care periods and for both perioperative pathways (range 2.1-4.5). For a major abdominal surgery, total time required was 248.5 min using FCL vs. 753.9 min using standard insulin therapy. For a minor abdominal surgery, total time required was 68.6 min and 133.2 min for FCL and standard insulin therapy, respectively.

Conclusions

The use of fully automated closed-loop insulin delivery for inpatient glucose management has the potential to alleviate the workload of diabetes management in an environment with adequately trained staff.

Key words

Diabetes, inpatients, artificial pancreas, insulin infusion systems, hospital care, time-motion studies.

Introduction

Hyperglycaemia is common in the perioperative setting [1] and has been associated with increased morbidity and mortality [2-4], among others. Alongside, several studies report positive clinical outcomes following improved glucose control [5]. Inpatient glucose management according to guidelines is time-intensive and significantly contributes to the workload of hospital staff and, consequently, costs of hospital care [6,7].

Enforced by the recently experienced challenges during the Covid pandemic[8], there is increasing interest in the use of diabetes technology for inpatient glucose management [9,10]. Amongst the most recent innovations are closed-loop insulin delivery systems, also referred to as the artificial pancreas. These systems are composed of a continuous glucose monitor (CGM) and an insulin pump coupled with an algorithm that controls insulin delivery in response to glucose levels. Compared to conventional insulin therapy, the use of fully automated closed-loop systems consistently improved glucose control without increasing the risk of hypoglycaemia in various hospital settings [11-14]. Thanks to their automatic mode of operation, there is no need for active hospital staff involvement, neither for frequent glucose monitoring, nor for insulin dose adjustment and administration. Thus, fully automated closed-loop systems may significantly reduce the workload for inpatient glucose management.

The objective of this time-motion study was to contrast the time required for perioperative glucose management using fully closed-loop vs. standard insulin therapy during hospitalization for elective surgery.

Research design and methods

Study design

The work was conducted within the framework of a randomized control trial comparing the efficacy of fully autonomous closed-loop therapy vs. standard insulin therapy for the management of perioperative glucose control, i.e. from hospital admission to discharge, at University Hospital Bern, Switzerland (NCT04361799) [14]. A time-motion study was used to quantify the time requirements for each insulin treatment modality.

Fully automated closed-loop (FCL) insulin therapy consisted of the CamAPS HX closed-loop application (CamDiab Ltd, Cambridge, UK) which resided on an unlocked Android phone and received sensor glucose data from a subcutaneous CGM sensor (Dexcom G6, Dexcom, San Diego, CA, USA) (Figure S1). Using the Cambridge adaptive model predictive control algorithm (version 0.3.71, HX variant) subcutaneous insulin infusion was automatically modulated every 8 to 12 min in response to sensor glucose data without the need for user input for meal management. Standard insulin therapy was performed according to local practice by the responsible clinical team. Participant characteristics can be found in the main publication [14].

Time-motion study

All processes and tasks involved in perioperative glucose management were defined according to the Suggested Time And Motion Procedures (STAMP) checklist.[15] A process analysis was conducted, and a set of tasks was created in collaboration with hospital staff and researchers familiar with the application of fully closed-loop insulin delivery systems. Tasks were allocated to three categories (treatment initialization, blood glucose monitoring and insulin therapy) and considered all three settings forming the perioperative care pathway (intraoperative, immediate care unit and general ward). Frequency of each task performed in each setting of the perioperative care pathway were estimated based on clinical guidelines and/or local standards assuming best standard of care[16]. We additionally determined task-specific minimal and a maximal frequency based on minimum and maximum level of surveillance. Standard care in the intraoperative and intermediate care period was considered intravenous (IV) insulin therapy, whereas subcutaneous (SC) basal-bolus insulin treatment was defined as the standard procedure of the general wards. An overview of the tasks in the FCL and standard care are provided in Table 1 (the estimated frequencies, together with minimum and maximum estimates, of the tasks in the respective perioperative care settings are reported in the Supplementary Appendix, Table S1).

The time requirement for each task in the FCL and standard insulin treatment modalities was measured 20 times except for the time required for reviewing glucose levels during closed-loop insulin delivery that was estimated based on feedback from study team members. Observers familiar with inpatient clinical practice and fully closed-loop insulin delivery workflows performed the measurements by shadowing staff responsible for respective tasks. To avoid confounding by specific working hours, tasks were shadowed during early and late clinical shifts. The measurements of specific tasks occurred in different patients to minimize patient-specific effects. Observation trainings were performed before the start of the assessments to minimize inter-observer variability. Start and stop times were directly recorded in a self-designed time-motion module within an electronic data capture system (REDCap®).

Calculation of time requirements

Mean duration and standard deviation (SD) were calculated for each task. Then, period-specific daily time requirements per patient were calculated. Finally, total time investments per patient and hospital stay were calculated on the basis of the following two theoretical scenarios representing perioperative care pathways of major and minor abdominal surgery: pancreatic surgery and sleeve gastrectomy. The length of surgery and hospital stay for the respective scenarios was retrieved from average values contained in internal quality control reports (for details see Table S2).

Statistical analysis

Because the frequency of tasks was estimated rather than measured, the variability in time requirements cannot be quantified precisely, making a statistical comparison between the two treatments formally invalid. For this reason, we performed a sensitivity analysis to estimate a lower and upper bound of the time requirements. The minimum estimate was calculated as the lower bound of the 95% confidence interval (CI) calculated for the minimum scenario. The maximum estimate was calculated analogously for the maximum scenario. Confidence intervals were calculated for each minimal and maximal scenario as the root sum square of the CI of the individual tasks involved in each scenario. Time requirements are reported as mean estimate [minimum estimate; maximum estimate]. Statistical analyses were performed with R (version 4.0.2).

Results

The process analysis revealed a total of six distinct tasks involved in glucose management using FCL insulin therapy and eight tasks for standard insulin therapy (Table 1). In summary, FCL-associated key tasks comprised the system set up, change of the insulin reservoir and catheter, remote blood glucose monitoring, change and calibration of the sensor. Tasks involved in the standard insulin treatment included treatment initialisation (insulin administration and blood glucose monitoring schedule), blood glucose measurements, insulin dose adjustment and administration. We assumed the use of IV insulin in the intraoperative period as well as during the post-operative stay at the Intermediate Care Unit. The assumed frequency of the respective task, according to a minimum and maximum level of surveillance are reported in Table S1.

The mean ± SD time requirements to complete tasks involved in FCL and standard insulin are reported in Table 1. Table 2 illustrates the time requirements to manage glucose in each of the assessed periods (preoperatively, intra-operatively, intermediate care units and general wards). FCL insulin therapy required 32.0 min [16.5 – 34.1] for treatment initialisation (e.g. entry of details into the app, filling and placement of the pump, placement and start of the sensor). In contrast, initialisation during the standard insulin therapy required 12.7 min [11.1 – 14.3]. Thereafter (intra-operative and post-operative periods), the continuation of care using the FCL insulin therapy was found to be substantially less time-intensive than with standard insulin therapy. The estimated times were 2.1 to 4.5 times lower compared to the time requirements for standard therapy (Table 2). The performed sensitivity analyses substantiate the reduced time required for FCL compared with standard therapy, with minimum time estimates for standard therapy exceeding maximum estimates for FCL in the intermediate care unit and general ward.

Regarding the cumulative time investment for glucose management over the entire hospital stay, the time required for a major elective surgery patient, using the scenario of pancreatic surgery (pre-surgery period, operation time 5h, length of IMC stay 48 hrs, length of stay on general wards 17 days), was significantly lower for FCL vs standard insulin therapy (248.5 min [105.8 – 444.4] vs 753.9 min [700.9 – 1565.4]). Similar time savings were observed for the sleeve gastrectomy scenario (pre-surgery period, operation time 2h, length of stay on the general wards 3 days) where time requirements were 68.6 min [38.9 – 101.6] for FCL and 133.2 min [127.8 – 260.0] for standard insulin therapy.

Discussion

In this proof of concept time-motion study, we contrasted the time required to manage perioperative glucose levels using fully automated insulin delivery versus standard insulin therapy using theoretical scenarios of major and minor elective surgery. We found that FCL insulin therapy more than halved the time required for perioperative glucose management compared to standard insulin therapy, across all assess periods in patients undergoing elective surgery. Time savings were notably most pronounced, to less than a quarter, in the setting where IV insulin delivery comprises the standard of care (e.g. in the intermediate care unit). The high workload associated with IV insulin delivery has been reported in a previous study[7] conducted in an intensive care unit. Authors concluded that glucose monitoring and insulin dose adjustments required nearly two hours of direct nursing time per patient per day. In our work, the use IV insulin was limited to higher intensity ward areas in line with local hospital policies. Other hospitals may, however, follow different guidelines.

The present study has limitations. While time for specific tasks involved in glucose management with either FCL or standard insulin therapy were quantified using time-motion observations, the frequency of these tasks and the cumulative time requirements for the perioperative care of minor and major surgery patients were based on a theoretical framework rather than real observations. Our methodology was chosen to overcome the various challenges (e.g. monitoring the entire process would require an unmanageable amount of resources) of constantly shadowing staff involved in the care of specific patients during the entire hospital stay. With the assumption of minimum and maximum levels of task frequency we tried to account for the fact that the level of care may be dependent on individual patient needs and staff availability. The fact that time savings with the use of FLC insulin therapy were consistently observed, even when compared to minimal levels of surveillance during standard care, strengthens our findings.

A second important limitation was that all FCL tasks were performed by a qualified study team rather than hospital. Although the maintenance tasks of FCL are easy to perform and feasibility of the use of diabetes technology by hospital staff was shown in previous work hospital staff [17], extra time for training and technical support may be necessary. Consequently, the present results represent estimates of the time required for trained personnel and do not correspond to the scenario of a new implementation of the technology in clinical practice. It is also important to note, that the evaluation whether a specific patient is suitable for FCL insulin therapy and transition back to non-automated standard care (e.g. worsening of the patients' condition or before hospital discharge) requires clinical decision making of a qualified person, which was not accounted for in the present study. Further considerations must be paid to hygiene aspects (e.g. development of standard operating procedures for hospital infection control), as non-disposable diabetes devices are not designed for multi-patient use.

Results from time-motion studies, in combination with information on healthcare costs (e.g. salary, equipment) and health outcome data, allow the calculation of treatment costs and cost-effectiveness. We have not pursued this route in the present study, since expenses for salaries and equipment are highly context-dependent and potentially sensitive. Our insights into potential time savings are still informative and may provide a starting point for future work. Since data on inpatient glucose management-related workload quantification is scarce, there is a need for more studies in the field, ideally when FCL insulin therapy or other therapeutic innovations are integrated in daily clinical workflows and managed by hospital staff and with concomitant collection of treatment efficacy and service cost data. Further research on the use of technology for inpatient diabetes management may also be used for regulatory submissions, as most diabetes technology devices (e.g. CGM and commercial automated insulin delivery systems) are not yet cleared for use in hospitals. Procedures such as the use of electrocautery and other medical interventions (e.g. use of vasopressors, hypothermia) during surgery may compromise the accuracy of CGM [18] and specific guidelines are necessary to ensure patient safety. For example, a workflow for CGM validation, which accepts a <20% deviation from POC glucose values and requires cross-comparison with POC values every 6 hours was recently developed [19].

In conclusion, fully closed-loop insulin therapy, in addition to its well-studied positive effects on glucose control, has the potential to substantially reduce the workload of inpatient glucose management and may help overcome periods with lack of hospital staff, reducing risks for patients.

References

1. Frisch A, Chandra P, Smiley D, et al. Prevalence and clinical outcome of hyperglycemia in the perioperative period in noncardiac surgery. *Diabetes Care*. Aug 2010;33(8):1783-8. doi:10.2337/dc10-0304
2. Umpierrez GE, Smiley D, Jacobs S, et al. Randomized study of basal-bolus insulin therapy in the inpatient management of patients with type 2 diabetes undergoing general surgery (RABBIT 2 surgery). *Diabetes Care*. Feb 2011;34(2):256-61. doi:10.2337/dc10-1407
3. Furnary AP, Gao G, Grunkemeier GL, et al. Continuous insulin infusion reduces mortality in patients with diabetes undergoing coronary artery bypass grafting. *J Thorac Cardiovasc Surg*. May 2003;125(5):1007-21. doi:10.1067/mtc.2003.181
4. Kotagal M, Symons RG, Hirsch IB, et al. Perioperative hyperglycemia and risk of adverse events among patients with and without diabetes. *Ann Surg*. Jan 2015;261(1):97-103. doi:10.1097/SLA.0000000000000688
5. de Vries FE, Gans SL, Solomkin JS, et al. Meta-analysis of lower perioperative blood glucose target levels for reduction of surgical-site infection. *Br J Surg*. Jan 2017;104(2):e95-e105. doi:10.1002/bjs.10424
6. Haque WZ, Demidowich AP, Sidhaye A, Golden SH, Zilbermint M. The Financial Impact of an Inpatient Diabetes Management Service. *Curr Diab Rep*. Jan 15 2021;21(2):5. doi:10.1007/s11892-020-01374-0
7. Aragon D. Evaluation of nursing work effort and perceptions about blood glucose testing in tight glycemic control. *Am J Crit Care*. Jul 2006;15(4):370-7.
8. Klonoff DC, Messler JC, Umpierrez GE, et al. Association Between Achieving Inpatient Glycemic Control and Clinical Outcomes in Hospitalized Patients With COVID-19: A Multicenter, Retrospective Hospital-Based Analysis. *Diabetes Care*. 02 2021;44(2):578-585. doi:10.2337/dc20-1857
9. Davis GM, Galindo RJ, Migdal AL, Umpierrez GE. Diabetes Technology in the Inpatient Setting for Management of Hyperglycemia. *Endocrinology and metabolism clinics of North America*. Mar 2020;49(1):79-93. doi:10.1016/j.ecl.2019.11.002
10. Spanakis EK, Urrutia A, Galindo RJ, et al. Continuous Glucose Monitoring-Guided Insulin Administration in Hospitalized Patients With Diabetes: A Randomized Clinical Trial. *Diabetes Care*. Aug 19 2022;doi:10.2337/dc22-0716
11. Bally L, Thabit H, Hartnell S, et al. Closed-Loop Insulin Delivery for Glycemic Control in Noncritical Care. *The New England journal of medicine*. Aug 9 2018;379(6):547-556. doi:10.1056/NEJMoa1805233
12. Bally L, Gubler P, Thabit H, et al. Fully closed-loop insulin delivery improves glucose control of inpatients with type 2 diabetes receiving hemodialysis. *Kidney Int*. Mar 2019;doi:10.1016/j.kint.2019.03.006
13. Boughton CK, Bally L, Martignoni F, et al. Fully closed-loop insulin delivery in inpatients receiving nutritional support: a two-centre, open-label, randomised controlled trial. *Lancet Diabetes Endocrinol*. Mar 2019;doi:10.1016/S2213-8587(19)30061-0
14. Herzig D, Suhner S, Roos J, et al. Perioperative Fully Closed-Loop Insulin Delivery in Patients Undergoing Elective Surgery: An Open-Label, Randomized Controlled Trial. *Diabetes Care*. Sep 01 2022;45(9):2076-2083. doi:10.2337/dc22-0438
15. Zheng K, Guo MH, Hanauer DA. Using the time and motion method to study clinical work processes and workflow: methodological inconsistencies and a call for standardized research. *J Am Med Inform Assoc*. Sep-Oct 2011;18(5):704-10. doi:10.1136/amiajnl-2011-000083
16. American Diabetes Association Professional Practice C, American Diabetes Association Professional Practice C, Draznin B, et al. 16. Diabetes Care in the Hospital: Standards of Medical Care in Diabetes-2022. *Diabetes care*. Jan 1 2022;45(Suppl 1):S244-S253. doi:10.2337/dc22-S016
17. Faulds ER, Jones L, McNett M, et al. Facilitators and Barriers to Nursing Implementation of Continuous Glucose Monitoring (CGM) in Critically Ill Patients With COVID-19. *Endocr Pract*. Apr 2021;27(4):354-361. doi:10.1016/j.eprac.2021.01.011

18. Herzig D, Vettoretti M, Guensch DP, et al. Performance of the Dexcom G6 Continuous Glucose Monitoring (CGM) System During Cardiac Surgery Using Hypothermic Extracorporeal Circulation. *Diabetes Care*. Feb 21 2023;doi:10.2337/dc22-2260
19. Davis GM, Faulds E, Walker T, et al. Remote Continuous Glucose Monitoring With a Computerized Insulin Infusion Protocol for Critically Ill Patients in a COVID-19 Medical ICU: Proof of Concept. *Diabetes Care*. Apr 2021;44(4):1055-1058. doi:10.2337/dc20-2085

Table 1. Tasks involved in perioperative glucose management

	Category	Task	Activity	Definition Start	Definition Stop	Duration (seconds) *Mean±SD*
Standard Insulin Therapy	Treatment initialisation	Prescription of BG monitoring and insulin chart	• Open and review patient EHR • Prescribe/adjust BG-measurement profile • Create/adjust insulin chart	Opening of patient EHR	Executed prescription	559±192
	BG monitoring	Preparation and Measurement	• Gather the equipment • Walk from nurses' station to the patient's bedside • Prepare measurement kit at bedside • Hand hygiene • Clean patient's finger with swab • Prick the patient's finger to get a blood drop • Transfer blood to the reagent strip • Apply pressure/dressing • Read the result on the glucometer • Turn off the meter and dispose of the test strip • Clean equipment, remove gloves, hand hygiene	Gathering of material	Cleaned equipment	202+110
	BG monitoring	Glucose control review	• Open patient EHR • Review BG values • Decision if monitoring or therapy needs adjusting • Close patient EHR	Opening of patient EHR	Patient EHR closed	180 (A*)
	Insulin therapy	Infusion pump setup	• Gather the equipment • Hand hygiene • Fill syringe • Setup infusion pump • Hand hygiene • Clean equipment	Gathering of material	Cleaned equipment	198±80
	Insulin therapy	Preparation	• Check prescribed insulin dose • Gather insulin from drug cabinet • Draw insulin from the vial • Let the dose double-check by colleague	Opening of insulin chart	Double-check absolved	148±91
	Insulin therapy	s.c. administration	• Walk from nurses' station to the patient's bedside • Prepare insulin administration kit at the patient's bedside • Hand hygiene • Clean patient's injection region • Administrate insulin • Clean equipment	Exit of nurses' station	Cleaned equipment	102±36
	Insulin therapy	i.v. administration	• Walk to the patient's bedside • Rate adjustment	Exit of nurses' station	Infusion rate adjusted	13±12

Fully Closed Loop Insulin Therapy	Treatment initialisation	System setup	• Open and review patient EHR • Enter TDD and body weight into app • Check doctor's mode in pump, adjust basal rate • Connect pump to app • Prepare the material for sensor and catheter placement • Connect transmitter with app •Enter sensor code into app • Sensor placement • Reservoir insertion/change • Catheter placement • Set glucose target, alarms, followers • Start auto-mode	Opening of patient EHR	Auto-mode started	1701±265
	BG monitoring	Sensor placement / change	•Gather the equipment • (Remove old sensor) • Unpack material • Set new sensor • Mount transmitter • Cover with dressing • Enter sensor code	Gathering of material	Sensor code entered	243±92
	BG monitoring	Sensor calibration	• See subtasks «BG monitoring preparation & measurement» Standard Insulin Therapy • Enter the BG value into app (A*=15sec)	Gathering of material	Cleaned equipment	217+110
	BG monitoring	Remote monitoring	• Checking sensor trace on Diasend	Opening of Diasend	Diasend closed	180 (A*)
	Insulin therapy	Catheter placement / change	•Gather the equipment • Unpack material • Remove old catheter • Set new catheter • Cover with dressing • Clean equipment	Gathering of material	Cleaned equipment	626±128
	Insulin therapy	Reservoir insertion / change	• Gather the equipment • Unpack material • (Remove empty reservoir) • Fill new reservoir • Insert the filled reservoir • Connect with catheter • Clean equipment	Gathering of material	Cleaned equipment	196±77

A* = Assumption; EHR, electronic health record; TDD, total daily dose; i.v. = intravenous; s.c. = Subcutaneous; SD, Standard Deviation; IQR, Interquartile range; BG, Blood glucose; CL, Closed-loop

Table 2. Daily time required for glucose management for each perioperative period

Standard insulin Therapy			Fully Closed-loop Insulin Therapy		
Preoperative			***Preoperative***		
Quantity	*Subtask*	*Time (min) / day*	*Quantity*	*Subtask*	*Time (min)*
1	Treatment initialisation (Prescription of BG monitoring and insulin chart)	9.3	1	Treatment initialisation System setup	28.4
1	BG monitoring	3.4	1	BG monitoring Sensor calibration	3.6
	Total time requirement	**12.7 min [min 11.1; max 14.3]**		**Total time requirement**	**32.0 min [min 16.5; max 34.1]**
IOP			***IOP***		
Quantity/hour	*Subtask*	*Time (min) /hour*	*Quantity/hour*	*Subtask*	*Time (min) / hour*
0.2	Insulin therapy – Infusion pump setup	0.7	1	BG monitoring Remote monitoring	2
1	BG Monitoring – Preparation & Measurement	3.4			
1	Insulin therapy – IV administration	0.2			
	Total time requirement	**4.3min [min 1.1; max 5.1]**		**Total time requirement**	2 min* **[min 0; max 2]**
IMC			***IMC***		
Quantity/day	*Subtask*	*Time (min) / day*	*Quantity/day*	*Subtask*	*Time (min) / day*
1	Insulin therapy Infusion pump setup	3.3	0.1	BG monitoring Sensor placement	0.4
12	BG Monitoring Preparation & Measurement	40.4	0.5	BG monitoring Sensor calibration	1.8
			0.5	Insulin therapy Catheter placement	5.2
12	Insulin therapy IV administration	2.6	0.14	Insulin therapy Reservoir insertion/ change	0.5
1	BG monitoring Glucose control review	3	1	BG monitoring Remote monitoring	3
	Total time requirement	**49.3 min [min 25.8; max 102.3]**		**Total time requirement**	**10.9 min [min 3.6; max 22.1]**
Ward			***Ward***		
Quantity/day	*Subtask*	*Time (min) / day*	*Quantity/day*	*Subtask*	*Time (min) / day*
4	BG Monitoring Preparation & Measurement	13.5	0.1	BG monitoring Sensor placement	0.4
			0.5	BG monitoring Sensor calibration	1.8
5	Insulin therapy Preparation	12.3	0.5	Insulin therapy Catheter placement	5.2
5	Insulin therapy SC insulin administration	8.5	0.14	Insulin therapy Reservoir insertion/change	0.5
1	BG monitoring Glucose control review	3	1	BG monitoring Remote monitoring	3
	Total time requirement	**37.3 min [min 35.1; max 80.8]**		**Total time requirement**	**10.9 min [min 3.6; max 22.1]**

*This task was not measured and is an assumption based on user experience.

BG, Blood Glucose; CL, Closed-loop; IOP, Intra-operative period; IMC, Intermediate Care Unit

The minimum estimate represents the lower bound of the 95% confidence intervals calculated for the minimal scenario. The maximum estimate was calculated analogously.